EFFICACY OF HERBICIDES IN WHEAT (*Triticum aestivum* L.) AND ASSESSMENT OF THEIR PERSISTENCE THROUGH BIOASSAY TECHNIQUE

A

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By

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ABSTRACT

A field experiment entitled "Efficacy of herbicides in wheat (*Triticum aestivum* L.) and assessment of their persistence through bioassay technique" was carried out at Instructional Farm, Junagadh Agricultural University, Junagadh on medium black clayey soils during *rabi* season of the year 2003-04 and 2004-05.

The experiment comprising 10 treatment was laid out in randomized block design with four replications. Treatments consisted of weed management viz., pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1), isoproturon 0.75 kg ha^{-1} pre-em. + 1 HW (T_2), isoproturon 0.75 kg ha^{-1} post-emergence at 30 DAS (T_3), fluchloralin 0.45 kg ha^{-1} pre-em. + 1 HW (T_4), metsulfuron 6 g ha^{-1} post-emergence at 30 DAS (T_5), 2,4-D (S.S.) 0.96 kg ha^{-1} post-emergence at 30 DAS (T_6), 2,4-D (E.E.) 0.75 kg ha^{-1} post-emergence at 30 DAS (T_7), 2 hand weedings at 20 & 40 DAS (T_8), weedfree (T_9) and unweeded control (T_{10}). Recently released wheat variety GW-322 was tested in the experiment.

The results of the experiment indicated that among different herbicides either applied as pre- or post-emergence in the trial was not found phytotoxic to the wheat crop as reflected in initial and final plant stand of the crop. Significantly the highest values of growth parameters

viz., plant height and leaf area index was observed under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW and remained equivalent to weedfree. This treatment being equivalent to weedfree, also recorded significantly more number of total and productive tillers and spikelets per spike, higher test weight and grain weight per plant over unweeded control.

Significantly higher grain yield was produced under 2 hand weedings (3804 kg ha^{-1}), pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (3801 kg ha^{-1}) and 2,4-D (S.S.) 0.96 kg ha^{-1} (3734 kg ha^{-1}) post-emergence and they proved superior to rest of the treatments and remained equivalent to weedfree (4042 kg ha^{-1}). The maximum straw yield was obtained under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (4366 kg ha^{-1}), metsulfuron 6 g ha^{-1} post-emergence (4328 kg ha^{-1}) and isoproturon 0.75 kg ha^{-1} pre-em. + 1 HW (4265 kg ha^{-1}) and remained equivalent to weedfree (4590 kg ha^{-1}).

Being equivalent effective to weedfree, among different treatments, pendimethalin 1 kg ha^{-1} pre-em. + 1 HW proved the most effective to reduce the weed population recorded at 20, 40 and 60 DAS as well as at harvest. This treatment also proved most effective to reduce dry weed weight which also reflected in higher weed control efficiency (92.02 %), higher herbicidal efficiency index (9.05 %) and lower weed index (5.93 %).

Chemical analysis of weeds and crop plants indicated that the lowest loss of nutrients by weeds was under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW and statistically similar to 2,4-D (S.S.) 0.96 kg ha^{-1} post-em. and metsulfuron 6 g ha^{-1} post-emergence and they remained equivalent to weedfree. Restriction in loss of nutrients favoured significantly higher nutrients uptake by the crop under these treatments.

Economical evaluation showed that the maximum gross returns was accrued under 2 hand weedings (32,750 Rs. ha^{-1}) closely followed by pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (32,748 Rs. ha^{-1}) and 2,4-D (S.S.) 0.96 kg ha^{-1} post-emergence (32,151 Rs. ha^{-1}) and remained at par with weedfree. While significantly the highest net returns was obtained under 2,4-D (S.S.) 0.96 kg ha^{-1} post-em. (20,760 Rs. ha^{-1}) and was found at par with pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (18,464 Rs. ha^{-1}). These two treatments, recorded additional net returns of 10593 and 8297 Rs. ha^{-1} over control, respectively.

The results of pot-bioassay revealed that the persistence effect of different herbicides applied in wheat crop was found non-significant on germination, plant height and dry matter production of mustard and cucumber at 30 as well as 60 DAS and significant on sorghum at 30 DAS.

Field-bioassay studies showed that different herbicides did not left their residual phytotoxic effect in the soil after harvesting wheat crop as it is proved through non-significant effect on germination, plant height and dry matter production of succeeding groundnut, greengram, cotton and pearlmillet.

Based on the pooled results of two years' experimentation, it is concluded that potential production and profit can be achieved by post-emergence application of 2,4-D (S.S.) @ 0.96 kg ha^{-1} at 30 DAS using spray volume of 500 liters. Pre-emergence application of pendimethalin 1 kg ha^{-1} supplemented by one hand weeding at 30 DAS also emerged out best treatments for minimizing weed problem in wheat. Both the herbicides were safe for standing crop as well as succeeding crops viz., groundnut, greengram, cotton and pearlmillet.

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CERTIFICATE-III

Date : 09-03-2006

This is to certify that the thesis entitled " EFFICACY OF HERBICIDES IN WHEAT (*Triticum aestivum* L.) AND ASSESSMENT OF THEIR PERSISTENCE THROUGH BIOASSAY TECHNIQUE" submitted by Mr. RAMANI VINODRAI BHIKHUBHAI to Junagadh Agricultural University, Junagadh in partial fulfillment of the requirements for the degree of Ph. D. in the subject of AGRONOMY after recommendation by the external examiner was defended by the candidate before the following members of the examination committee. The performance of the candidate in the oral examination was satisfactory, we therefore, recommend that the thesis be approved.

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This is to certify that Mr. RAMANI VINODRAI BHIKHUBHAI student of Ph. D. (class) AGRONOMY (Department) has made all corrections/modifications in the thesis entitled " EFFICACY OF HERBICIDES IN WHEAT (*Triticum aestivum* L.) AND ASSESSMENT OF THEIR PERSISTENCE THROUGH BIOASSAY TECHNIQUE" as suggested by the external examiner and the advisory committee in the oral examination held on 09-03-2006. The final copies of the thesis duly bound and corrected have been submitted on 13 – 03 – 2006.

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Place : Junagadh
Date : 9th March 2006. **(V. B. Ramani)**

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CHAPTER I

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important staple food crop cultivated almost in all the countries of the world. Wheat in India, is next to paddy both in area and production, but it stands first in productivity amongst the cereals. In India, it is grown in 25.07 million hectares with a production of 68.76 million tones every year (Singhal, 2003). Gujarat having an area of 6.78 lakh hectares under irrigated wheat and producing 19.89 lakh tones grains with productivity of 2934 kg/ha (Anon., 2004). The productivity of wheat in Gujarat is slightly higher than national average 2743 kg/ha but lower as compared to Punjab (4696 kg/ha) and Haryana (4167 kg/ha) (Singhal, 2003). These may be due to various reasons viz., improper time of sowing and scheduling of irrigation, lack of timely weed control and imbalance use of fertilizer. Out of various possible reasons timely sowing and weed management has got vital importance for successful cultivation of irrigated wheat.

Weed problem is one of the major barriers responsible for low productivity of wheat because, weed competes with the crop for moisture, nutrients, space, light etc. Moreover they increase production cost, decrease yield of the crop, harbors insects and plant diseases, decrease quality of farm produce and reduce values of the land. The weed in India are causing substantial losses to agriculture production and the annual losses in terms of money come to the Rs.1650 crores (Joshi, 2002). In agriculture weed causes more damage compared to insects, pests and diseases but due to hidden loss by weed in crop production, it has not drawn much attention of agriculturists (Rao, 2001).

Wheat suffers badly due to infestation of wide variety of grasses and broad leaf weeds. Unchecked weed growth reduces the wheat yield to the magnitude of 21.75% under South Saurashtra conditions (Anon.,1998).On an average more than 66% reduction in the grain yield of wheat due to mixed population of weeds in wheat has been observed by Singh and Singh, 2005.

Day by day, weed control through herbicides is increasing and popularizing among farmers. Because, weed control through manual methods is time consuming and tedious and become very costly due to unavailability of labour in peak period and labour charges are also high due to shifting of agricultural labours to industries for better and assured wages. Wheat is sown at very narrow row spacing. Therefore, cultural methods of weed control could not be performed and manual control becomes unaffordable. Hence, use of herbicides popularized particularly in irrigated wheat crop.

A number of herbicides are recommended for field crops. Continuous use of herbicides may lead to residue accumulation in the soil, restrict the crop choice in a rotation and pollute the drinking water and environment which ultimately causes health hazards. Ideally, a herbicide should remain active in soil for a period sufficient to provide satisfactory weed control and then it must degrade in to innocuous products before the close of the crop season. The persistence of any herbicides may varies with agro-climatic situations because it depends on soil type, microbes, soil pH, moisture, temperature, sunlight etc.

Control of weed in the field by soil-applied herbicide is based upon the premise that the herbicide will move from the treated soil into the targeted pest species. This concept may be used by the synthesizing chemist to evaluate the phytotoxicity of different herbicides. The residue chemist uses this concept to determine the rate at which a herbicide is degraded in soil. A farmer, using crop rotations, needs to know whether the phytotoxic properties of a compound have disappeared before the planting a sensitive crop into a previously treated soil. A bioassay, using a sensitive crop in the treated soil as the growth medium, can provide useful information for each of these situations (Lavy and Santelmann, 1986).

Many reactions occur from the time a compound is added to the soil until all traces of its presence have disappeared. Bioassay may be used to study the activity, persistence and movement of herbicides in soils. The effects of various soil properties and environmental conditions on herbicide phytotoxicity and the absorption, movement and degradation in plants. Two basic assumptions are made when bioassay is used: (a) the bioassay species will show injury response in proportion to herbicide concentration and (b) the response obtained are reproducible.

Bioassay sometimes may be used to determine the presence or absence of a particular herbicide. Generally, this task is more difficult because herbicides in the same family may produce similar symptoms. Some qualitative determination is possible. However, herbicides other than the hormone types are less suited to qualitative bioassay.

Through bioassay, the property of a chemical is measured in terms of some biological responses. Sensitive plant species called as indicator or test species are used for conducting bioassay. The major advantage of this technique is that the procedure followed is generally more economical and easy to perform, costly equipment and chemicals are not required. The indicator plant is grown in a field or pot and is compared with that of similar plant grown in untreated soil.

The cultivators are not aware of proper dose of herbicides, time of application, economics and their persistence in the soil. Several selective herbicides are available in the market, which are treated to be effective for particular crop. The farmers have to make decisions about the selection of right type of herbicides. No systemic research work has been conducted to evaluate the persistence of several herbicides in past. In Saurashtra region, pendimethalin and 2,4-D are widely used herbicide in wheat for control of weeds. Metsulfuron is promising herbicide which is most effective against broad leaf weeds as well as *Asphodelus tenuifolius* in wheat (Vala, 2000). Information on residues of herbicides and it's tolerance among crop species are very meager. No practically and systematic research work has so far been done in past. Therefore, the present investigation entitled “Efficacy of herbicides in wheat (*Triticum aestivum* L.) and assessment of their persistence through bioassay technique” was under taken at Instructional Farm, Junagadh Agricultural University, Junagadh during *rabi* season of 2003-2004 and 2004-2005 with following objectives.

1. To evaluate the efficacy of pendimethalin, isoproturon and fluchloralin as pre-emergence and isoproturon, metsulfuron and 2,4-D (Sodium salt and ethyle ester) as post-emergence application for weed management in wheat.
2. To study the effect of pendimethalin, isoproturon and fluchloralin as pre-emergence and isoproturon, metsulfuron and 2,4-D (S.S. and E.E.) as post-emergence application on growth and yield of wheat.
3. To study the persistence of pendimethalin, isoproturon, fluchloralin metsulfuron and 2,4-D (S.S. and E.E.) through bioassay technique in wheat.

4. To arrive at an economically viable conclusion for weed management in wheat under South Saurashtra Agro-climatic conditions.

CHAPTER II
REVIEW OF LITERATURE

Weed problem is one of the major barrier responsible for low productivity of wheat because weed compete with the crop for moisture, nutrients, space, light etc. Moreover, they increase production cost also. Day by day weed control through herbicides is increasing and popularizing among farmers. A number of herbicides are recommended for field crop. Continuous application of herbicide to each crop in the intensive cropping system may lead to residue accumulation in soil. This causes considerable health hazards and environmental pollution. Persistence studies are essential to determine the duration of herbicidal efficacy and effect on follow up crop. To present a brief review of research accomplishment made at various places on different fields related to this investigation are presented under appropriate heads in this chapter.

2.1 Weed flora in wheat crop

2.2 Losses caused by weeds in wheat

2.3 Critical period of crop-weed competition

2.4 Effect of herbicides on weed parameters

2.5 Influence of weed management on growth & yield attributes of wheat

2.6 Effect of weed management on yield of wheat

2.7 Influence of weed management on nutrient uptake by weeds and crop.

2.8 Economics of different weed management practices in wheat

2.9 Bioassay studies

2.1 Weed flora in wheat crop

Weed form integral part of each and every agrophytocoensis. Thus, their interference with crop plant is but natural. Because of their high competitive ability and allelopathic influence, weed cause an irreversible damage to crops. Knowledge on the composition of weed flora in a particular crop and their correct identity are necessary to formulate effective measures for their control.

Sufficient sunshine and favourable temperature with adequate irrigation and nutrients in *rabi* season provide a very congenial conditions for rapid growth of various weed species. Weeding at an early stages of crop growth in wheat is a very important practice because heavy infestation of weeds hampers the crop growth as well as greater reduction in wheat yield. Slow growth of wheat plants during early growth stage is provide favourable conditions for the growth of various weed flora at the time of germination and also subsequent growth periods. Hence, an attempt has been made to review the literature pertaining to weed flora observed in the wheat field at various locations under different agro-ecological situations.

The major weed flora observed by Patel and Upadhyay (1991) consisted of *Eragrostis tenella* Roem & Sch., *Digitaria abscendens* Scop. and *Cynodon dactylon*Pers. in grasses, *Cyperus rotundus* L. in sedges and *Chenopodium album*L., *Digera arvensis* Forsk, *Chenopodium murale* L., *Phyllanthus niruri*L., *Boerheavia diffusa* L., *Tribulus terrestris* L., *Portulaca oleraceae*L., and *Melilotus alba* Lunk. in wheat field at Anand (Gujarat).

Deshmukh *et al*. (1995) conducted field trials on weed control in wheat during *rabi* 1992-93 on clay soil at Akola (Maharashtra). They noted the dominant weeds viz., *Chenopodium album*L., *Parthenium hysterophorus* L., *Euphorbia hirta* L., *Argemone maxicana* L. and *Anagallis arvensis* L.

Singh and Singh (1996) from a field experiment conducted during the *rabi* season of 1990-91 to 1992-93 at Crop Research Station, Ghagharaghat (UP) on sandy loam soil reported the major weed flora viz., *Phalaris minor* Retz., *Avena fatua* L. and *Fumeria parviflora* L. While *Chenopodium album*L., *Anagallis arvensis* L. *Convolvulus arvensis* L. and *Melilotus alba* Lunk. were the major broad leaf weeds.

In a field trial conducted at Regional Research Station, Madhopur (West Champaran) during the *rabi* season of 1987-88 and 1988-89 on calcareous sandy loam soil by Singh *et al*. (1996) observed the major weed flora *Chenopodium album*L., *Anagallis arvensis* L. *Melilotus alba* Lunk., *Melilotus indica* All., *Fumeria parviflora* L., *Vicia sativa* L., *Laulea pinnatifide* L. and *Convolvulus arvensis* L. among the dicot and *Cynodon dactylon* Pers. and *Cyperus rotundus* L. among the monocot.

Azad and Singh (1997) observed important weed species in wheat at R. S. Pura (Jammu) on clay loam soil were *Phalaris minor* Retz., *Cynodon dactylon* Pers., *Avena fatua* L., Poa annua L. besides other associated weeds viz., *Anagallis arvensis* L., *Melilotus indica* All., *Fumeria parviflora* L. and *Vicia sativa* L.

A field experiment was conducted during *rabi* season of 1991-92 at Varanasi(UP) on sandy clay loam soil by Singh *et al.* (1997). They reported that the relative composition of weed flora in unweeded plot of 60 days was *Phalaris minor*(18%), *Cynodon dactylon*(8.3%), *Cyperus rotundus*(11.1%), *Melilotus* spp.(24.2%), *Chenopodium album*(13.8%), *Anagallis arvensis*(20.7%) and other weed species about 4 % of total weed flora.

The major weed species present in wheat crop at Kanpur (UP) were *Phalaris minor* Retz., *Chenopodium album*L., *Anagallis arvensis* L. and *Cyperus rotundus* L. (Tewari *et al*., 1998).

Field experiment was conducted at Hisar (Haryana) during winter season of 1995-96 and 1996-97 on sandy loam soil. Balyan *et al*. (1999) reported that experimental field was infested with the natural populations of grass weeds viz., *Phalaris minor* and *Avena ludoviciana* and broad leaf weeds viz., *Chenopodium album, Lathirus aphaca, Vicia sativa, Convolvulus arvensis* and *Fumaria parviflora*.

Kurchania *et al*. (2000) carried out field experiment during winter season of 1995-96 and 1996-97 at Jabalpur (MP). They reported that experimental field was infested with broad leaf weeds viz., *Medicago hispida*, *Melilotus alba*, *Trifolium flagiferum*, *Cichorium intybus*, *Chenopodium album*, *Indigofera linifolia*, *Anagallis arvensis, Vicia sativa* and *Sonchus arvensis* and grassy weeds viz., *Phalaris minor* and *Cynodon dactylon.* The broad leaf weeds constituted 67.5% of the total weed population.

Field experiment was conducted by Sukhadia *et al*. (2000) at Junagadh (Gujarat) during winter season of 1993-94 to 1997-98 on Vertisol. They reported that experimental field was infested by *Echinichloa colonum*(54.03%), *Cyperus rotundus*(14.53%), *Digera arvensis*(14.25%), *Eluropus villosus*(5.52%), *Physalis minima*(3.26%) and other weed species(8.41%).

Chopra *et al*. (2001) conducted field experiment during winter seasons of 1996-97 and 1997-98 at Baraut (UP) on sandy loam soil. They observed that *Phalaris minor* was the most predominant weed among grassy weed, *Melilotus indica* , *Fumaria parviflora*, *Chenopodium album*, *Anagalis arvensis*, *Cirsium arvensis* and *Rumex dentatus* among broad leaf weeds. Among the sedges, *Cyperus rotundus* was present.

The field was dominated by natural infestation of *Poa annua*, *Coronopus didymus*, *Veronica persica* and *Capsella bursa-pestoris* at Bajaura (HP) when conducted field experiment during winter season of 1997-98 and 1998-99 on sandy loam soil (Sharma and Thakur, 2002).

Singh and Singh (2002) reported weed flora in wheat field of Pantnagar (Uttaranchal) consisted of *Phalaris minor*, *Avena ludoviciana*, *Chenopodium album*, *Melilotus alba*, *Melilotus indica*, *Medicago denticulata*, *Fumaria parviflora and Anagalis arvensis.*

The weed flora of the experimental site were *Chenopodium album*, *Chenopodium murale*, *Anagalis arvensis*, *Convolvulus arvensis*, *Coronopus didymus*, *Melilotus indica* and *Phalaris minor* observed by Jat *et al.* (2003) at Udaipur (Rajasthan) during winter seasons of 1999-2000 and 2000-2001 on clayey loam soil.

Singh and Singh (2004) conducted a field experiment on sandy loam soil at Jodhpur (Rajasthan) during winter seasons of 1998-99 and 1999-2000. They observed that the wheat field was dominated by broad leaf weeds, accounting for about 97% of total weed flora in weedy check conditions. *Chenopodium album*(51.31%), *Chenopodium murale*(24.5%), *Melilotus indica*(6.74%), *Fumaria parviflora*(5.45%), *Asphodelus tenuifolius*(4.5%), *Cynodon dactylon*(3.11%), *Convolvulus arvensis*(2.39 %) and *Rumex dentatus*(1.91%).

The major weed species in wheat were *Phalaris minor, Lolium temulentun, Vicia satia, Avena fatua, Coronupus didymus, Anagalis arvensis* and *Lathyrus aphaca* (Kumar *et al.*, 2005).

Prasad *et al.* (2005) found that experimental crops were mainly infested by *Rumex dentatus*(65%). *Phalaris minor*(8%), *Parthenium hysterophorus* (6%), *Anagalis arvensis* (5%), *Melilotus alba*(4.5%) and *Cynodon dactylon*(4%) at Varanasi (UP) during winter 2000-01 and 2001-02 on gangetic alluvial soils having sandy clay loam texture.

2.2 Losses caused by weed in wheat

Weeds constitute a major limiting factor in successful crop production and cause huge yield losses which, however, depend upon nature and intensity of the weed flora, duration of crop-weed competition, various soil factors and agro-climatic conditions prevailing under a particular region.

Among total annual losses of agricultural produce from various pests in India, weed account for 45 per cent, insects 25 per cent, diseases 20 per cent and other pest 5 per cent (Rao, 2001).

Panwar *et al*. (1995) while working on a sandy loam soil at Hisar (Haryana) reported that the grain yield of wheat was reduced from 52.1 to 54.2% when plots were weedy for the whole season during both years.

Result of an experiment conducted at G. B. Pant University of Agri & Tech., Pantnagar in 1989 to 1991 revealed that grain yield of wheat was reduced to the extent of 51.2% under unweeded control (Kumar and Singh, 1996).

The field experiment was carried out during the winter seasons of 1994-95 and 1995-96 at Jabalpur (MP) by Dixit and Bhan (1997) and reported that the presence of weeds for whole seasons reduced the potential yield of wheat by 40.1 and 38.9% in the respective year.

A field experiment was conducted during *rabi* season of 1991-92 at Varanasi (UP) on sandy clay loam soil by Singh *et al*. (1997). They reported that the grain yield of wheat was severely affected by *P. minor* (39.25% reduction) followed by *Melilotus* spp.(29.14% reduction) while under weedy check the reduction was to the tune of 57.25 %.

Field experiments were taken to study the comparative yield losses due to weeds in wheat during *rabi* seasons 1989-90 to 1992-93 at experimental farm, Almora. Pandey *et al*. (1998) reported that the season long weed competition caused 28.9 to 52.2% reduction in wheat yield.

A field experiment was carried out during *rabi* season of 1996-97 and 1997-98 at Meerut (UP) to study the weed crop competition in wheat by Chopra *et al.*(1999). They observed that uncontrolled weeds caused 30.7% grain yield loss as compared to season long weedfree conditions.

Chopra *et al*. (2001) conducted field experiment during winter seasons of 1996-97 and 1997-98 at Baraut (UP) on sandy loam soil and observed that unchecked weeds caused nearly 37.7% grain yield loss.

Singh and Singh (2002) recorded more than 66% reduction in the grain yield of wheat in weedy plots as compared to weedfree plots at Pantnagar (Uttaranchal) during winter seasons of 1996-97 and 1997-98.

The average yield loss due to uncontrolled weed through out season in wheat crop was recorded to the tune of 45.89% as compared to weedfree conditions by Pandey and Prakash (2003) at Almora (Uttaranchal) on sandy loam soil during 1998-99 and 1999-2000.

A field experiment was conducted during winter seasons of 2000-01 and 2001-02 at Pantnagar (Uttaranchal) on clay loam soil by Singh *et al*. (2004). Results indicated that uncontrolled weeds resulted in 40.2% reduction in the grain yield of wheat.

An experiement was conducted at IARI, New Delhi during winter seasons of 1998-99 and 1999-2000 on sandy loam soil by Pandey and Verma (2004). They recoded about 35% reduction in average grain yield due to weed competition.

Singh and Singh (2005) executed experiment at Pantnagar (Uttaranchal) during winter seasons of 2002-2005. They reported that on an average there was more than 66% reduction in the grain yield of wheat due to mixed population of weeds in weedy plots.

2.3 Critical period of crop-weed competition

Weeds that germinate along with crop are more damaging than the later emerging weeds. There is a period (time span) before and after which presence of weeds does not cause any appreciable reduction in crop yield, as irrecoverable loss has been done. Hence, establishing the critical period of crop weed competition is essential to develop effective and economical weed control measures.

Results of an experiment carried out at Anand (Gujarat) on crop-weed competition in wheat revealed that the critical period of crop weed competition ranging between 30 to 45 DAS (Anonymous, 1994).

Saraswat and Mishra (1998) found that the critical period of crop-weed competition varies from 30-45 DAS of wheat crop.

Chopra *et al*. (1999) while working on sandy loam soil to find out the critical period of competition between weeds and wheat crop, during the *rabi* seasons of 1996-97 and 1997-98 at Agriculture Farm, Meerut noted that the 6.28, 8.09, 20.93 and 24.96% reduction in seed yield, when weeds were allowed to compete with the crop for initial period of 15, 30, 45 and 60 days and removed thereafter, respectively.

A field experiemnt was carried out at Peshawar (Pakistan) during the *rabi* season of 2000-01 by Khan *et al*. (2002). They found that weed competition for the first 42 days did not reduced significantly the yield of wheat. When weeds were allowed to compete beyond 42 days, that is up to 56 days or longer, a significant reduction in yield was observed. A weedfree period up to 45 days or more resulted in a grain yield statistically similar to season long weedfree conditions. Therefore, the critical period of weed crop competition was determined as the period between 42 and 56 days after sowing in wheat.

Pandey and Prakash (2003) investigated weedy or non-weedy conditions for up to 40, 60, 80, 100 and 120 DAS at Almora (Uttaranchal) during 1998-99 and 1999-2000 under rain fed conditions on sandy loam soils. Weedy conditions up to 40 DAS gave grain yield which was at par with that of the whole season of weedfree conditions.

2.4 Effect of herbicides on weed parameters

Studies conducted by Singh *et al*. (1994) at Jabalpur during 1990-91 on weed control in wheat revealed that the pre-emergence application of isoproturon 1 kg ha^{-1} had 95.12% weed control efficiency which was almost equal to hand weeding(93.85%). Isoproturon @ 1 kg ha^{-1} pre or post-emergence controlled almost all the annual monocot and dicot weeds.

Field experiments were conducted at Pusa (Bihar) during the *rabi* season of 1989-90 and 1990-91 by Pandey *et al*. (1997). The results revealed that pendimethalin 1 kg ha^{-1} and isoproturon 1 kg ha^{-1} recorded significantly lower weed count and weed dry biomass and recorded maximum weed control efficiency over weedy check. Effectiveness of pendimethalin at 1 kg ha^{-1} as pre-emergence application wheat crop is well documented in later studies (Jain *et al*., 1998; Chopra *et al*., 2001and Singh and Singh, 2004).

Sharma and Sharma(1997) carried out field experiment at Bajaura (Kullu) during winter season of 1993-94 and 1994-95 for the control of complex weed flora in wheat. It was observed that post-em. application of metsulfuron methyl 4 g ha^{-1} was found very effective against all the broad leaf weeds, however it's combination with isoproturon (1.25 kg ha^{-1}) most effectively controlled all the weeds and gave higher yield over rest of the weed management practices. Sole application of metsulfuron methyl up to 8 g ha^{-1} as post-emergence were found effective against broad leaved weeds (Balyan *et al*., 1999; Chopra *et al*., 2001 and Sardana *et al*., 2001) and its combination with isoproturon for the control of all the weeds (Sardana *et al*., 2001 and Singh and Singh, 2002) under various agro-ecological situations in India.

An experiment was conducted in wheat crop at National Research Center for Weed Science, Maharjpur Jabalpur (M.P.). Bhan and Dixit (1998) noted that the pre-emergence pendimethalin application was not as effective as isoproturon. The greatest weed control efficiency was obtained with 1.0 kg ha^{-1} isoproturon applied just before irrigation. Pre-irrigation 1.0 kg/ha isoproturon had a weed control efficiency of 80 per cent. Effectiveness of isoproturon has been reported particularly against grassy weeds where its problem is severe (Balyan *et al*., 1999 and Singh and Singh, 2002).

Field experiment was tried at Junagadh (Gujarat) during winter season of 1993-94 to 1997-98 on Vertisol (Sukhadia *et al*., 2000). The results showed that all the weed management treatments significantly reduced the weed density and weed dry weight as compared with unweeded control. The lowest dry weight of weeds was observed under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW at 30 DAS. This treatment also registered the highest (93%) weed control efficiency.

Poonia *et al*. (2001) studied the effect of weed management treatments on wheat at Navgaon(Alwar). Results revealed that post-em. 2,4-D at 0.75 kg ha^{-1} recorded the lowest weed biomass (WCE 91.4%) compared with other weed control measures. Against broad leaved weeds, effectiveness of 2,4-D sole application has been well advocated (Sardana *et al*., 2001) and its combination with isoproturon (Sardana *et al*., 2001; Singh and Singh, 2000 and Prasad *et al*., 2005) in various parts of India.

Singh and Saha (2001) observed that pendimethalin @ 1 kg ha^{-1} pre-em., isoproturon @ 1.5 kg ha^{-1} post-em., 2,4-D @ 1.5 kg ha^{-1} post-em., combination of pendimethalin 0.5 kg ha^{-1} pre-em. + isoproturon 1 kg ha^{-1} post-em. and pendimethalin 0.5 kg ha^{-1} pre-em. + 2,4-D 1 kg ha^{-1} post-em. recorded significantly lower weed biomass and weed index and higher weed control efficiency over weedy check.

Nayak *et al*. (2003) executed a field trial at Jabalpur (MP) during *rabi* 1998-99 on clayey soil. Results revealed that the weed biomass was minimum under hand weeding and was at par with 2,4-D (0.5 kg ha^{-1}) alone and in combination with metsulfuron methyl were applied. Weed control efficiency was maximum(94.15%) in hand weeding closely followed by 2,4-D 0.5 kg ha^{-1} + metsulfuron methyl 4 g ha^{-1}(90.98%) and 2,4-D 0.5 kg ha^{-1}(89.90%).

Post-emergence application of metsulfuron methyl at 3 to 5 g ha^{-1} and 2,4-D 0.75 kg ha^{-1} gave excellent control of broad leaved weeds species than farmers practices and weedy check at Kota (Rajasthan). Respective dose of metsulfuron recorded 78.2, 82.9 and 80.5% weed control efficiency (Singh and Ali 2004).

Singh and Singh (2004) investigated an experiment at Jodhpur (Rajasthan) during *rabi* season 1998-99 and 1999-2000. They observed that pendimethalin 0.75 kg ha^{-1} integrated with one hand weeding reduced significantly the density of *Chenopodium* spp. as well as other weed species.

The field experiment was carried out at Varanasi (UP) during rabi seasons of 2000-01 and 2001-02 on sandy clay loam soil by Prasad *et al*. (2005). The results indicated that post-emergence application of isoproturon + 2,4-D (1 + 0.5 kg ha^{-1}) significantly reduced the population and dry matter production of weeds over weedy.

2.5 Influence of weed management on growth and yield attributes of wheat

Weeds which emerge out with crop plants offer severe crop-weed competition for space, sunlight, water and nutrients and bring about the considerable interference on crop growth will ultimately reflect on the yield attributing characters and grain yield of wheat crop adversely.

An experiment conducted during the *rabi* seasons of 1988-89 and 1989-90 at Jorhat(Assam), to evaluate efficacy of herbicides for controlling weeds in wheat on sandy loam soil. Gogai and Kalita (1995) reported that application of isoproturon @ 0.75 kg ha^{-1} was equally effective in controlling weeds and improving the growth and yield components of wheat which were comparable with hand weeded plots. Similarly, positive effect of isoproturon on different yield attributes viz., effective tillers plant^{-1}, spikelet ear^{-1}, grain ear^{-1}, ear length and test weight have been also observed in different patrts of India (Naik *et al*., 1997 and Jat *et al*., 2003).

Angiras and Sharma (1996) from their field experiment carried out at Palampur (H.P.), concluded that the effective tillers and ear length recorded significantly higher by the weed control treatments over unweeded check.

The result of an experiment undertaken at I.G.K.V. Zonal Agricultural Research Station, Ambikapur (M.P.) during *rabi* season of 1991-92 on sandy loam soil by Dwivedi *et al*. (1996) revealed that plant height was not influenced significantly due to various weed control treatments. Similar results also reported by Walia and Brar, 1996 and Walia *et al*., 1996 under Punajab conditions. However, effective tillers were significantly more in weed control treatments as compared to unweeded crops.

Singh and Singh (1996) executed an experiments at Ghaghraghat and observed that the herbicidal treatments produced higher yield attributes like spikelets ear^{-1}, ear length, effective tiller plant^{-1} and 1000 grain weight than weedy check.

Field studies were carried out during the *rabi* seasons of 1991-92 and 1992-93 on weed control in wheat crop at R. S. Pura (J & K) on clay loam soil by Azad and Singh (1997). The results indicated that the effective tillers significantly reduced in unweeded control compared with other weed control treatments, whereas, it was significantly higher in pre-emergence application of isoproturon @ 1.0 kg ha^{-1}. Final plant stand remained unaffected due to various weed control measures.

For the control of weeds in wheat, a field experiment was conducted at Ludhiana during 1994-95 and 1995-96 by Walia *et al*.(1997). On an average of two years, application of metsulfuron at 10 and 20 g ha^{-1}, 2,4-D 0.5 and 0.8 kg ha^{-1} and their combinations recorded significantly higher number of effective tillers over unweeded control. However, application of metsulfuron up to 5 g ha^{-1} has been improved various growth and yield attributes viz., plant height, effective tillers, number of spikes, number of grains ear^{-1}, spike length and test weight at various locations in India were reported by Sardana *et al*., 2001; Sharma and Thakur, 2002; Jat *et al*., 2003 and Singh and Ali, 2004. Similarly, incase of 2,4-D favourable effects on these parameters have been reported by Sardana *et al*., 2001; Jat *et al*., 2003 and Singh and Ali, 2004. While positive effects of their combinations have been observed by Sardana *et al*., 2001.

Thakur *et al*. (1998) at Pusa (Bihar) recorded the highest values for effective tillers $plant^{-1}$, ear length, grain weight ear^{-1} in hand weeded and herbicide treated plots over unweeded control.

A field experiment was undertaken by Pandey *et al*. (2000) during the winter season of 1996-97 and 1997-98 at Pusa (Bihar) on clay loam soil. The results showed that weed control through herbicides viz., post-emergence application of isoproturon 1.0 kg ha^{-1}, 2,4-D 0.8 kg ha^{-1} and combination of isoproturon 0.5 kg ha^{-1} + 2,4-D 0.125 kg ha^{-1} recorded significantly higher plant height, effective tillers, ear length, test weight than weedy check.

Field trial was carried out during winter season of 1995-96 and 1996-97 at Ranchi (Jharkhand) on sandy clay loam soil by Singh and Saha (2001). They observed that pendimethalin @ 1 kg ha^{-1} pre-em., isoproturon @ 1.5 kg ha^{-1} post-em., 2,4-D @ 1.5 kg ha^{-1} post-em., combination of pendimethalin 0.5 kg ha^{-1} pre-em. + isoproturon 1 kg ha^{-1} post-em. and pendimethalin 0.5 kg ha^{-1} pre-em. + 2,4-D 1 kg ha^{-1} post-em. recorded significantly taller plants, greater number of effective tillers and fertile spikelets as compared to weedy check. Similarly, Yadav *et al*., 2001 reported that application of pendimethalin @ 2.0 kg ha^{-1} pre-em. recorded significantly higher values of tillers $plant^{-1}$, grains $ear^{-1}$and test weight over weedy control.

Singh and Singh (2004) investigated a field experiment on sandy loam soil at Jodhpur (Rajasthan) during winter seasons of 1998-99 and 1999-2000. Pre-emergence application of pendimethalin at 0.75 kg ha^{-1} supplemented by one hand weeding or 2,4-D 0.5 kg ha^{-1} at 30 DAS gave significantly higher spikes m^{-2}, grains $spike^{-1}$, 1000 grain weight due to better weed control.

Pandey and Kumar (2005) conducted a field experiment at Pusa (Bihar) during the winter seasons of 2000-01 and 2001-02 on clay loam soil. They found that hand weeding at 30 DAS, post-em. application of 2,4-D (SS) 800 g ha^{-1} and isoproturon 750 g ha^{-1} produced significantly higher leaf area index (60 DAS), effective tillers, length of ear and grains per ear over weedy check.

2.6 Effect of weed management on yield of wheat

Panwar *et al*. (1995) reported from the results of an experiment conducted during the *rabi* seasons of 1991 and 1992 at CCS, Hisar on a sandy loam soil that all the weed control treatments significantly increased the grain yield of wheat over the weedy check during both the years.

A field study on control of mixed population of wild oat and broad leaf weeds from wheat was carried out at Ludhiana (Punjab) during 1992-93 and 1993-94. Isoproturon plus (isproproturon + 2,4-D) 0.75 kg ha^{-1} applied before first irrigation provided good control of all weeds in wheat as compared to recommended treatment of isoproturon 0.56 kg ha^{-1} and resulted in to 182.8% higher yield over unweeded control (Kaur *et al.*,1996). Combination of isoproturon and 2,4-D out yielded unweeded control and found better than rest of the treatments (Pandey *et al*., 2000; Pandey *et al*., 2001; Singh and Singh, 2002 and Pandey *et al*., 2005).

Singh *et al*. (1996) reported that weed control treatments resulted in significant increase in grain yield as compared to control. However, all the herbicidal treatments gave comparable grain yield to hand weeding treatment.

Azad (1997) observed that the unweeded control had gave significantly less grain and straw yields than hand weeding and pre and post-emergence application of isoproturon.

Naik *et al*. (1997) studied the effect of weed control treatments on wheat during the *rabi* seasons of 1989-1990 and 1990-91 at Jabalpur on clay soil with wheat Lok-1 and reported that the grain yield was recorded significantly higher with applications of isoproturon @ 1.0 kg ha^{-1} than unweeded control. Similarly, post-emergence application of isoproturon at 0.75 to 1.5 kg ha^{-1} produced equivalent yield to that of weedfree in various agro-ecosystem of India (Bhan and Dixit, 1998; Balyan *et al*., 1999; Pandey *et al*., 2000; Pandey *et al*., 2001; Singh and Saha, 2001; Singh and Singh, 2002; Jat *et al*., 2003 and Pandey *et al*., 2005).

Pandey *et al*. (1997) investigated a field experiment at Pusa (Bihar). From the results they reported that hand weeding and herbicidal weed control treatments gave significantly higher grain and straw yields that the weedy check.

A field experiment was conducted for three consecutive years (186-87 to 1988-89) to study the effect of weed control methods on wheat at Majhera (U.P.) on sandy loam soil. Singh (1997) reported that all the weed control treatments significantly increased the grain yield over the weedy check. The percentage increase in grain yield over unweeded control was 42.2, 23.2 and 8.2 under 2 hand weeding (25 and 45 DAS), isoproturon 1.5 kg ha^{-1} and 2 mechanical hoeing (25 and 45 DAS), respectively. Similar results were reported by Nayak *et al*. (2003).

Sharma and Sharma (1997) observed that post-em. application of metsulfuron methyl 4 g ha^{-1} was found very effective against all the broad leaf weeds. Positive effect of metsulfuron alone at 3 to 10 g ha^{-1} on wheat yield have been observed under various climatic conditions of India (Walia *et al*. 1997; Tewari *et al*., 1998; Balyan *et al*., 1999; Kurchania *et al*., 2000; Chopra *et al*., 2001; Sharma and Thakur, 2002 and Jat *et al*.,2003). However it's combination with isoproturon (1.25 kg ha^{-1}) most effectively controlled all the weeds and gave higher yield over rest of the weed management practices. Similarly results obtained by Singh and Singh (2002). Superiority of combination of metsulfuron with 2,4-D have been reported by Kurchania *et al*. (2000) and Nayak *et al*. (2003).

Field studies for the control of weeds in wheat were conducted in 1994-95 and 1995-96 at CCS, HAU, Regional Research Station, Karnal on a clay loam soils with wheat Cv. WH-542. Singh *et al*. (1998) reported that during both the years the minimum grain yield (4280, 3267 kg ha^{-1}) were recorded under weedy check which were significantly lower than weed free and herbicide treated plots.

Field studies were carried out during the *rabi* seasons of 1992-93 and 1993-94 at Pusa (Bihar) by Thakur *et al*. (1998). The results of this investigation revealed that grain yield was recorded significantly higher under weed control treatments than weedy check.

To evaluate various herbicides in wheat, a field experiment was undertaken by Balyan and Malik (2000) at Hisar (Haryana) during winter seasons of 1998-99 and 1999-2000. The results indicated that metsulfuron 4 and 6 g ha^{-1} provided 97 to 98 % control of *Rumex retroflexus* when applied 30 DAS in wheat. Similarly, 2,4-D ester and sodium salt at 425 and 1000 g ha^{-1} provided 95 to 98 % control of this weed. Above herbicidal treatments gave more or less similar yields to that of weedfree yields in both the seasons. Application of 2,4-D at 0.75 to 1.5 kg ha^{-1} produced significantly higher yield over weedy and comparable to weedfree at various Research Centres in India (Pandey *et al*., 2000; Pandey *et al*., 2001; Poonia *et al*., 2001; Singh and Saha, 2001; Jat *et al*., 2003 and Nayak *et al*., 2003).

Sukhadia *et al*. (2000) carried out a field experiment at Junagadh (Gujarat) during winter season of 1993-94 to 1997-98 on Vertisol. Results indicated that pendimethalin 1 kg ha^{-1} pre-emergence + HW 30 DAS in wheat was most effective against weeds and provided highest grain and straw yields. While sole application of pendimethalin at 1 kg ha^{-1} produced higher yield over unweeded control (Chopra *et al*., 2001 and Singh and Saha, 2001) also at 2 kg ha^{-1} (Yadav *et al*., 2001) and it's integration with 2,4-D or isoproturon (Singh and Saha, 2001).

On farm experiments were conducted during winter season 1997-98 to 2000-01 at Pantnagar (Uttaranchal) on sandy loam to silty clay loam soil. From the results Bhardwaj *et al*. (2004) reported that application of isoproturon 1 kg ha^{-1} mixed with 2,4-D @ 0.5 kg ha^{-1} as post-em. proved best resulting in higher wheat yield as compared to no weeded plots.

Jat *et al*. (2004) executed a field experiment at Udaipur (Rajasthan) during *rabi* seasons of 1998-99 and 1999-2000 on clay loam soil. They observed that application of pendimethalin 1 kg ha^{-1} as pre-em. resulted in highest grain (47.2 q ha^{-1}), straw (63.3 q ha^{-1}) yields followed by isoproturon (0.75 kg ha^{-1} at 30 DAS).

Pandey and Verma (2004), while working at IARI, New Delhi during winter seasons of 1998-99 and 1999-2000 on sandy loam soil observed that the effect of post-emergence application of isoproturon (1 kg ha^{-1}) and 2,4-D (0.5 kg ha^{-1}) mixture was consistent in respect to yield of wheat and it was superior to all other treatments.

A field experiment was conducted during winter seasons of 2000-01 and 2001-02 at Pantnagar (Uttaranchal) on clay loam soil by Singh *et al*. (2004). Results indicated that significantly highest grain yield of wheat was obtained with metsulfuron 4 g ha^{-1} post-emergence. Post-emergence application of 2,4-D 0.5 kg ha^{-1} also produced significantly higher grain yield over weedy check.

A field experiment was carried out by Singh and Ali (2004) at Kota (Rajasthan) during *rabi* seasons of 1999-2000 and 2000-01 on clay loam soil. They observed that post-em. application of metsulfuron methyl at 3 to 5 g ha^{-1} and 2,4-D at 0.75 kg ha^{-1} recorded significantly higher grain and straw yields.

Singh and Singh (2004) investigated a field experiment on sandy loam soil at Jodhpur (Rajasthan) during winter seasons of 1998-99 and 1999-2000. The results showed that pre-emergence application of pendimethalin at 0.75 kg ha^{-1} supplemented by one hand weeding or 2,4-D 0.5 kg ha^{-1} at 30 DAS gave significantly higher grain yield due better weed control.

A field experiment was conducted at Pusa (Bihar) by Pandey *et al*. (2005) during the winter seasons of 1997 and 1998 on clay loam soil. They found that hand weeding resulted in the maximum increase in grain and straw yields, being significantly higher than that obtained under post-em. application of 2,4-D (SS) 0.8 kg ha^{-1} and isoproturon 0.75 kg ha^{-1} alone but at par with that obtained in mixture of 2,4-D (SS) 0.4 kg ha^{-1} + isoproturon 0.4 kg ha^{-1}.

The field experiment was carried out at Varanasi (UP) during *rabi* seasons of 2000-01 and 2001-02 on sandy clay loam soil by Prasad *et al*. (2005). The results indicated that post-emergence application of isoproturon + 2,4-D (1 + 0.5 kg ha^{-1}) produced significantly higher number of earheads and grain yield over weedy plots.

2.7 Influence of weed management on nutrient uptake by weeds and crop

To study the effect of various herbicides, a field experiment was conducted at Hisar (Haryana) during the winter seasons of 1990-91 to 1991-92 by Malik *et al*. (1995). Isoproturon 1 kg ha^{-1} and 2,4-D 0.500 kg ha^{-1} alone and combination of isoproturon 0.75 + 2,4-D 0.500 kg ha^{-1} as post-em. recorded higher nutrients removal by wheat and lower by associate weeds. In undisturbed environment of weedy check, the weeds depleted 58.51, 14.3 and 50.1 kg ha^{-1} N, P and K, respectively as against 23.5, 5.5 and 24.6 kg ha^{-1} in hand hoeing and 28.7, 6.6 and 29.7 kg ha^{-1} in herbicides applied.

Malik *et al*. (1995) conducted a field experiment at Hisar (Haryana) during the winter seasons of 1990-91 to 1991-92 and the results revealed that weeds depleted 45.6, 11.3 and 45.6 kg ha^{-1} N, P and K, respectively when allowed to grow with the wheat crop up to harvest, whereas the use of herbicides increased nutrient uptake by wheat and decreased nutrient uptake by weeds.

To find out nutrient uptake by wheat and associated weeds, a field experiment was executed at Pusa (Bihar) during *rabi* seasons of 1996-97 and

1997-98 on clay loam soils. Weed control treatments increased the N, P and K uptake by the crop by 135.5 to 149.0%, 133.9 to 148.5% and 133.3 to 145.6%, respectively. As compared to weedy check, weed control treatments reduced the N, P and K depletion by weeds by 69.2 to 75.4%, 68.2 to 74.3% and 69.2 to 75.0%, respectively (Pandey *et al*., 2000).

A field trial was conducted at Pusa (Bihar) during *rabi* seasons of 1997-98 and 1998-99 on clay loam soil by Pandey *et al*. (2001). The results showed that 2,4-D at 0.8 kg ha^{-1}, isoproturon at 0.75 kg ha^{-1} and 2,4-D at 0.4 kg ha^{-1} + isoproturon at 0.4 kg ha^{-1} as post-em. at 30 DAS recorded significantly lower removal of nutrients (N, P and K) by weeds compared to weedy check. These treatments recorded significantly higher nutrients uptake by crop.

Field experiment was carried out during winter season of 1995-96 and 1996-97 at Ranchi (Jharkhand) on sandy clay loam by Singh and Saha (2001). They observed that pendimethalin @ 1 kg ha^{-1} pre-em., isoproturon @ 1.5 kg ha^{-1} post-em., 2,4-D @ 1.5 kg ha^{-1} post-em., combination of pendimethalin 0.5 kg ha^{-1} pre-em. + isoproturon 1 kg ha^{-1} post-em. and pendimethalin 0.5 kg ha^{-1} pre-em. + 2,4-D 1 kg ha^{-1} post-em. recorded significantly lower uptake of NPK by weeds and higher by crops than weedy check.

Jat *et al*. (2004) undertaken a field experiment at Udaipur (Rajasthan) during rabi seasons of 1998-99 and 1999-2000 on clay loam soil. They observed that application of pendimethalin 1 kg ha^{-1} as pre-em. resulted in highest P uptake (30.4 kg ha^{-1}) by crop followed by isoproturon (0.75 kg ha^{-1} at 30 DAS).

Kumar *et al*. (2005) conducted field experiment at Palampur (HP) during winter season of 1995-96 and 1996-97. They reported that uncontrolled weed growth, depleted 83.4, 18.7 and 80.8 kg ha^{-1} of NPK, respectively which was 47.1, 11.5 and 55.2 kg ha^{-1} higher than total uptake of these nutrients by wheat crop. Isoproturon 1 kg ha^{-1} post-em. reduced weed dry weight and NPK depletion by weed and increase grain yield and NPK uptake by wheat.

2.8 Economics of different weed management practices in wheat

A field experiment was carried out during the winter season of 1996-97 and 1997-98 at Pusa (Bihar) on clay loam soil. From the results Pandey *et al*. (2000) reported that weed control through herbicides viz., post-emergence application of isoproturon 1.0 kg ha^{-1}, 2,4-D 0.8 kg ha^{-1} and combination of isoproturon 0.5 kg ha^{-1} + 2,4-D 0.125 kg ha^{-1} recorded significantly higher net return than weedy check.

Sukhadia *et al*. (2000) conducted a field experiment at Junagadh (Gujarat) during winter season of 1993-94 to 1997-98 on Vertisol. Results indicated that the highest net return (Rs. 34078 ha^{-1}) was accrued under 2,4-D 1 kg ha^{-1} post-em. closely follwed by pendimethalin 1 kg ha^{-1} pre-emergence + HW at 30 DAS (Rs. 33948 ha^{-1}).

An investigation was carried out during the winter season 1997-98 and 1998-99 at Morena (MP) on sandy loam soil. The results indicated that application of pendimethalin @ 2.0 kg ha^{-1} pre-em. recorded significantly higher net return over weedy control(Yadav *et al*., 2001).

A field experiment was conducted during winter seasons of 1999-2000 and 2000-01 at Udaipur (Rajashtan) on clayey loam soil with Lok-1 wheat. Jat *et al*. (2003) reported that among herbicidal applications, isoproturon 0.75 kg ha^{-1}, metsulfuron methyl 3 and 4 g ha^{-1}, 2,4-D 0.4 kg ha^{-1} post-em. at 30 DAS recorded higher net return as compared to weedy check.

Jat *et al*. (2004) investigated a field experiment at Udaipur (Rajasthan) during *rabi* seasons of 1998-99 and 1999-2000 on clay loam soil. They observed that maximum benefit : cost ratio (3.60) was obtained from isoproturon (0.75 kg ha^{-1} at 30 DAS) followed by pendimethalin 1 kg ha^{-1} as pre-em. (3.15).

Singh and Singh (2004) conducted a field experiment on sandy loam soil at Jodhpur (Rajasthan) during winter seasons of 1998-99 and 1999-2000. The higher additional net return of Rs. 8063 was obtained with pendimethalin at 0.75 kg ha^{-1} supplemented by one hand weeding over rest of the treatments.

A field experiment was conducted at Pusa (Bihar) by Pandey *et al*. (2005) during the winter seasons of 1997 and 1998 on clay loam soil. They observed that net return under hand weeding, post-em. application of 2,4-D (SS) 0.8 kg ha^{-1}, isoproturon 0.75 kg ha^{-1} alone and 2,4-D (SS) 0.4 kg ha^{-1} + isoproturon 0.4 kg ha^{-1} being at par among themselves significantly excelled the weedy check.

2.9 Bioassay studies

Bioassay is a major tool for quantitative and qualitative determination of herbicide residual effect. In this method, the property of a chemical is measured in terms of some biological responses. Sensitive plant species called as indicator or test species are used for conducting bioassay. The major advantage of this technique is that the procedure followed is generally more economical, easy to perform and costly equipment are not required. The indicator plant is grown in a field or pot and is compared with that of similar plant grown in untreated soil.

To elucidate potential carryover effect of environment and soil factors on metsulfuron bioactivity was examined by Anderson (1985) in a Platner loam and a Valent sand soil with a maize root bioassay. Increasing soil temperature from 8 to 24°C in the loam soil reduced the duration of metsulfuron bioactivity by 49%. The temperature effect on metsulfuron bioactivity in the sand was less pronounced, as the 16°C increase resulted in only 20% reduction of duration of bioactivity. The effect of soil water content on metsulfuron bioactivity was soil and temperature related. Increasing soil water, increased metsulfuron degradation in the sand at 24°C, but not at 16°C, while in the loam, metsulfuron degradation was not affected by soil water level at either temperature. Incorporating metsulfuron in soil reduced the duration of bioactivity, while the presence of growing wheat plants in metsulfuron-treated soil did not affect the duration of bioactivity. Metsulfuron retained on surface straw residue was washed off by simulated rainfall, but duration of metsulfuron bioactivity was increased by this straw residue retention.

Kulshrestha and Yaduraju (1987) reported that residues of pendimethalin, applied to wheat @ 1.0-1.5 kg ha^{-1} pre-emergence in 0-5, 5-10 and 10-15 cm soil depths were analyzed periodically by GLC during 1985-86. More than 80% of the total residues were present in the 0-5 cm layer. The half-life of pendimethalin ranged between 58 and 63 days. Approximately 35% pendimethalin dissipated in 35 days and about 20% remained in soil at the time of wheat harvest. A bioassay (during 1986-87) with sorghum seedlings revealed that although 60-70% reduction in growth was recorded at 60 days after treatment (DAT), pendimethalin @ 1.5 kg ha^{-1} did not persist in quantities sufficient to cause phytoxicity to sorghum at 90 DAT.

Field trials were conducted by Yadav *et al*, 1993 on sandy loam at Hisar in 1987-88 to evaluate the persistence of pre-emergence pendimethalin applied to wheat cv. WH 283 @ 0, 1, 2 and 4 kg/ha under three irrigation levels. Herbicide residues were determined using a sorghum bioassay. The rate of degradation of pendimethalin was very slow for the 1st 50 days, then it increased steadily until 100 days, after which the rate of degradation was maintained. After 200 days 63.5, 75.2 and 88.0% reductions in the initial concentration of pendimethalin applied to wheat were observed with 2, 4 and 6 irrigation events, respectively. The half-life of the chemical was 76, 92 and 122 days with 6, 4 and 2 irrigation events, respectively.

Singh and Vaishya (1993) conduced experiments in laboratory and field on silty loam at Faizabad during the winter of 1990-92, the persistence of the following herbicide treatments after their application to wheat was investigated using a cucumber seed bioassay isoproturon alone @ 1 kg/ha, 2,4-D sodium salt @ 0.5 kg ha^{-1} and isoproturon + 2,4-D @ 0.5 + 0.5, 1 + 0.5, 0.5 + 0.25 and 1 + 0.5 kg ha^{-1}. The application of isoproturon and 2,4-D alone and as tank mixtures at different concentration did not cause considerable variations in the seed germination, plant height and dry matter production of cucumbers grown in soil taken after the harvest of the wheat crop. It is concluded that these herbicide treatments do not leave harmful levels of residues in the soil after the wheat harvest.

Field and laboratory experiments were conducted at H. P. K. V. Palampur during *rabi* 1992-93 and 1993-94 by Sharma and Angiras (1996). They observed that the residue of pendimethalin 1.5 kg ha^{-1} pre-emergence applied in wheat was only 0.001 ppm in soil after harvest of wheat through biassay using oat as indicator plant.

Persistence of trifluralin and pendimethalin applied at 1.0, 1.5 and 2.0 kg ha^{-1} was studied under laboratory conditions in the sterilised and unsterilised field soils at Hisar (Haryna) by Pahwa and Bajaj (1997). Persistence was studied by taking samples at 15 days interval using bioassay technique with sorghum seeds as test material. Persistence of both the herbicides decreased with time. Higher dose resulted in the greater persistence in both types of soils. Pendimethalin has greater inhibitory effects on germination.

Field and pot culture experiments were conducted at Hisar. The results revealed that residual toxicity of metsulfuron after 120 days of it's application on onion was more at low soil moisture than higher level. Solar light did not play any role in altering persistence of this herbicide. Half life of metsulfuron at 15, 25 and 35^{0} C was found to be 147, 108 and 70 days, respectively. The degradation rate of metsulfuron was faster in acidic silty loam soil as compared to high pH Hisar soil(Yadav *et al*, 1997).

Cucurbits, maize and moong were grown in soil collected after the harvest of a wheat crop treated with herbicide for the control of *Phalaris minor* in Ludhiana, India, during 1997-98 and 1998-99. Crop growth and development, as indicated by dry matter accumulation (g pot^{-1}), were normal when grown in soil samples that had been treated with recommended rates of new herbicides such as fenoxaprop-p-ethyl @ 100 g ha^{-1}, clodinafop @ 60 g ha^{-1}, sulfosulfuron @ 45 g ha^{-1}, diclofop-methyl @ 90 g ha^{-1} and tralkoxydim @ 0.35 kg ha^{-1} as compared to untreated plots. Application of sulfosulfuron @ 45 g ha^{-1} showed phytotoxicity on cucurbits. However, growth and development of maize and moong was not influenced by the residual effects of any herbicide applied to wheat(Walia *et al*., 2000).

The sorghum bioassay technique was employed for detection of pendimethalin residues in the soil by Bhan and Kewat (2002) at Jabalpur on clayey soil. They observed that pendimethalin at 1 kg ha^{-1} was dissipate by 30.4 % at 30 days which was increase up to 80 % at 45 days.

Pot study was carried out during 1995-96 and 1996-97. Isoproturon was applied @ 0.47, 0.94, 1.88, 2.82 and 3.76 kg ha^{-1} to pots at Ludhiana by Walia *et al*., 2002. They observed that residual concentration of isoproturon estimated by adopting bioassay techniques indicated that dry matter per pot of muskmelon up to recommended dose (@ 0.94 kg ha^{-1}) was statistically at par with control, whereas higher levels of isoproturon showed phytotoxicity on test plant. However, no phytotoxicity on maize and moong was observed even at higher levels.

Field experiment was conducted at Kota (Rajasthan) during *rabi* seasons of 1999-2000 and 2000-01 on clay loam soil by Singh and Ali (2004). They observed that post-em. application of metsulfuron methyl at 3 to 5 g ha^{-1} and 2,4-D 0.75 kg ha^{-1} gave excellent control of broad leaved weeds species than farmers practices and weedy check. Residual studies at same site on soybean showed that either of the doses of metsulfuron methyl did not leave any residual toxicity to the succeeding soybean crop as plant stand, plant dry matter and yield of the succeeding crop did not showed any visual phytotoxic symptoms.

Different field experiments were conducted by Yadav *et al*. (2004) at Hisar (Haryana) to study on residual impact of various herbicides applied in wheat on succeeding *kharif* season crops during 1996 to 2001 on sandy loam soil. Metsulfuron (4 and 8 g ha^{-1}), 2,4-D (0.5 & 1 kg ha^{-1}), isoproturon (1 kg ha^{-1}) and pendimethalin (1.5 kg ha^{-1}) applied in wheat did not exhibit any adverse effect on mungbean, maize, cowpea, pigeonpea, pearlmillet and cotton.

CHAPTER III
MATERIALS AND METHOD

A field experiment entitled "Efficacy of herbicides in wheat (*Triticum aestivum* L.) and assessment of their persistence through bioassay technique" was carried out during *rabi* season of the year 2003-04 and 2004-05. The details of the experimental procedure adopted, materials used and techniques followed during the course of present investigation are described in this chapter.

3.1 Experimental Sites

The field experiment was laid out on the plot no. D-6 of the Instructional Farm, Department of Agronomy, College of agriculture, Junagadh Agricultural University, Junagadh.

3.2 Climate and Weather Conditions

Geographically Junagadh is situated at 21.5^0 N latitude 70.5^o E longitude with altitude of 60 meters above the mean sea level. Junagadh is situated in South Saurashtra Agro-climatic region of Gujarat state and enjoy a typically subtropical climate characterized by fairly cold and dry winters, hot and dry summer and warm and moderately humid monsoon. The rainy season commences in the second fortnight of June and ends of September with an average rainfall of 848 mm (average of last 10 years). July and August are the months of heavy rainfall. Partial failure of monsoon once in three to four years is of common occurrence in this region. Winter sets in the month of November and continues till the month of February. January is the coldest month of winter. Summer season commences during the second fortnight of February and ends by middle of June. April and may are the hottest months of summer.

Weekly average of weather data pertaining to the period of present investigation recorded at the Meteorological Observatory, Junagadh Agricultural University, Junagadh are presented in Table 3.1 and 3.2 and graphically depicted in Fig. 3.1 and 3.2. It could be seen from the meteorological data that weather condition was more or less congenial for satisfactory growth and development of wheat crop under irrigated condition. The lowest temperature of 10.2^0 and 10.8^0 C was recorded during the winter season of 2003-04 and 2004-05, respectively.

3.3 Physico-Chemical Properties of the Soil

Soil samples were drawn randomly before commencement of the experiment from each replication of the experimental plot to a depth of 0-15 cm. and a composite sample was prepared and analyzed for physico-chemical properties of the soil. The values of soil analysis along with methods followed are furnished in Table 3.3.

The data presented in Table 3.3 indicate that the soil of the experimental plot was clayey in texture and slightly alkaline in reaction. The soil was low in available nitrogen, while medium in available phosphorus and potassium.

3.4 Cropping History of the Experimental Field

The cropping history of the experimental plot no. D-6 of Instructional Farm, JAU. Junagadh for the preceding three years is furnished in Table 3.4

Table 3.1: Mean weekly weather parameters during the crop growth period (2003-04)

Month	Std. Week	Temp. (^oC)		R.H (%)	Sunshine Hours	Wind velocity (km h^{-1})	Evapo (mm)
		Max.	Min.				
November	45	36.4	19.9	66	9.9	2.7	4.8
	46	34.6	18.5	72	9.9	3.1	4.4
	47	32.5	17.0	49	8.5	5.0	5.5
	48	34.2	15.2	68	9.0	2.5	4.6
December	49	34.2	13.8	71	9.1	2.4	3.9
	50	31.3	15.9	63	8.0	4.8	4.5
	51	28.5	10.9	65	8.7	5.0	5.1
	52	28.4	**10.2**	63	8.8	4.6	4.5
January	01	28.4	11.9	64	8.5	5.2	4.6
	02	31.2	12.7	67	9.0	3.2	4.0
	03	30.5	12.9	79	8.5	3.3	3.9
	04	27.6	10.8	64	9.2	4.5	4.4
	05	28.8	12.9	54	9.3	5.2	5.6
February	06	31.4	12.6	55	9.5	5.4	5.9
	07	32.9	13.8	62	9.5	5.0	5.8
	08	34.0	16.4	64	9.1	4.8	6.1
	09	36.5	17.4	53	9.7	4.9	7.4
March	10	38.9	18.3	46	8.0	5.3	8.0
	11	40.6	21.1	39	10.0	6.6	9.6
	12	40.6	20.3	63	10.2	6.1	9.1
	13	37.2	20.0	75	10.3	5.6	8.2
April	14	38.4	23.0	81	8.5	6.9	8.6
	15	37.7	23.9	81	9.4	6.1	8.9
	16	37.8	24.5	78	9.0	8.8	9.4
	17	40.3	25.1	81	9.0	7.5	9.1
	18	40.9	25.4	48	8.5	8.4	8.5

Table 3.2: Mean weekly weather parameters during the crop growth period (2004-05)

Month	Std. Week	Temp. (^oC)		R.H (%)	Sunshine Hours	Wind velocity (km h^{-1})	Evapo (mm)
		Max.	Min.				
November	45	35.3	19.9	55	7.1	2.9	5.3
	46	36.1	21.3	69	7.3	2.2	4.1
	47	35.5	17.8	70	8.5	2.4	4.3
	48	34.1	15.8	66	8.6	2.2	4.0
December	49	33.2	15.8	66	7.7	2.7	4.1
	50	34.5	14.3	62	8.3	2.7	4.5
	51	31.8	14.5	76	5.7	3.0	3.2
	52	29.9	15.0	71	4.5	3.1	3.5
January	01	27.6	11.3	65	7.2	6.7	5.4
	02	28.8	10.9	73	7.8	5.3	4.3
	03	28.0	**10.8**	60	8.3	4.24	4.3
	04	28.2	12.1	62	5.9	4.9	4.5
	05	27.3	11.7	55	8.5	6.04	5.6
February	06	31.6	15.0	71	8.1	3.79	4.3
	07	31.9	16.4	76	9.0	5.5	5.6
	08	27.7	11.0	38	9.3	6.34	6.7
	09	35.8	18.3	65	9.1	5.07	6.8
March	10	31.9	19.3	78	8.1	5.86	6.0
	11	36.7	19.4	57	10.5	5.79	8.1
	12	36.6	20.8	76	10.3	6.56	8.3
	13	37.8	20.7	61	10.0	6.46	8.8
April	14	41.4	20.9	36	10.3	6.13	10.5
	15	38.4	19.8	39	9.2	6.9	9.9
	16	41.5	25.0	36	9.8	6.91	10.7
	17	38.8	24.5	80	10.0	6.81	9.4
	18	38.6	25.1	80	9.8	7.37	9.1

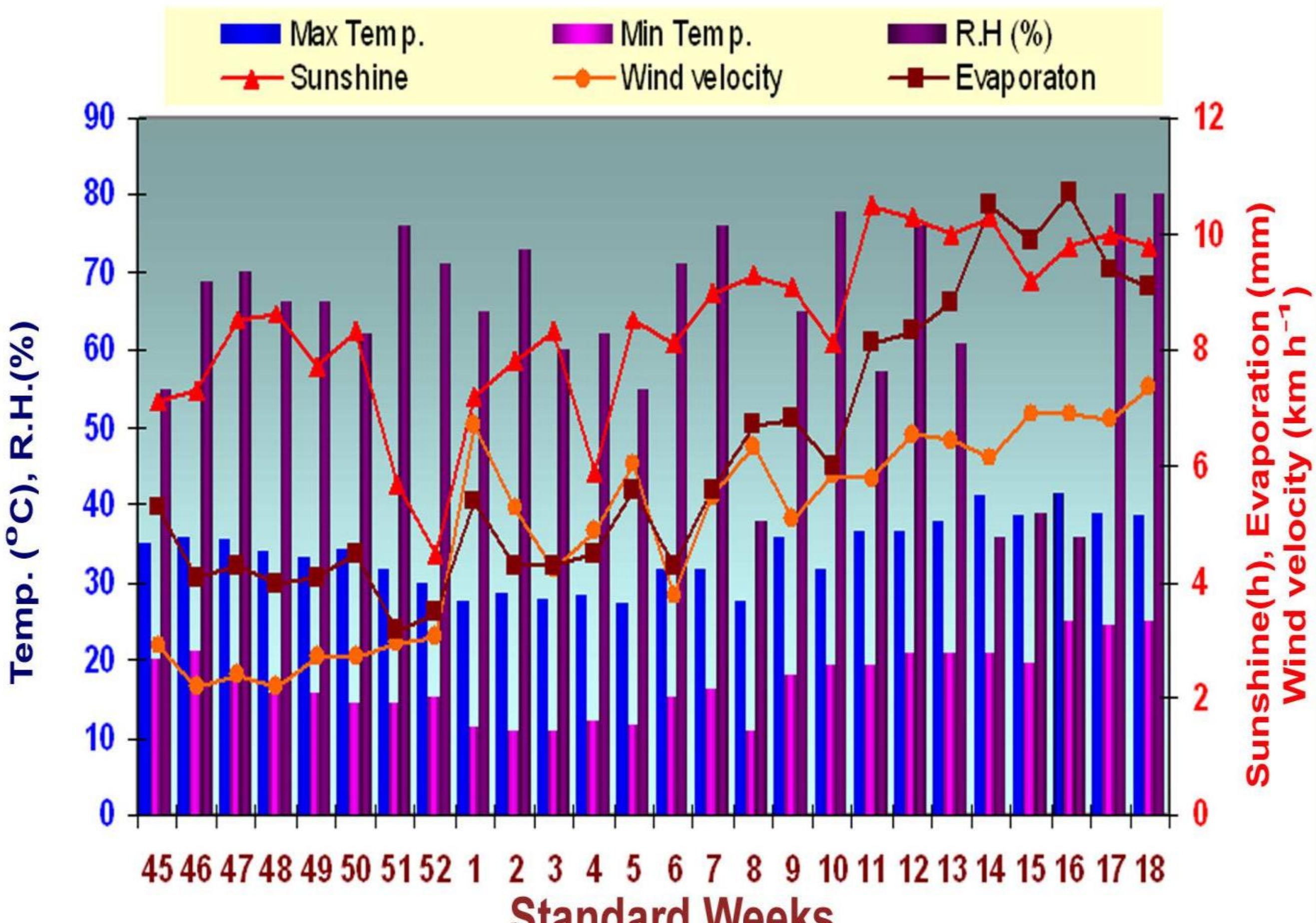


Fig. 3.1 Meteorological data recorded during the crop season-2003-04

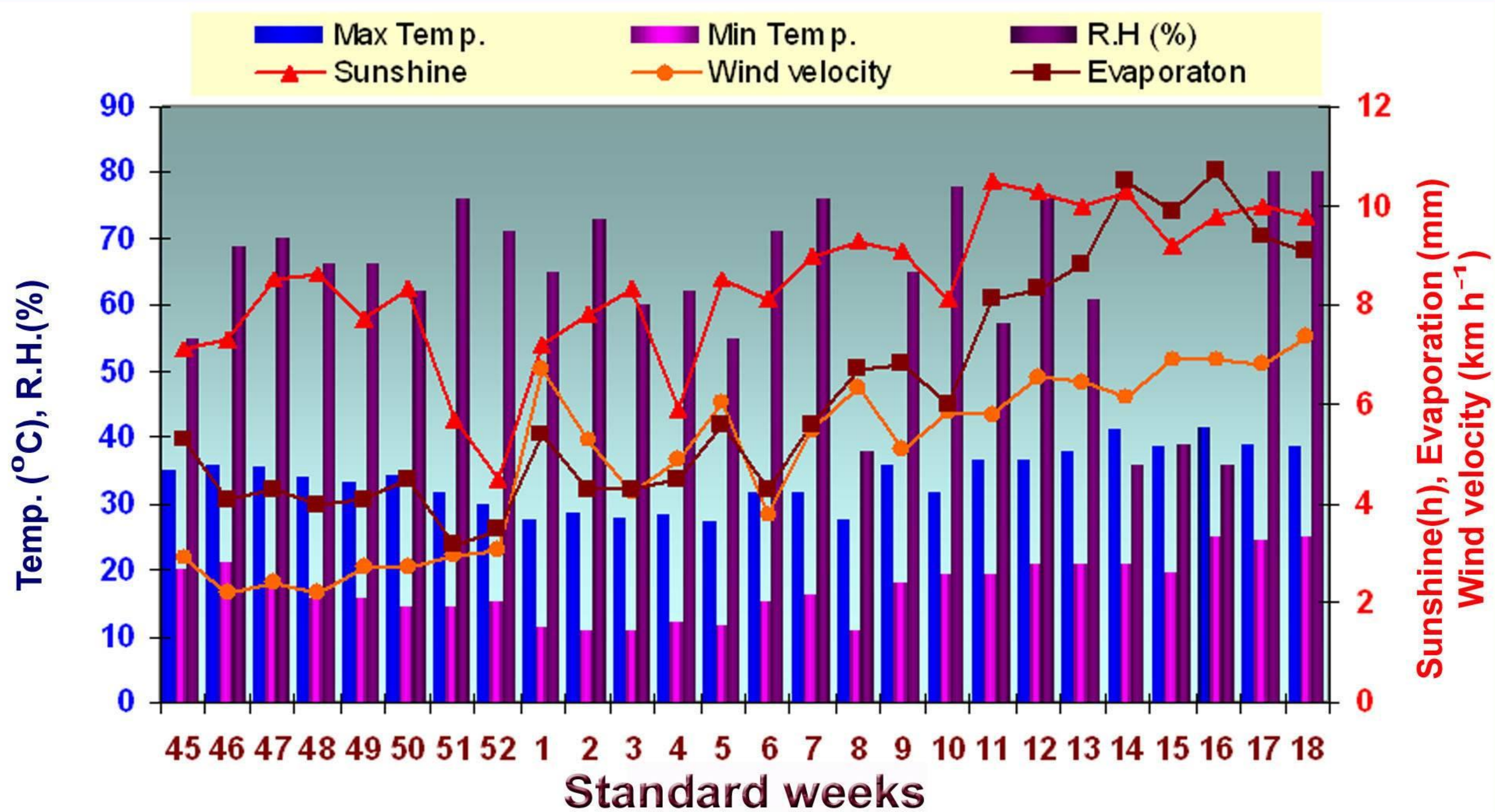


Fig. 3.2 Meteorological data recorded during the crop season-2004-05

Table 3.3: Physico-chemical properties of the soil

Particulars	Value of 0-15 cm depth	Method employed
A. Mechanical composition		
1. Sand (%)	28.40	International Pipette method (Piper,1950)
2. Silt (%)	27.20	
3. Clay (%)	43.40	
Textural class	Clayey	
B. Chemical Properties		
1. Organic carbon (%)	0.96	Walkely and Black Method (Jackson, 1967)
2. Available nitrogen (kg ha^{-1})	224.6	Alkaline $KMnO_4$ method (Subbaiah and Asija,1956)
3. Available P_2O_5 (kg ha^{-1})	23.04	Olsen's method (Olsen *et al.*, 1954)
4. Available K_2O (kg ha^{-1})	272.0	Flame photometric method (Jackson, 1967)
5. Soil pH (1:2.5)	8.05	pH meter (Richards,1954)
6. Electrical Conductivity (dS m^{-1}) at 25°C (1:2.5)	0.26	EC meter (Jackson, 1967)

Table 3.4 : Cropping history of experimental field

Year	**Season**	**Crop**	**Fertilization** (kg ha^{-1})		
			N	**P_2O_5**	**K_2O**
2001-2002	*Kharif*	G'nut	12.5	25	0
	Rabi	Wheat	120	60	0
	Summer	Fallow	-	-	-
2002-2003	*Kharif*	G'nut	12.5	25	0
	Rabi	Wheat	120	60	0
	Summer	Fallow	-	-	-
2003-2004	*Kharif*	Groundnut	12.5	25	0
	Rabi	Present experiment	120	60	0
	Summer	Fallow	-	-	-
2004-05	*Kharif*	Groundnut	12.5	25	0
	Rabi	Present experiment	120	60	0

3.5 Salient Features of the Variety

The variety GW 322 released recently for entire state from the Wheat Research Station, Vijapur (Gujarat) was selected for this study. This variety was developed through pedigree method from the cross PBW 173 x GW 196 and its duration is 107 days. The plant is usually 75-82 cm in height and dark green coloured with blooming. The spikes are dense, parallel in shape and dirty white awned. The grains are amber in colour and hard in texture. The variety is highly responsive to fertilizer, resistance to leaf and stem rust diseases and resistance to shattering.

3.6 Experimental Details

The experiment comprising of 10 treatments was laid out in Randomized Block Design with four replications during both the years. The layout is depicted in Fig 3.3. The gross and net plot sizes were 6.0 x 2.70 m (12 rows) and 5.0 x 1.80 m (8 rows), respectively. The details of treatments are given as under

T_1 : Pendimethalin 1.000 kg ha^{-1} pre-emergence + 1 HW at 30 DAS

T_2 : Isoproturon 0.750 kg ha^{-1} pre-emergence + 1 HW at 30 DAS

T_3 : Isoproturon 0.750 kg ha^{-1} post-emergence at 30 DAS

T_4 : Fluchloralin 0.450 kg ha^{-1} pre-emergence + 1 HW at 30 DAS

T_5 : Metsulfuron 0.006 kg ha^{-1} post-emergence at 30 DAS

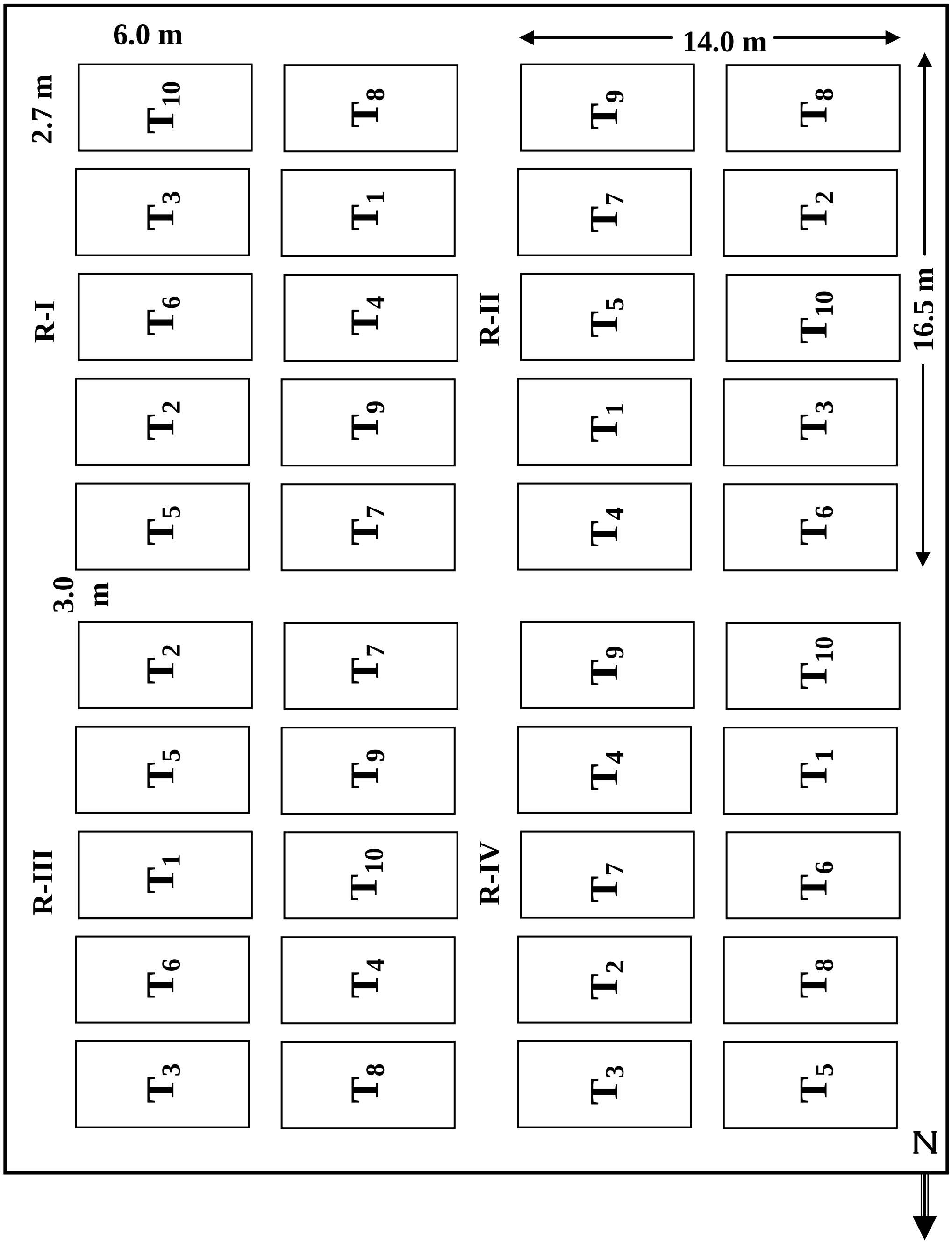
T_6 : 2,4-D (SS) 0.960 kg ha^{-1} post-emergence at 30 DAS

T_7 : 2,4-D (EE) 0.750 kg ha^{-1} post-emergence at 30 DAS

T_8 : 2 Hand weedings (at 20 and 40 DAS)

T_9 : Weed-free

T_{10} : Unweeded control



Design : Randomized Block Design

Replication : 4 (Four)

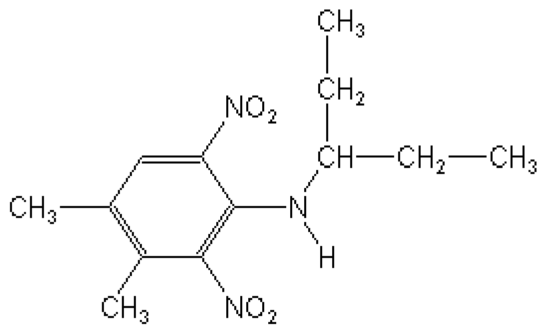
Plot size : Gross : 6.00 m x 2.70 m, Net : 5.00 m x 1.80 m

Fig. 3.3 Lay out of field experiment

Field view of the experiment

3.6.1 Properties of Herbicides

(a) Pendimethalin



Chemical name:

N-[1-(ethyl-propyl)-3,4-dimethyl-2-6 dinitrobenzene amine.]

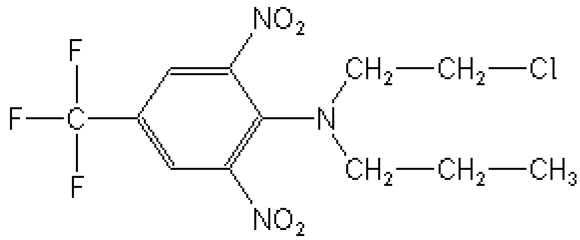
Trade name : Stomp, Tata – Penida, Pendiguard

Manufactures : BASF, Tata, Gharda

Mode of Action: This herbicide does not inhibit seed germination but rather inhibit early seedling growth shortly after seed germination. This is caused by the disruption of cell division. It means inhibits both cell division and cell elongation in shoot and root meristem of susceptible weed species. Growth is inhibited directly following absorption through shoot and hypocotyls.

Uses: Pendimethalin controls annual grasses and certain broad leaf weeds in many crops. It is applied pre-emergence, early post emergence and pre-plant incorporated depending on the crop. It does not require soil incorporation with adequate rainfall or overhead irrigation because of its low volatility. Certain crops like cotton, soybean, groundnut, peas and sunflower can physiologically tolerate to pendimethalin, so pre-plant incorporation or pre-emergence may also be used here. Crops like wheat, rice, maize, seeded onion and carrots tolerate pendimethalin because the seeds are placed below herbicide layer, where only pre-emergence spray is used.

(b) Fluchloralin



Chemical name:

N(2chloroethyl)2,6dinitroNpropyl4(trifluoromethyl)aniline

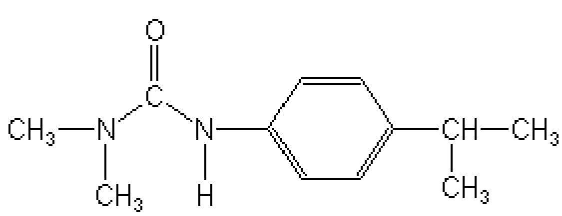
Trade name: Basalin

Manufactures : BASF

Mode of Action: Fluchloralin cause mitotic abrasions. Disruption of nuclear and cell division is a major component of their action. At molecular level, the affected tissues show reduced levels of RNA, proteins and several enzymes.

Uses: Fluchloralin is a pre-emergence herbicide used in cereal crops particularly wheat and rice, pulse crops, groundnut and many vegetable crops for selective control of many annual broadleaf weeds and grasses. The susceptible weeds are affected during germination or seedling emergence. For better results, soil incorporation is needed.

(c) Isoproturon



Chemical name:

N-(4-isopropyl phenyl)-N,N-diethyl urea.

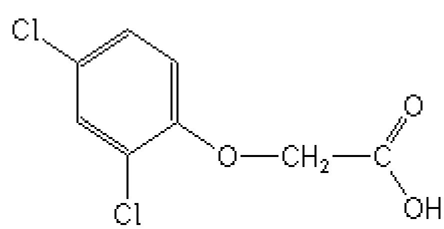
Trade name: Isoguard, Tolkan, Arelon

Manufactures : Gharda Chemicals Ltd., Hechest, Rhone-poulenc

Mode of Action: Pre and post-emergence selective herbicide. It acts principally by absorption through the roots and leaves.

Uses: Isoproturon is a versatile herbicide for the control of annual grass weeds, particularly, canary grass (*Phalaris minor*) and wild oat (*Avena fatua*) in wheat. Besides, it will also control some broad leaf weeds like *Anagallis, Melilotus, Convolvulus* and *Chenopodium* spp. It is active on the susceptible weeds, both as pre and post-emergence treatments. Though in India its maximum use has been made in the latter form. It is very commonly applied as spray treatments, 30-35 days after sowing winter grains; soon after the first irrigation of the crop. The annual grasses at this stage are young and susceptible to isoproturon. Its effective rates are 0.75- 1.0 kg ha^{-1} on medium soils and up to 1.5 kg ha^{-1} on the heavy soils.

(d) 2,4-D



Chemical name:

2,4-dichlorophenoxy acetic acid.

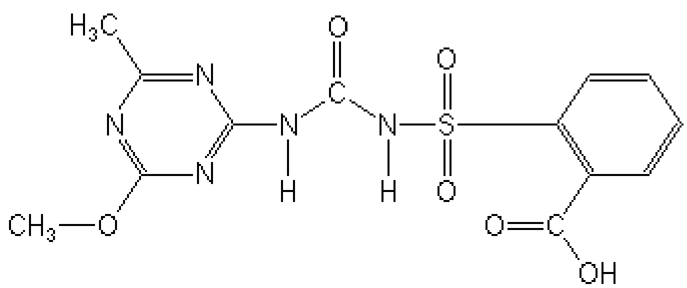
Trade name: Fernoxone (Sodium salt), Agrodon

Manufactures : ICI, Devi dayal

Mode of Action: Cell proliferation (i) Extension enzyme activated – cell wall become loose – it absorb uncontrolled and non-osmotic water absorption which leads to desiccation of cell, (ii) In leaf due to proliferation of cells, reduction in intercellular spaces which stops gas exchange activity.

Uses: 2,4-D is an excellent selective, post-emergence herbicide for the control of herbaceous, dicot weeds and nut sedges shoot in small grains, sugarcane, grass lands, lawn and road sides. When used as a pre-emergence herbicide, it will also control many grasses from seeds for a couple of weeks. Certain dicot crops such as cotton, tobacco, tomato and chickpea are extremely sensitive to 2,4-D. On non-cropped lands it is an important component herbicide for general vegetation control. It is also used in waterbodies, particularly for the control of water hyacinth.

(e) Metsulfuron methyl



Chemical name:

Methyl 2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)-amino]carbonyl]amino]sulfonyl]benzoate.

Trade name: Algrip, Hook

Manufactures : Du-pont, Northern minerals

Mode of Action: This herbicide which is active at very low concentration, kill plants by interfering with the bio-synthetic pathway of three branched chain amino acids, valine, leucine and isoleucine, through inhibition of the enzyme acetolactate synthase.

Uses: Metsulfuron methyl is a broad spectrum herbicide effective in cereals when applied pre or post-emergence. Metsulfuron belongs to the sulfonylurea group of herbicides. The selectivity of the herbicide is due to more rapid metabolism of the herbicide into non-toxic metabolites in tolerant than in susceptible species. However, in some susceptible weed species, the leaves may remain green but they are stunted and non competitive. Metsulfuron is used for the control of broad leaf weeds in barley and wheat and non-cropped lands. It is also used for brush control. In barley and wheat, it is applied post-emergence at the two-leaf stage to the boot stage of the crop.

3.7 Cultural Operation

The calendar of cultural operations carried out during the course of experimentation is given in Table 3.5.

3.7.1 Land preparation

The experimental field was ploughed in the second week of the November with the help of tractor plough followed by harrowing with blade harrow and planking to achieve fine tilth.

3.7.2 Fertilization

The crop was fertilized with 60 kg nitrogen and 60 kg phophorus ha^{-1} through urea and di-ammonium phosphate as a basal application at the time of sowing. Remaining 60 kg nitrogen in the form of urea was top dressed at 20 days after sowing.

Table 3.5 : Calendar of cultural operations

Sr.No.	Field operation	Frequency	Date of operation	
			2003-04	2004-05
A	Pre sowing operation			
	Tractor ploughing	1	11-11-2003	10-11-2004
	Harrowing with blade harrow	1	14-11-2003	12-11-2004
	Planking, opening of furrow	1	14-11-2003	12-11-2004
	Field lay out	1	17-11-2003	16-11-2004
	Basal fertilizer application	1	18-11-2003	18-11-2004
B	Sowing			
	Sowing the seeds with the help of bullock drawn seed drill	1	18-11-2003	18-11-2004
C	Post sowing operation			
	Application of pre-emergence herbicides	1	19-11-2003	19-11-2004
	Top dressing of fertilizers	1	09-12-2003	15-12-2004
	Application of post-emergence herbicides	1	17-12-2003	18-12-2004
	Irrigation (Total)	-	11 Irrigation	10 irrigation
	Hand weeding	-	As per the treatments	
	Plant protection measures	-	-	-
	Harvesting	-	27-2-2004	3-3-2005
	Threshing	-	3-3-2004	11-3-2005

3.7.3 Sowing

The crop was sown on November, 18 during both the years at 22.5 cm inter row spacing using bullock drawn automatic seed drill with seed rate of 120 kg/ha.

3.7.4 Irrigation

First irrigation was given immediately after sowing for satisfactory germination of the crop and remaining irrigations were given as per the recommended schedule.

3.7.5 Pest and diseases

No serious pest and diseases were observed during the period of experimentation.

3.7.6 Harvesting and threshing

The crop was harvested at maturity on 27th February 2004 and 3rd March 2005. Border two rows from each side of the plot and 0.5 m strips on both sides of 6 m row length of gross plot were harvested as border area. Then remaining plants in the net plot was harvested. The harvested plants were bundled, sun-dried and weighted before threshing to record total (grain + straw) yield. Threshing was carried out and grains per net plot collected were winnowed, cleaned and weighed.

3.8 Treatment Evaluation

The crop response to different treatments application under the present investigation was evaluated on basis of growth, yields, weed studies, nutrient uptake and bioassay studies in wheat, which are given in Table 3.6.

(A) Growth parameters

3.8.1 Plant stand

Numbers of plants per 1 m row length at 20 DAS and at harvest were counted and recorded.

3.8.2 Plant height

The plant height at harvest was measured of randomly selected five plants. Average value for each net plot was computed and recorded.

3.8.3 Leaf Area Index (LAI)

Numbers of leaflets from five randomly selected plants were counted to get average number of leaflets per plant. The randomly selected leaflets starting from small to large leaflets from each plant were used for measuring the leaflet area with the help of leaf area meter (Licor 3000). The leaf area index (LAI) was calculated from the formula given below

$$LAI = \frac{\text{Leaf area } (m^2)}{\text{Land area } (m^2)}$$

Where, Leaf area= Leaf area per plant in m^2 and

Land area = Land area occupied by a plant in m^2

(B) Yield attributes and Yield

3.8.4 Number of tillers

Total and productive tillers per 0.5 m row length were recorded at harvest.

Table 3.6: Growth, yields, weed studies, nutrient uptake and bioassay studies in wheat

No.	Character	Sample	Time of recording
A) Growth parameters			
1	Plant stand	1m row length	20 DAS & At harvest
2	Plant height	5 Plants / net plot	At harvest
3	Leaf Area Index	5 Plants / net plot	At 50% Flowering
B) Yield Attributes and yield			
1	Total number of tillers	0.5 m row length	At harvest
2	Productive tillers	0.5 m row length	At harvest
3	Spiklets / spike	5 spikes / net plot	At harvest
4	Grain weight / plant	5 Plants / net plot	At harvest
5	Test weight (g)	Random sample from net plot	At harvest
6	Grain yield (kg ha^{-1})	Net plot	At harvest
7	Straw yield (kg ha^{-1})	Net plot	At harvest
C) Weed studies			
1	Species wise weed counts	0.36 m^2	At 20,40,60 DAS & At harvest
2	Dry weight of weeds (kg ha^{-1})	Net plot	At harvest
3	Weed index		
4	Weed control efficiency		
5	Herbicidal efficiency index		
D) Chemical Studies			
(1) Nutrient uptake by weeds			
i	Nitrogen uptake by weeds (kg ha^{-1})		
ii	Phosphorus uptake by weeds (kg ha^{-1})		
iii	Potash uptake by weeds (kg ha^{-1})		
(1) Nutrient uptake by crop			
i	Nitrogen uptake by crop (kg ha^{-1})		
ii	Phosphorus uptake by crop (kg ha^{-1})		
iii	Potash uptake by crop (kg ha^{-1})		
E) Bioassay studies (Indicator plants)			
(1) Pot studies (at 30 and 60 days after application of herbicides)			
i	Germination (%)	Per pot	At 10 DAS
ii	Plant height	5 plants	At 30 DAS
iii	Dry matter production	5 plants	At 30 DAS
(2) Field studies (After harvest)			
i	Germination (%)	Net plot	At 10 DAS
ii	Plant height	5 plants / net plot	At 30 DAS
iii	Dry matter production	5 plants / net plot	At 30 DAS

3.8.5 Spikelets per spike

Five spikes were harvested from the net plot randomly and average number of spikelets per spike was recorded.

3.8.6 Grain weight per plant (g)

Five plants were harvested from the net plot randomly and allowed to sun dry for six days. All the spikes from these plants were threshed and clean manually, weighted and average value of grain weight per plant was recorded for each plot.

3.8.7 Test weight (g)

From bulk produce of each net plot, a representative grain sample was drawn and one thousand seeds were counted randomly. Their weight was recorded as 1000 seed weight.

3.8.8 Grain yield (kg/ha)

The produce of each net plot was threshed and collected separately and grain yield was recorded. The grain yield per net plot was then converted into hectare basis.

3.8.9 Straw yield (kg/ha)

The straw yield was recorded by subtracting the grain yield from total yield of each net plot and subsequently the values were converted on hectare basis.

(C) Weed Studies

3.8.10 Weed counts

The weed counts were taken at 20, 40, 60 DAS and at harvest. The weed counts were taken from the tagged spot of 0.36 m^2 in the randomly selected each net plot. The spot was earmarked by iron quadrate having dimension of 0.6 x 0.6 m^2 length and width, respectively.

3.8.11 Dry weight of weeds

The weeds were air dried completely till they reached to constant weight and finally dry weight of weeds was recorded for each treatment after harvest.

3.8.12 Weed index (WI)

The weed index was calculated by using the following formula (Gill and Kumar, 1969).

$$WI = \frac{YHW\text{-}Yt}{YHW} \times 100$$

Where, WI = Weed index

YHW = Average yield of crop in weed free plot

Yt = Average yield of crop in plot under other weed control treatment.

3.8.13 Weed Control efficiency

The weed control efficiency was calculated by using the following formula (Mani *et al*., 1973).

$$WCE = \frac{DWC - DWT}{DWC} \times 100$$

Where, WCE = Weed control efficiency

DWT = Dry weight of weeds in treated plot.

DWC = Dry weight of weeds in unweeded control plot.

3.8.14 Herbicidal Efficiency Index (HEI)

Herbicidal efficiency index was calculated by using the following formula (Krishnamurty *et al*., 1975).

$$\text{HEI} = \frac{\dfrac{\text{Yield from treatment - Yield from control}}{\text{Yield from control}} \times 100}{\text{Per cent weed weight in the treatment}}$$

Where, HEI = Herbicidal efficiency index

(E) Chemical Studies

Chemical analyses of crop plants and weeds were carried out by taking representative sample excluding roots from each net plot at harvest of crop. The samples were oven dried at 60 ^{0}C for 24 hours and then powdered by using pestle and mortar. Finally, powdered samples were utilized for extraction of various elements.

3.8.15 Nitrogen content

Nitrogen content in plant was determined on per cent dry weight basis as per method of modified Kjeldahls as described by Jackson (1967). Nitrogen uptake was calculated by the following formulae.

$$\text{N uptake by crop (kg ha}^{-1}\text{)} = \frac{\text{N content in total yield (straw + grain) \%} \times \text{Total yield (straw + grain) (kg ha}^{-1}\text{)}}{100}$$

$$\text{N uptake by weeds (kg ha}^{-1}\text{)} = \frac{\text{N content in dry matter of weeds \%} \times \text{Dry matter of weeds (kg ha}^{-1}\text{)}}{100}$$

3.8.16 Phosphorus content

The known quantities of powdered samples were digested in a diacid mixture as per method described by Johnson and Ulrich (1969). Phosphorus was determined by Vandomolybdo-phosphate yellow colour method (Jackson, 1967). Phosphorus uptake was calculated by the following formulae.

$$\text{P uptake by crop (kg ha}^{-1}\text{)} = \frac{\text{P content in total yield (straw + grain) \%} \times \text{Total yield (straw + grain) (kg ha}^{-1}\text{)}}{100}$$

$$\text{P uptake by weeds (kg ha}^{-1}\text{)} = \frac{\text{P content in dry matter of weeds \%} \times \text{Dry matter of weeds (kg ha}^{-1}\text{)}}{100}$$

3.8.17 Potash content

Potash was extracted by diacid digestion and then determined by Flame photometer method (Jackson. 1967). Potash uptake was calculated by the following formulae.

$$\text{K uptake by crop (kg ha}^{-1}\text{)} = \frac{\text{K content in total yield (straw + grain) \%} \times \text{Total yield (straw + grain) (kg ha}^{-1}\text{)}}{100}$$

$$\text{K uptake by weeds (kg ha}^{-1}\text{)} = \frac{\text{K content in dry matter of weeds \%} \times \text{Dry matter of weeds (kg ha}^{-1}\text{)}}{100}$$

(F) Bioassay Studies

Bioassay is a major tool for quantitative and qualitative determination of herbicide residues. In this method, the property of a chemical is measured in terms of some biological responses. The response is measured through two different types viz., (i) plant part response and (ii) total plant response (Lavy and Santelmann, 1986). The second procedure is adopted in this experiment in which the entire plant may exhibit chlorosis or a suppression or inhibition of growth. This response may be demonstrated by harvesting the sensitive plants and evaluating growth parameters.

3.8.18 Pot studies (at 30 and 60 DAS during crop growth)

Plastic pots of 20 cm diameter and 10 cm height were used for raising sorghum, mustard and cucumber as indicator plants. Pots were filled with 500 g soil sample taken from each net plot at 0-15 cm depth. Counted seeds were sown in each pot for different test. Water was applied as and when required.

3.8.18.1 Germination (%)

Numbers of plants were counted at 10 DAS from each pot and converted in to the per cent basis.

3.8.18.2 Plant height

The plant height was measured from ground level to the top of main shoot of randomly selected 5 plants in each pot at 30 days after sowing (DAS).

Pot studies of the experiment

3.8.18.3 Dry matter production

The randomly selected five plants from each pot were dried in the oven at 65 $\pm$ 5 ^{0}C till the constant weight. The average value of dry matter per 5 plants (g) was recorded.

3.8.19 Post harvest field studies

After harvesting of the wheat crop bioassay study was carried out in the same field. Four crops viz., groundnut, greengram, pearlmillet, and cotton were grown as indicator plants. Fix number of seeds of the indicator plants were sown in each plot for different test.

3.8.19.1 Germination (%)

Numbers of plants were counted from each row and converted in to the per cent basis.

3.8.19.2 Plant height

The plant height was measured from ground level to the top of main shoot of randomly selected 5 plants in each row at 30 DAS.

3.8.19.3 Dry matter production

Randomly selected five plants of each crop were dried in the oven at 65 $\pm$ 5 ^{0}C till the constant weight. The average value of dry matter per plant (g) was record.

3.9 Economic Evaluation

In order to evaluate the economic effectiveness of different treatments and to ascertain the most remunerative treatment, the expenses include all cultural operations starting from preparatory tillage to harvesting and threshing of crop and cost of inputs viz., seeds, fertilizers, irrigation, herbicides etc. applied to each treatment were computed and added. The gross realization was worked out on the basis of mean grain and straw yield per hectare of each treatment and at prevailing market price during the year 2003-04 and 2004-05. The net realization of each treatment was calculated by deducting the total cost of cultivation from the gross returns.

3.10 Statistical Analysis

(a) Analysis of variance and test of significance

The statistical analysis of the data of various characters studied in the investigation was carried out as per randomized block design. Significance of difference was tested by F test (Gomez and Gomez, 1984).

The critical difference for the treatment comparison was worked out, where ever the F-test was found significant at 5 per cent level of significance. To elucidate treatment effects, summary tables along with critical difference at 5 per cent were prepared and their analysis of variance are given in the appendices at the end.

An attempt was also made to analyses the correlation between grain yield and growth parameters, yield attributing characters, weed parameters and nutrient uptake.

CHAPTER IV
EXPERIMENTAL RESULTS

Results of the field experiment entitled "Efficacy of herbicides in wheat (*Triticum aestivum* L.) and assessment of their persistence through bioassay technique." carried out at Instructional Farm, Junagadh Agricultural University, Junagadh during *rabi* season of the year 2003-04 and 2004-05 are presented in this chapter along with statistical inferences. The data pertaining to growth, yield attributes, yields, weed population, dry weight of weeds, weed index, weed control efficiency, herbicidal efficiency index and data on bio-assay studies were subjected to statistical analysis and "Analysis of variance" have been furnished in Appendices I to XIII The results have also been presented graphically wherever felt necessary. The efficacy of various treatments were adjudged by a comparative assessment of growth, yield attributes, yields and other characters. All findings pertaining to different treatments are described here in the following heads.

4.1 Growth parameters
4.2 Yield attributes
4.3 Yield
4.4 Weed study
4.5 Nutrient uptake by weeds and crop
4.6 Economics
4.7 Bioassay studies
4.8 Correlation studies

4.1 GROWTH PARAMETERS

4.1.1 Plant population

The data on the effect of different treatments on initial and final plant population of wheat are presented in Table 4.1 and their analysis of variance is furnished in Appendix I.

Table 4.1. Effect of different treatments on plant population at 20 DAS and at harvest

Treatment	20 Days After Sowing			At Harvest		
	2003-04	**2004-05**	**Pooled**	**2003-04**	**2004-05**	**Pooled**
T1	66.0	67.8	66.9	48.3	49.8	49.0
T2	61.0	58.5	59.8	43.3	40.5	41.9
T3	67.0	62.8	64.9	49.3	44.8	47.0
T4	68.5	67.5	68.0	50.8	49.5	50.1
T5	67.8	62.3	65.0	50.0	44.3	47.1
T6	67.5	58.0	62.8	49.8	40.0	44.9
T7	63.8	59.3	61.5	46.0	41.3	43.6
T8	62.0	61.3	61.6	44.3	43.3	43.8
T9	67.8	62.3	65.0	50.0	44.3	47.1
T10	65.0	61.3	63.1	47.3	43.3	45.3
S.Em.±	4.8	3.6	3.0	4.8	3.6	3.0
C.D. (0.05)	N.S.	N.S.	N.S.	N.S.	N.S.	N.S
C.V. %	14.75	11.71	13.40	20.21	16.49	18.61

4.1.1.1 Initial plant population

Effect of different weed management treatments was found non-significant on initial plant population recorded at 20 DAS during 2003-04 and 2004-05 as well as in the pooled results. The results indicate that there was no significant phytotoxic effect of different herbicides applied as pre-emergence on wheat crop. However, pre-emergence application of isoproturon 0.750 kg ha^{-1} showed initial chlorosis effect on few plants which was recovered at later stage.

4.1.1.2 Final plant population

Different weed management treatments did not influence significantly the plant population recorded at harvest during 2003-04, 2004-05 and in the pooled results. Thus results clearly showed that there was no adverse effect of different herbicides applied either as pre-emergence or as post-emergence on wheat crop.

4.1.2 Plant height

The data on plant height recorded at harvest are presented in Table 4.2 and their analysis of variance is furnished in Appendix I. The data are also graphically depicted in Fig.4.1

During 2003-04, being at par among themselves, pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1), fluchloralin 0.45 kg ha^{-1} pre-em. + 1 HW (T_4), 2 hand weeding (T_8) and 2,4-D (S.S.) 0.96 kg ha^{-1} post-em. (T_6) recorded equivalent plant height to weedfree (T_9) and significantly higher over rest of the treatments as well as unweeded control (T_{10}).

During 2004-05, among different treatments significantly higher plant height was observed under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1) and remained at par with metsulfuron 6 g ha^{-1} post-em. (T_5), 2,4-D

(S.S.) 0.96 kg ha^{-1} post-em.(T_6) and weedfree (T_9). Unweeded control recorded significantly the lowest plant height.

In pooled results, being at par among themselves, pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1), fluchloralin 0.45 kg ha^{-1} pre-em. + 1 HW (T_4), and metsulfuron 6 g ha^{-1} post-em. (T_5) recorded equivalent plant height to weedfree (T_9) and significantly higher over rest of the treatments as well as unweeded control (T_{10}).

4.1.3 Leaf Area Index

The data pertaining to leaf area index recorded at 50 % flowering are presented in Table 4.2 and their analysis of variance is furnished in Appendix I. The data also graphically depicted in Fig. 4.1

During 2003-04, significantly higher leaf area index was recorded under metsulfuron 6 g ha^{-1} post-em. (T_5) and it remained at par with rest of the treatments and proved significantly superior over unweeded control (T_{10}). While in the year 2004-05 significantly higher leaf area index were recorded under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1) and remained at par with metsulfuron 6 g ha^{-1} post-em. (T_5), isoproturon 0.75 kg ha^{-1} post-em. (T_3) and weedfree (T_9).

When the results were pooled over two years, significantly higher leaf area index was observed under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1) and remained at par with rest of the treatments, except treatments isoproturon 0.75 kg ha^{-1} pre-em. + 1 HW (T_2) and unweeded control (T_{10}).

Table 4.2. Effect of different treatments on plant height and leaf area index

Treatment	Plant height (cm)			Leaf area index		
	2003-04	2004-05	Pooled	2003-04	2004-05	Pooled
T1	80.3	71.8	76.0	3.67	3.23	3.45
T2	75.4	67.4	71.4	2.73	2.52	2.63
T3	76.4	67.6	72.0	3.32	2.90	3.11
T4	78.9	68.1	73.5	3.53	2.69	3.11
T5	76.4	70.2	73.3	3.69	3.13	3.41
T6	77.0	68.4	72.7	2.93	2.43	2.68
T7	74.5	64.9	69.7	3.30	2.45	2.88
T8	77.8	68.0	72.9	3.49	2.66	3.08
T9	77.1	72.5	74.8	3.22	3.56	3.39
T10	72.1	57.5	64.8	1.71	1.13	1.42
S.Em.±	1.3	1.4	1.0	0.37	0.26	0.27
C.D. (0.05)	3.8	4.2	2.8	1.06	0.76	0.78
C.V. %	3.42	4.25	3.81	23.16	19.49	21.78

4.2 YIELD ATTRIBUTES

4.2.1 Number of tillers

The data on total number of tillers and productive tillers recorded at harvest are presented in Table 4.3 and their analysis of variance is furnished in Appendix II. The data are also graphically depicted in Fig.4.2

Different treatments did not exert their significant effect on total number of tillers during 2003-04. However, effect was found significant during 2004-05 as well as in the pooled results. During 2004-05, maximum number of total tillers was observed under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1) and metsulfuron 6 g ha^{-1} post-em. (T_5) and remained at par with weedfree. While in pooled results, all the treatments being at par among themselves produced significantly higher total tillers over unweeded control.

In the year 2003-04, all the treatments being at par among themselves produced significantly higher productive tillers over unweeded control. While during 2004-05 treatments, weedfree (T_9) and metsulfuron 6 g ha^{-1} post-em. (T_5) remaining on same bar and recorded significantly higher productive tillers over rest of the treatments. When the results were pooled over two years, significantly higher productive tillers were obtained under weedfree treatment (T_9) and remained at par with pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1) and metsulfuron 6 g ha^{-1} post-em. (T_5).

4.2.2 Spikelets per spike

The data on number of spikelets per spike recorded at harvest are presented in Table 4.4 and their analysis of variance is furnished in Appendix II. The data are also graphically depicted in Fig.4.2

Table 4.3. Effect of different treatments on total and productive tillers per 0.5 meter row length

Treatment	Total tillers			Productive tillers		
	2003-04	**2004-05**	**Pooled**	**2003-04**	**2004-05**	**Pooled**
T1	55.8	49.5	52.6	49.8	44.3	47.0
T2	50.3	47.3	48.8	44.8	43.3	44.0
T3	51.5	47.8	49.6	44.5	44.5	44.5
T4	56.8	44.5	50.6	48.8	41.3	45.0
T5	56.0	49.5	52.8	46.5	47.0	46.8
T6	51.8	44.8	48.3	43.3	40.0	41.6
T7	55.3	43.8	49.5	48.0	39.0	43.5
T8	57.5	44.8	51.1	49.0	40.5	44.8
T9	51.8	53.0	52.4	51.3	50.8	51.0
T10	48.0	33.5	40.8	35.8	30.8	33.3
S.Em.±	3.1	1.8	1.8	2.8	1.8	1.7
C.D. (0.05)	NS	5.1	5.4	8.2	5.2	4.8
C.V. %	11.55	7.64	10.11	12.26	8.55	10.75

Effect of different treatments was found significant on number of sikelets per spike during 2003-04, 2004-05 as well as in the pooled results. Significantly the highest number of spikelets of 15.65 was recorded under 2 hand weedings (T_8) during 2003-04 and it remained at par with pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1), metsulfuron 6 g ha-1 post-em. (T_5), isoproturon 0.75 kg ha^{-1} post-em. (T_3), fluchloralin 0.45 kg ha^{-1} pre-em. + 1 HW (T_4) and isoproturon 0.75 kg ha^{-1} pre-em. + 1 HW (T_2) and found equivalent to weedftree (T_9). During 2004-05, maximum number of sikelets were recorded under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1) and 2 hand weedings (T_8) over rest treatments. While in pooled results, being at par among themselves, all the treatments produced significantly higher spikelets over unweeded control.

4.2.3 Grain weight per plant

The data pertaining to grain weight per plant recorded at harvest are presented in Table 4.4 and their analysis of variance is furnished in Appendix II. The data are also graphically depicted in Fig. 4.3

Different weed management treatments influenced the grain weight per plant significantly during both the years and in pooled results. Significantly the higher grain weight per plant was observed under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1) during individual year and found equivalent to weedfree (T_9). However, in the pooled results non of the treatments proved equivalent to weedfree (T_9). On the other hand, significantly lowest grain weight of 3.53, 3.09 and 3.31g per plant were recorded under unweeded control during 2003-04, 2004-05 and in the pooled results, respectively.

Table 4.4. Effect of different treatments on spikelets per spike and grain weight per plant

Treatment	Spikelets per spike			Grain weight g $plant^{-1}$		
	2003-04	**2004-05**	**Pooled**	**2003-04**	**2004-05**	**Pooled**
T1	15.50	16.05	15.78	5.55	5.11	5.33
T2	15.25	15.00	15.13	4.68	4.24	4.46
T3	15.35	14.65	15.00	4.60	4.16	4.38
T4	15.30	14.70	15.00	4.85	4.41	4.63
T5	15.50	15.10	15.30	4.58	4.14	4.36
T6	14.90	14.70	14.80	5.28	4.84	5.06
T7	14.90	14.30	14.60	4.55	4.11	4.33
T8	15.65	15.80	15.73	4.60	4.16	4.38
T9	15.40	16.40	15.90	5.95	5.51	5.73
T10	13.20	11.30	12.25	3.53	3.09	3.31
S.Em.±	0.21	0.33	0.39	0.18	0.18	0.13
C.D. (0.05)	0.60	0.97	1.25	0.51	0.51	0.36
C.V. %	2.75	4.52	3.72	7.36	8.09	7.71

4.2.4 Test weight

The results on test weight are presented in Table 4.5 and their analysis of variance is furnished in Appendix III. The data are also graphically depicted in Fig. 4.3

Effect of different treatments was found significant on test weight during 2003-04 and 2004-05 as well as in the pooled results. The significantly higher test weight was recorded under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1) over unweeded check and remained at par with isoproturon 0.75 kg ha^{-1} post-em. (T_3), 2,4-D (E.E.) 0.75 kg ha^{-1} post-em. (T_7), metsulfuron 6 g ha-1 post-em. (T_5), 2,4-D (S.S.) 0.96 kg ha^{-1} post-em. (T_6) and fluchloralin 0.45 kg ha^{-1} pre-em. + 1 HW (T_4), 2 hand weedings (T_8) and proved equivalent to weedfree (T_9).

4.3 YIELD

4.3.1 Grain yield

The data pertaining to the effect of different weed control treatments on grain yield of wheat are presented in Table 4.6 and their analysis of variance is furnished in Appendix III. The data are also graphically depicted in Fig.4.4

Results summarized in Table 4.6 reveal that grain yield was significantly influenced due to different weed management treatments tried in this experiment during both years and in the pooled results. Being equivalent to weedfree (T_9), the maximum grain yield of 3972 kg ha^{-1} and 3804 kg ha^{-1} were obtained under treatment 2 hand weedings (T_8) during 2003-04 and in pooled results and statistically at par with treatments pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1) and 2,4-D (S.S.) 0.96 kg ha^{-1} post-em. (T_6). While during 2004-05, pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1) produced significantly higher grain yield of 3732 kg ha^{-1} and found at par with 2 hand weedings (T_8). Unweeded control (T_{10})

Table 4.5. Effect of different treatments on test weight of wheat

Treatments	Test weight (g)		
	2003-04	2004-05	Pooled
T1	44.15	39.15	41.65
T2	39.45	34.45	36.95
T3	43.13	38.13	40.63
T4	41.85	36.85	39.35
T5	42.48	37.48	39.98
T6	42.05	37.05	39.55
T7	42.53	37.53	40.03
T8	41.58	36.58	39.08
T9	42.90	37.90	40.40
T10	31.60	26.60	29.10
S.Em.±	1.32	1.32	0.94
C.D. (0.05)	3.84	3.84	2.66
C.V. %	6.44	7.33	6.85

Table 4.6. Effect of treatments on grain yield and straw yields of wheat

Treatment	Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})		
	2003-04	**2004-05**	**pooled**	**2003-04**	**2004-05**	**pooled**
T1	3870	3732	3801	3963	4769	4366
T2	3403	3077	3240	4116	4414	4265
T3	3620	2912	3266	3769	4369	4069
T4	3681	3091	3386	4176	3742	3959
T5	3528	3189	3358	4185	4471	4328
T6	3968	3500	3734	4106	4160	4133
T7	3468	3044	3256	3699	3943	3821
T8	3972	3636	3804	3745	4521	4133
T9	4176	3907	4042	4611	4569	4590
T10	2944	1948	2446	2861	2658	2760
S.Em.±	158	241	144	273	307	205
C.D. (0.05)	458	699	409	792	891	583
C.V. %	8.62	15.04	11.87	13.91	14.76	14.37

recorded significantly the lowest grain yield of 2944, 1948 and 2446 kg ha^{-1} in both years and in pooled results, respectively. The magnitude of increase in average grain yield under weedfee (T_9), 2 hand weedings (T_8), pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1) and 2,4-D (S.S.) 0.96 kg ha^{-1} post-em. (T_6) over unweeded control (T_{10}) was 65.25 , 55.52 , 55.40 and 52.66 per cent, respectively.

4.3.2 Straw yield

The data on straw yield are presented in Table 4.6 and their analysis of variance is furnished in Appendix III. The data are also depicted graphically in Fig.4.5

Effect of different treatments was found significant on straw yield during 2003-04, 2004-05 and pooled results. Significantly higher straw yield of 4185 kg ha^{-1} was produced under metsulfuron 6 g ha^{-1} post-em. (T_5) and remained at par with fluchloralin 0.45 kg ha^{-1} pre-em. + 1 HW (T_4), isoproturon 0.75 kg ha^{-1} pre-em. + 1 HW (T_2), 2,4-D (S.S.) 0.96 kg ha^{-1} post-em. (T_6) and pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1) during 2003-04. During 2004-05 and in pooled results, significantly higher straw yield of 4769 and 4366 kg ha^{-1} were obtained under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1) and statistically found at par with 2 hand weeding (T_8), metsulfuron 6 g ha^{-1} post-em. (T_5), 2,4-D (S.S.) 0.96 kg ha^{-1} post-em. (T_6) and 2,4-D (E.E.) 0.75 kg ha^{-1} post-em. (T_7) during 2004-05 and with the treatments metsulfuron 6 g ha^{-1} post-em. (T_5), isoproturon 0.75 kg ha^{-1} pre-em. + 1 HW (T_2), 2,4-D (S.S.) 0.96 kg ha^{-1} post-em. (T_6), 2 hand weedings (T_8) and isoproturon 0.75 kg ha^{-1} post-em. (T_3) in pooled results. Unweeded control (T_{10}) recorded significantly the lowest straw yield of 2861, 2658 and 2760 kg ha^{-1} in both years and in pooled results, respectively. The magnitude of increase in average straw yield under weedfee (T_9), pendimethalin 1 kg ha^{-1} pre-

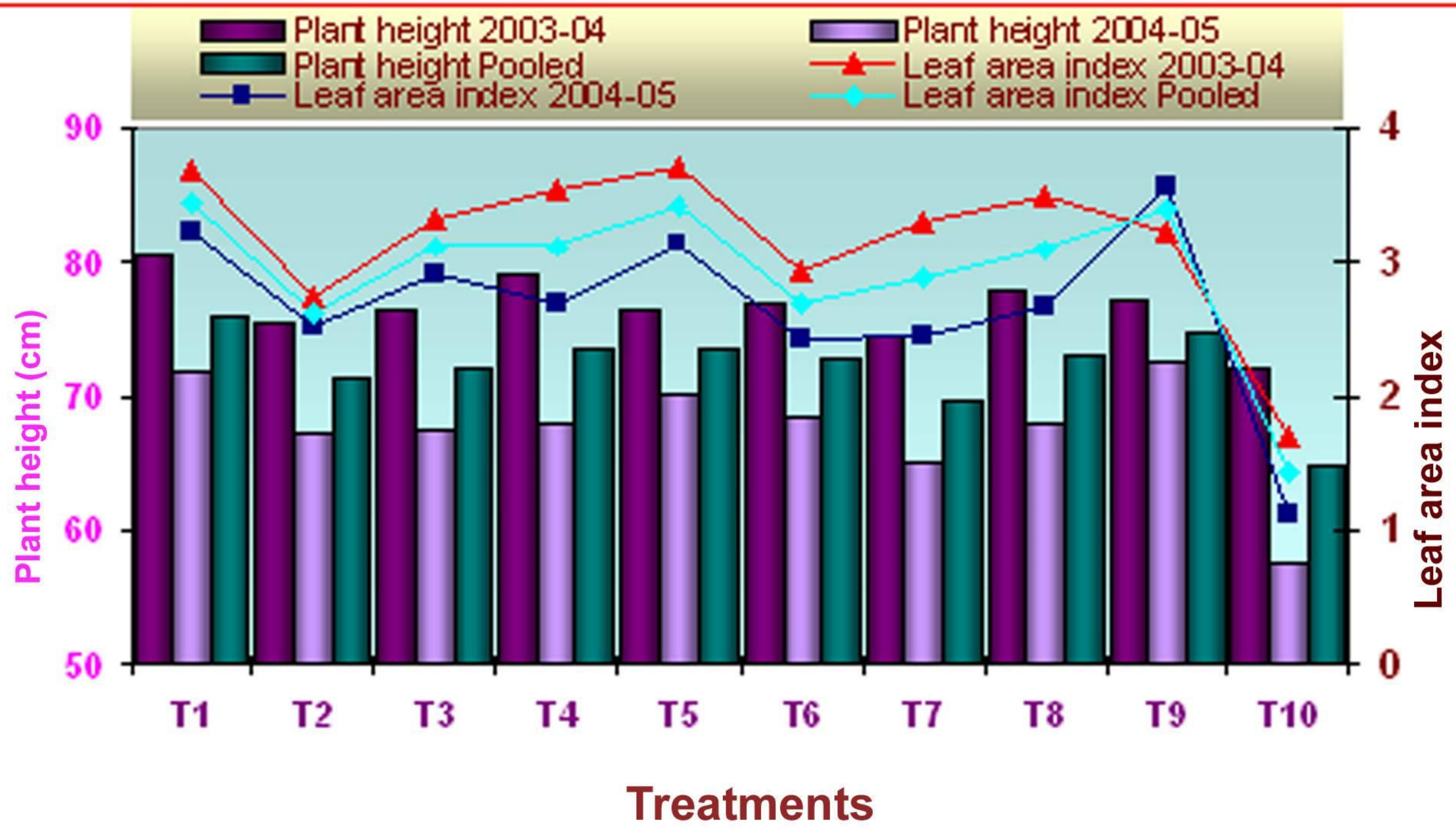


Fig. 4.1 Plant height and leaf area index as affected by different treatments

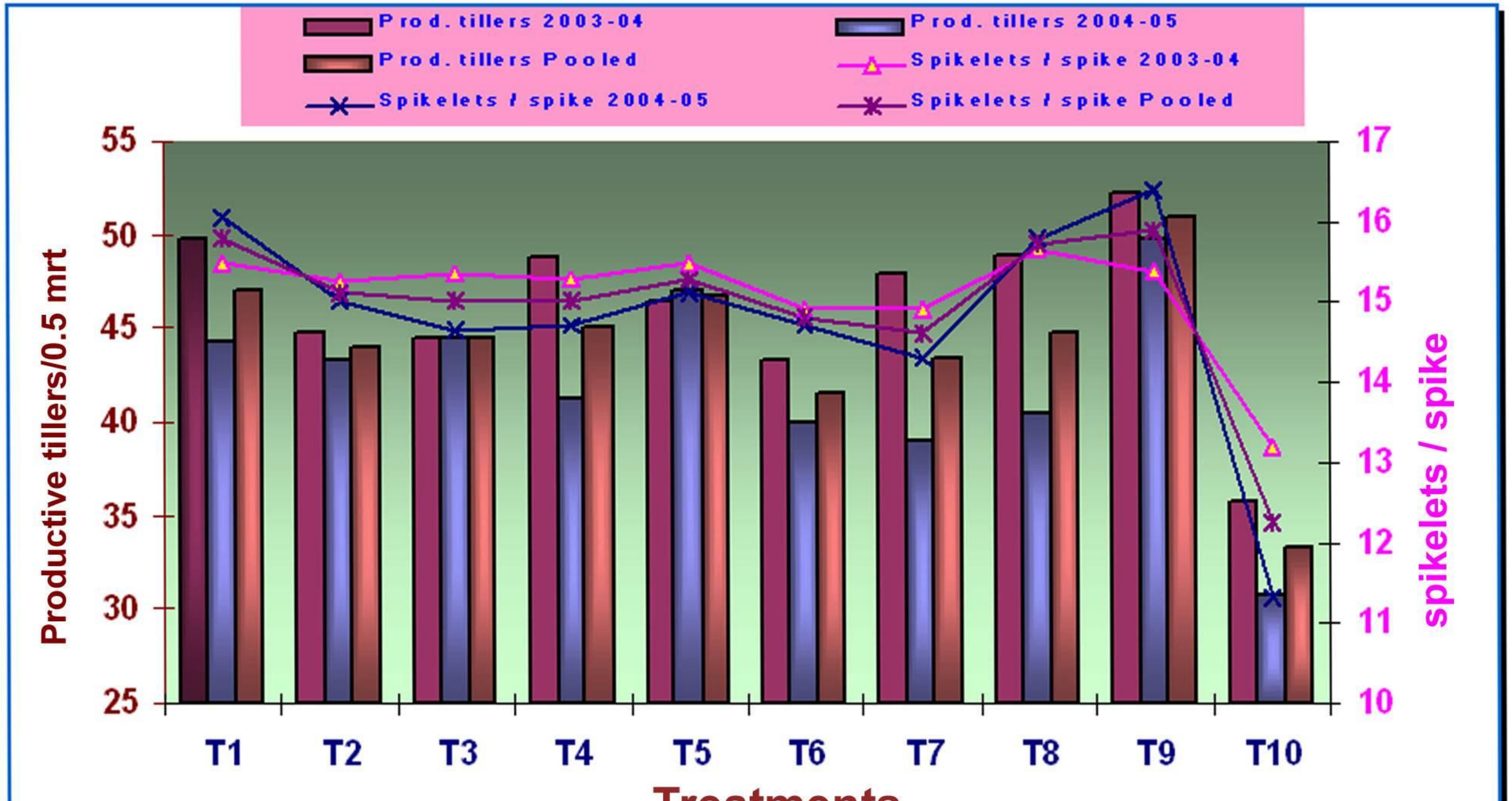


Fig. 4.2 Productive tillers and spikelets/ spike as affected by different treatments

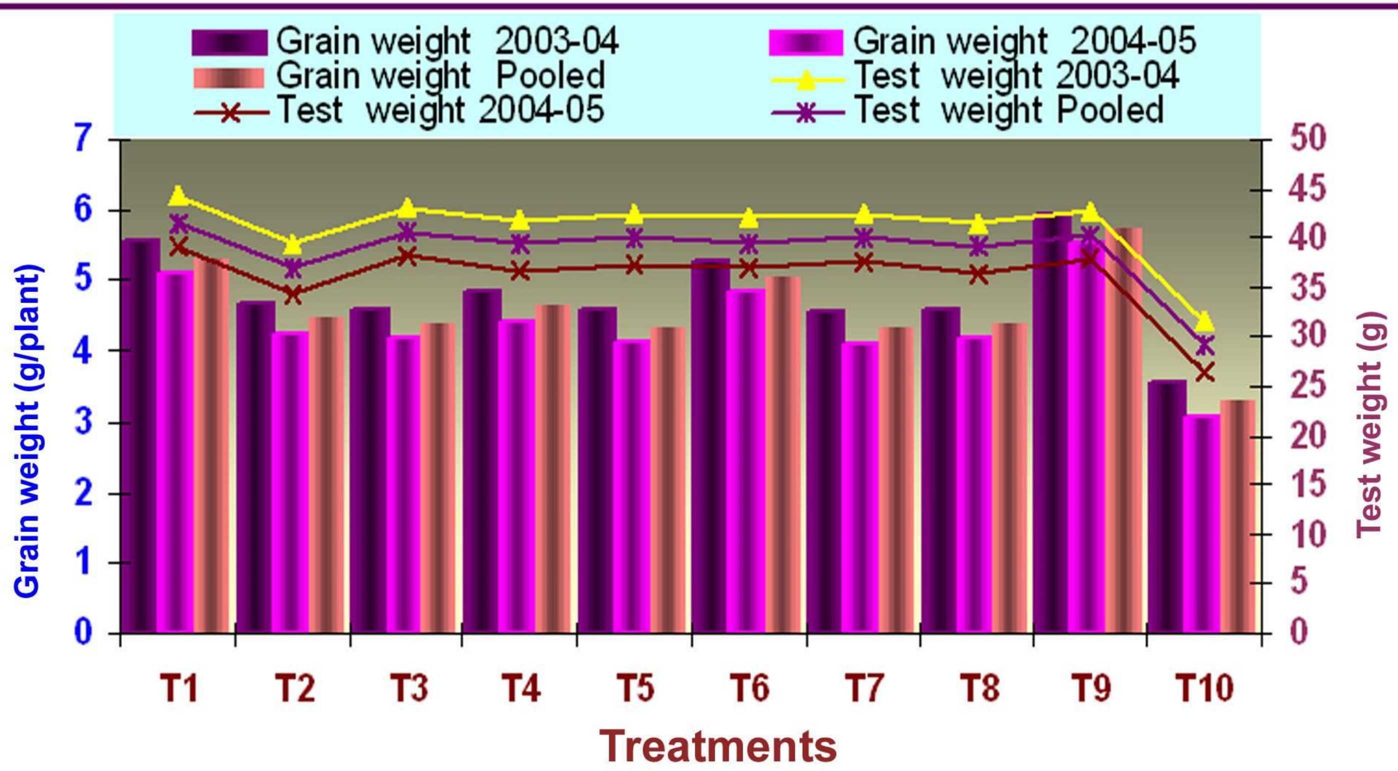


Fig. 4.3 Grain weight and test weight as affected by different treatments

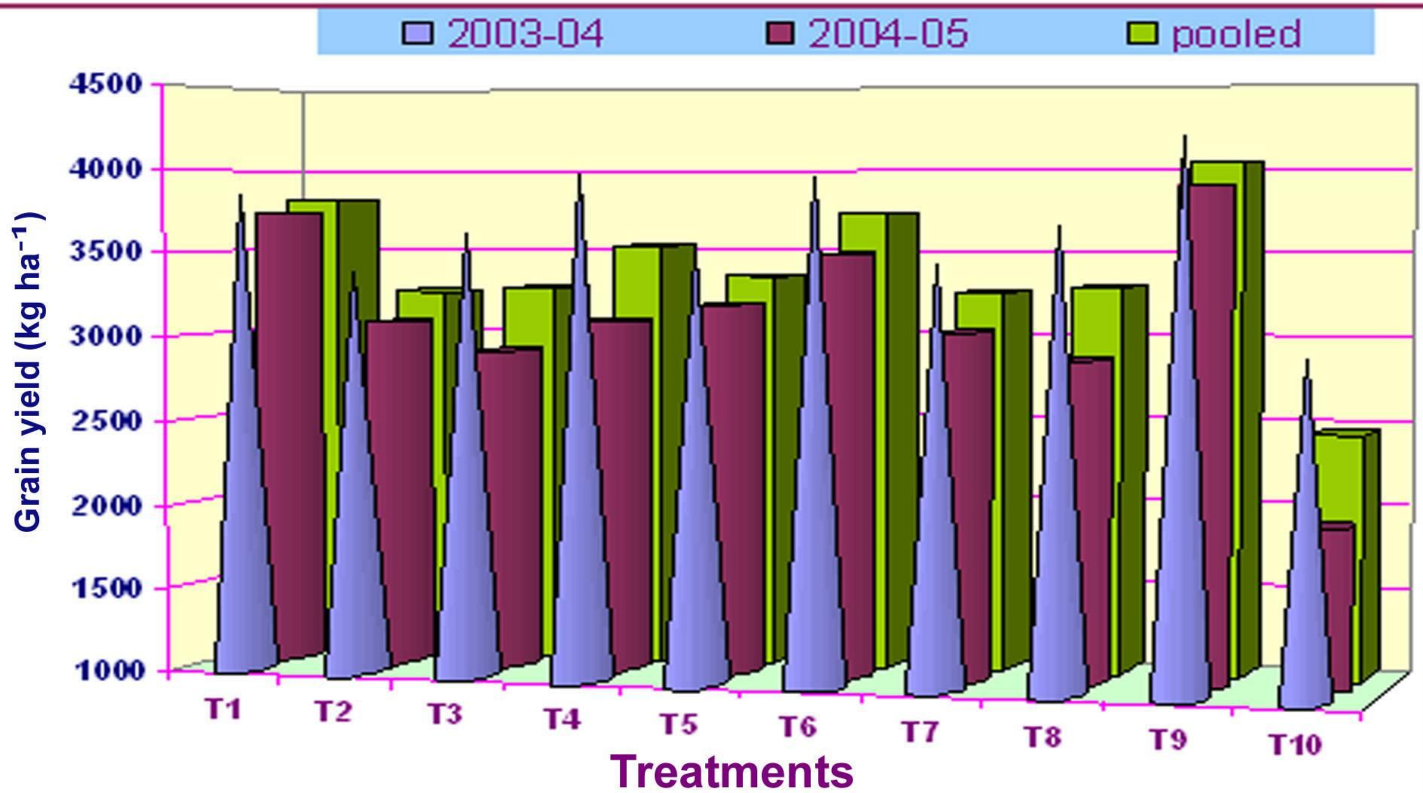


Fig. 4.4 Grain yield as affected by different treatments

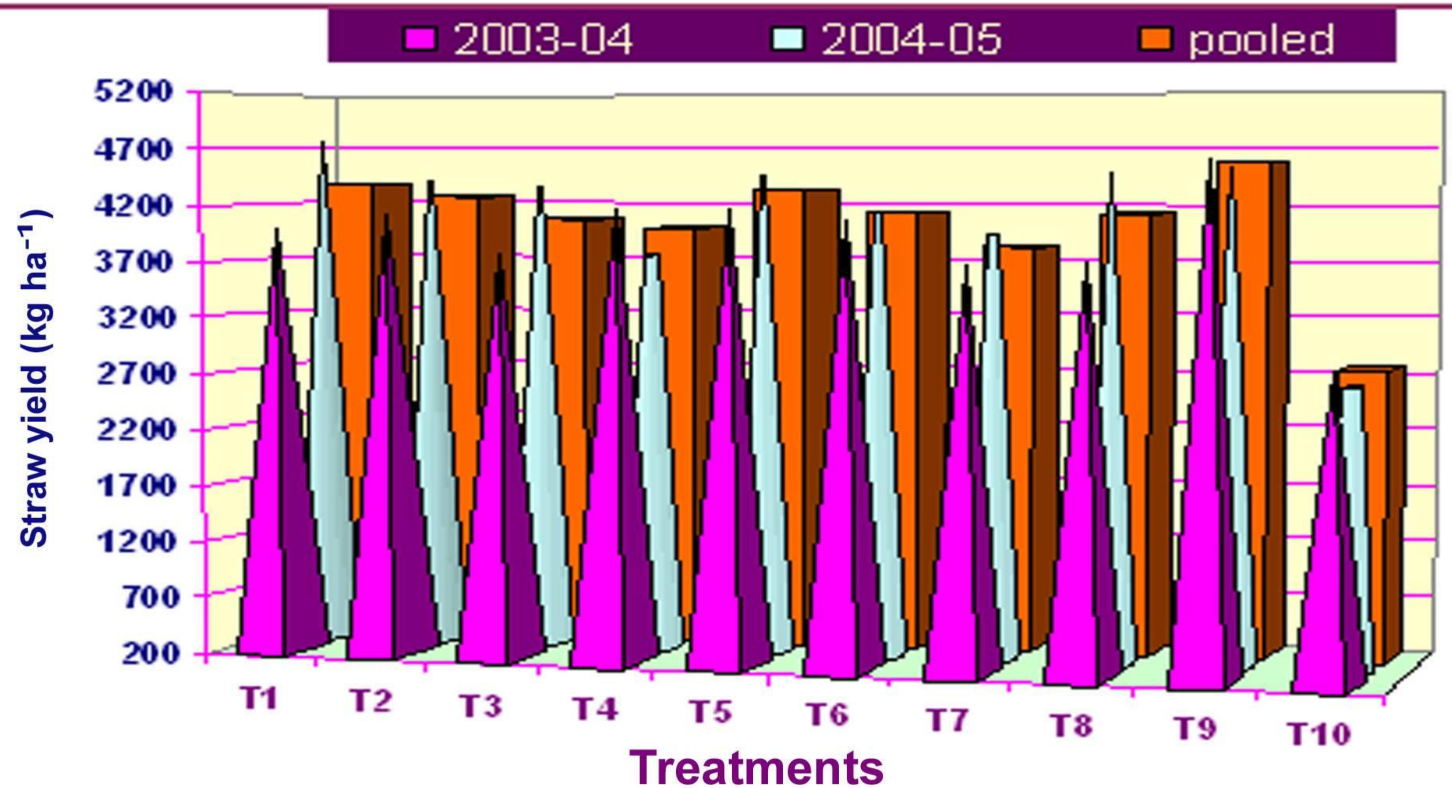


Fig. 4.5 Straw yield as affected by different treatments

em. + 1 HW (T_1), metsulfuron 6 g ha^{-1} post-em. (T_5), isoproturon 0.75 kg ha^{-1} pre-em. + 1 HW (T_2), 2,4-D (S.S.) 0.96 kg ha^{-1} post-em. (T_6), 2 hand weeding (T_8) and isoproturon 0.75 kg ha^{-1} post-em. (T_3) over unweeded control (T_{10}) was 66.30, 58.18, 56.81, 54.53, 49.75, 49.75 and 47.43 per cent, respectively.

4.4 WEED STUDY

4.4.1 Weed flora

2003-04

The weed flora in the experimental site constituted by monocot weeds viz., *Brachiaria* spp. (59.1 %) and *Asphodelus tenuifolius* L. Cav. (4.4 %) and dicot weeds viz., *Indigofera glandulosa* (3.8 %) and *Digera arvensis* Forsk. (3.1 %) and sedges viz., *Cyperus rotundus* L. (1.3 %) and other minor weed species were *Echinochloa colonum* L**.** Beauv., *Chenopodium album* L., *Euphorbia hirta* L., *Physalis minima* L., *Portulaca oleracea* L. and *Tridex procumbens* L. (28.3 %).

2004-05

The weed flora in the experimental site constituted by monocot weeds viz., *Brachiaria* spp. (64.8 %) and *Asphodelus tenuifolius* L. Cav. (3.3 %) and dicot weeds viz., *Indigofera glandulosa* (5.7 %) and *Digera arvensis* Forsk. (1.6 %) and sedges viz., *Cyperus rotundus* L. (3.3 %) and other minor weed species were *Echinochloa colonum* L. Beauv., *Chenopodium album* L., *Euphorbia hirta* L., *Physalis minima* L., *Portulaca oleracea* L. and *Tridex procumbens* L. (21.3 %).

4.4.2 WEED COUNT

4.4.2.1 At 20 DAS

The data pertaining to weed count under different weed control treatments are presented in Table 4.7 and their analysis of variance is furnished in Appendix IV.

Table 4.7. Effect of different treatments on weed population at 20 and 40 days after sowing

Treatment	(No 0.36 m^{-2})					
	20 DAS			40 DAS		
	2003-04	2004-05	Pooled	2003-04	2004-05	Pooled
T1	2.14 (5.25)	2.34 (5.00)	2.24 (5.13)	1.93 (3.75)	0.84 (0.25)	1.38 (2.00)
T2	2.76 (7.25)	3.83 (14.50)	3.30 (10.88)	2.65 (7.75)	2.58 (6.75)	2.62 (7.25)
T3	5.01 (27.00)	7.67 (59.00)	6.34 (43.00)	5.34 (29.50)	7.46 (55.75)	6.40 (42.63)
T4	2.69 (7.75)	4.70 (23.25)	3.69 (15.50)	2.36 (5.50)	2.74 (7.50)	2.55 (6.50)
T5	6.31 (43.25)	7.55 (57.50)	6.93 (50.38)	6.25 (42.75)	8.19 (67.50)	7.22 (55.13)
T6	4.71 (22.50)	7.75 (59.75)	6.23 (41.13)	5.29 (28.25)	7.44 (55.00)	6.36 (41.63)
T7	5.12 (26.00)	6.42 (41.50)	5.77 (33.75)	5.11 (25.75)	7.52 (57.00)	6.32 (41.38)
T8	4.92 (24.25)	6.81 (46.25)	5.86 (35.25)	4.20 (17.50)	6.35 (40.25)	5.28 (28.88)
T9	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
T10	7.37 (56.00)	7.39 (56.00)	7.38 (56.00)	8.81 (78.50)	9.43 (89.75)	9.12 (84.13)
S.Em.±	0.64	0.45	0.39	0.61	0.38	0.62
C.D.(0.05)	1.87	1.30	1.11	1.77	1.10	1.98
C.V. %	20.90	16.28	18.94	18.57	14.21	16.15

Figures in parenthesis are original values of weed population

Different weed management treatments exerted their significant effect on weed count recorded at 20 DAS during both the years and in the pooled results. Among different treatments, significantly less weed count was observed under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1) during 2003-04, 2004-05 and in pooled results. However, it was found at par with isoproturon 0.75 kg ha^{-1} pre-em. + 1 HW (T_2) and fluchloralin 0.45 kg ha^{-1} pre-em. + 1 HW (T_4) during 2003-04 and with isoproturon 0.75 kg ha^{-1} pre-em. + 1 HW (T_2) in pooled results. The highest weed count was observed under unweeded control during 2003-04 and in pooled results, while during 2004-05, 2,4-D (S.S.) 0.96 kg ha^{-1} post-em. (T_6) recorded significantly higher weed count.

4.4.2.2 At 40 DAS

The data pertaining to weed count as influenced due to different weed control treatments are presented in Table 4.7 and their analysis of variance is furnished in Appendix IV.

Different weed management treatments exerted their significant effect on weed count recorded at 40 DAS during both the years and in the pooled results. All the treatments significantly reduced weed density as compared to unweeded control. Significantly less weed count was registered under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW during 2003-04, 2004-05 and in pooled results. However, it was found at par with fluchloralin 0.45 kg ha^{-1} pre-em. + 1 HW (T_4) and isoproturon 0.75 kg ha^{-1} pre-em. + 1 HW (T_2) during 2003-04and in pooled results.

4.4.2.3 At 60 DAS

The results on weed population as affected due to different weed control treatments are presented in Table 4.8 and their analysis of variance is furnished in Appendix IV.

Table 4.8. Effect of different treatments on weed population at 60 days after sowing and at harvest

Treatment	(No 0.36 m^{-2})					
	60 DAS			At Harvest		
	2003-04	2004-05	Pooled	2003-04	2004-05	Pooled
T1	1.70	0.93	1.31	1.65	0.93	1.29
	(3.00)	(0.50)	(1.75)	(2.75)	(0.50)	(1.63)
T2	2.59	3.14	2.87	2.59	3.04	2.82
	(7.25)	(9.75)	(8.5)	(7.25)	(9.00)	(8.13)
T3	5.18	6.98	6.08	4.99	6.52	5.76
	(27.50)	(48.75)	(38.13)	(25.50)	(42.50)	(34.00)
T4	2.04	3.04	2.54	2.04	2.87	2.46
	(3.75)	(9.25)	(6.50)	(3.75)	(8.00)	(5.88)
T5	5.49	7.53	6.51	5.09	7.24	6.17
	(34.75)	(57.00)	(45.88)	(30.00)	(52.50)	(41.25)
T6	4.74	6.88	5.81	4.28	6.55	5.41
	(23.25)	(47.00)	(35.13)	(18.50)	(42.50)	(30.50)
T7	4.36	7.01	5.69	3.89	6.75	5.32
	(18.75)	(49.50)	(34.13)	(14.75)	(45.75)	(30.25)
T8	3.07	3.85	3.46	3.01	3.71	3.36
	(9.75)	(15.25)	(12.50)	(9.25)	(14.00)	(11.63)
T9	0.71	0.71	0.71	0.71	0.71	0.71
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
T10	8.87	9.56	9.22	8.42	9.20	8.81
	(80.00)	(92.25)	(86.13)	(72.00)	(85.25)	(78.63)
S.Em.±	0.66	0.31	0.53	0.59	0.28	0.55
C.D.(0.05)	1.90	0.91	1.70	1.72	0.82	1.77
C.V. %	19.85	12.58	17.24	18.27	11.96	15.06

Figures in parenthesis are original values of weed population

Weed count recorded at 60 DAS was significantly influenced due to different weed management treatments during both the years and in the pooled results. Significantly less weed count was observed under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW(T_1) and statistically at par with isoproturon 0.75 kg ha^{-1} pre-em. + 1 HW(T_2) and fluchloralin 0.45 kg ha^{-1} pre-em. + 1 HW (T_4) in the pooled results and also two hand weedings (T_8) during 2003-04. While pendimethalin 1 kg ha^{-1} pre-em. + 1 HW recorded significantly the lowest weed count among different treatments during 2004-05. Significantly the highest weed population of 80, 92.25 and 86.13 per 0.36 sq.m. was recorded under unweeded control.

4.4.2.4 At harvest

The results on weed population as influenced due to different weed control treatments are presented in Table 4.8 and their analysis of variance is furnished in Appendix IV.

The population of weeds recorded at harvest was significantly influenced due to different weed management treatments during both the years and in the pooled results. Similar results were observed as recorded at 60 DAS during 2003-04 and 2004-05 as well as in the pooled results.

4.4.3 Population of individual weed species at 60 DAS

The data pertaining to population of individual weed species as influenced due to different weed control treatments are presented in Table 4.9 and their analysis of variance is furnished in Appendix V. The data are also graphically depicted in Fig.4.6

Different weed management treatments exerted their significant effect on average population of individual weed species recorded at 60 DAS. All the treatments significantly reduced density of *Brachiaria* spp., *Asphodelus tenuifolius*, *Indigofera glandulosa* and *Digera arvensis* as

Table 4.9. Effect of different treatments on population of individual weed species at 60 days after sowing (Pooled)

Treatment	**(No 0.36 m^{-2})**				
	Brachiaria spp.	*Asphodelus tenuifolius*	*Indigofera glandulosa*	*Digera arvensis*	*Cyperus rotundus*
T1	0.71	0.77	0.77	0.71	1.24
	(0.00)	(0.13)	(0.13)	(0.00)	(1.50)
T2	2.39	1.17	0.77	0.82	1.20
	(5.75)	(1.38)	(0.13)	(0.25)	(1.50)
T3	5.28	1.54	1.15	0.71	1.15
	(29.13)	(2.38)	(1.50)	(0.00)	(1.25)
T4	1.09	1.13	1.08	0.71	1.23
	(0.88)	(1.13)	(0.88)	(0.00)	(1.38)
T5	6.21	0.71	0.71	0.71	1.34
	(41.88)	(0.00)	(0.00)	(0.00)	(1.85)
T6	5.26	1.08	0.82	0.82	0.95
	(28.88)	(0.88)	(0.25)	(0.25)	(0.50)
T7	5.08	0.85	0.99	0.71	1.41
	(28.00)	(0.38)	(0.75)	(0.00)	(1.75)
T8	2.63	1.06	1.05	0.71	0.84
	(7.00)	(0.88)	(0.75)	(0.00)	(0.25)
T9	0.71	0.71	0.71	0.71	0.71
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
T10	7.22	1.69	2.03	1.49	1.44
	(53.50)	(3.25)	(4.13)	(2.00)	(2.00)
S.Em.±	0.38	0.20	0.14	0.08	0.20
C.D.(0.05)	1.07	0.56	0.40	0.23	NS
C.V. %	19.30	20.38	17.87	18.36	19.02

Figures in parenthesis are original values of population of individual weed species.

compared to unweeded control which recorded the maximum density of the respective weed species. However, treatment metsulfuron 6 g ha^{-1} post-em. (T_5) failed to control *Brachiaria* spp. and treatments isoproturon 0.75 kg ha^{-1} pre-em. + 1 HW (T_2), isoproturon 0.75 kg ha^{-1} post-em. (T_3) and fluchloralin 0.45 kg ha^{-1} pre-em. + 1 HW (T_4) failed to control *Asphodelus tenuifolius*. The population of *Cyperus rotundus* did not influence due to different treatments.

4.4.4 Dry weight of weeds

The data pertaining to dry weight of weeds as influenced by different weed control treatments are presented in Table 4.10 and their analysis of variance is furnished in Appendix IV. The data are also graphically depicted in Fig.4.7

There were conspicuous differences in dry weight of weeds among different weed management treatments at harvest. Treatment pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1) was proved superior to rest of the treatments by recording minimum dry weight of weeds and remained on same bar with weedfree (T_9) during both the year. However, when the results were pooled over two seasons, all treatments being at par with weedfree (T_9) proved effective to control weeds over unweeded control (T_{10}), except treatment isoproturon 0.75 kg ha^{-1} post-em. (T_3). Significantly the highest weed dry weight of 645, 1914 and 1279 kg ha^{-1} was observed under unweeded control. Reduction in dry weight of weeds under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1), 2 hand weedings (T_8), fluchloralin 0.45 kg ha^{-1} pre-em. + 1 HW (T_4), metsulfuron 6 g ha^{-1} post-em. (T_5), isoproturon 0.75 kg ha^{-1} pre-em. + 1 HW (T_2), 2,4-D (S.S.) 0.96 kg ha^{-1} post-em. (T_6) and 2,4-D (E.E.) 0.75 kg ha^{-1} post-em. (T_7)

Table 4.10. Effect of different treatments on dry weight of weeds

Treatment	Dry weight of weeds (kg ha^{-1})		
	2003-04	2004-05	Pooled
T1	48	154	101
T2	224	370	297
T3	394	1177	785
T4	131	448	289
T5	154	436	295
T6	170	679	424
T7	355	787	571
T8	224	285	255
T9	0	0	0
T10	645	1914	1279
S.Em.±	28	71	194
C.D. (0.05)	80	205	622
C.V. %	23.49	22.65	25.00

over unweeded control was 92.10, 80.06, 77.40, 76.94, 76.77, 66.85 and 55.36 per cent, respectively.

4.4.5 Weed index, Weed control efficiency and Herbicidal efficiency index

The mean data on weed index, weed control efficiency and herbicidal efficiency index as influenced due to different weed management treatments are presented in Table 4.11 and the data are also graphically depicted in Fig. 4.8

Different weed management treatments exerted their remarkable effect on weed index, weed control efficiency and herbicidal efficiency index.

Among different treatments, the lowest weed index was recorded under treatment 2 hand weedings (T_8) with 4.01% closely followed by pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1) with 5.93 % and 2,4-D (S.S.) 0.96 kg ha^{-1} post-em. (T_6) with 8 %. The highest weed index of 20.65 % was noticed under isoproturon 0.75 kg ha^{-1} pre-em. + 1 HW (T_2).

Among different weed management treatments, the highest weed control efficiency (92.02 %)was registered under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1). The lowest weed control efficiency (36.91%) was observed under isoproturon 0.75 kg ha^{-1} post-em. (T_3).

Among different herbicidal treatments, the highest herbicidal efficiency index of 9.05 % was recorded under treatment pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1). The lowest herbicidal efficiency index of 0.74 % was observed under treatment isoproturon 0.75 kg ha^{-1} post-em. (T_3) and closely followed by treatment 2,4-D (E.E.) 0.75 kg ha^{-1} post-em. (T_7) with herbicidal efficiency index of 0.99 %.

Table 4.11. Effect of different treatments on weed index, weed control efficiency and herbicidal efficiency index

Treatment	Weed Index (%)	Weed Control Efficiency (%)	Herbicidal Efficiency Index (%)
T1	5.93	92.02	9.05
T2	20.65	71.85	1.94
T3	19.72	36.91	0.74
T4	14.98	77.42	2.23
T5	16.48	76.40	2.18
T6	8.00	68.14	2.02
T7	18.96	51.42	0.99
T8	4.01	74.13	*
T9	0.00	100.00	*
T10	40.71	0.00	*

4.5 NUTRIENT UPTAKE BY WEEDS AND CROP

4.5.1 Nitrogen uptake by weeds and crop

The data pertaining to nitrogen uptake by weeds and crop as influenced due to different weed control treatments are presented in Table 4.12 and their analysis of variance is furnished in Appendix VI. The data are also graphically depicted in Fig. 4.9 and 4.10, respectively

Different weed management treatments exerted their significant effect on nitrogen uptake by weeds and crop during both the years and in the pooled results.

Significantly the lowest depletion of nitrogen by weeds was recorded under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1) among different treatments during 2003-04, 2004-05 and in pooled results. However, in pooled results it remained at par with 2 hand weedings (T_8), fluchloralin 0.45 kg ha^{-1} pre-em. + 1 HW (T_4), isoproturon 0.75 kg ha^{-1} pre-em. + 1 HW (T_2), metsulfuron 6 g ha^{-1} post-em. (T_5), 2,4-D (S.S.) 0.96 kg ha^{-1} post-em. (T_6) and 2,4-D (E.E.) 0.75 kg ha^{-1} post-em. (T_7). The maximum loss of nitrogen 13.11, 39.43 and 26.27 kg ha^{-1} by weeds was occurred under unweeded control (T10) during 2003-04, 2004-05 and in pooled results, respectively.

Among different treatments, the crop removed significantly higher amount of nitrogen under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW(T_1) during 2003-04, 2004-05 and in pooled. But it was at par with rest of the treatments during 2003-04 and 2004-05 , except 2,4-D (E.E.) 0.75 kg ha^{-1} post-em. (T_7) and treatments 2,4-D (E.E.) 0.75 kg ha^{-1} post-em. (T_7) and fluchloralin 0.45 kg ha^{-1} pre-em. + 1 HW(T_4), respectively. While in pooled results it was statistically at par with and 2,4-D (S.S.) 0.96 kg ha^{-1} post-em. (T_6) and metsulfuron 6 g ha^{-1} post-em. (T_5). The lowest uptake

Table 4.12. Effect of different treatments on N uptake by weeds and crop at harvest

Treatment	By weeds (kg ha^{-1})			By crop (kg ha^{-1})		
	2003-04	2004-05	Pooled	2003-04	2004-05	Pooled
T1	0.98	3.14	2.06	81.15	89.01	85.08
T2	4.34	7.54	5.94	74.78	78.63	76.70
T3	8.04	23.97	16.00	73.58	76.41	75.00
T4	2.94	8.90	5.92	77.91	71.71	74.81
T5	3.14	8.89	6.01	76.86	80.48	78.67
T6	3.45	13.74	8.59	80.39	79.97	80.18
T7	7.22	16.23	11.72	71.32	73.17	72.25
T8	4.61	5.82	5.22	73.86	77.80	75.83
T9	0.00	0.00	0.00	87.42	88.54	87.98
T10	13.11	39.43	26.27	57.65	48.37	53.01
S.Em.±	0.36	0.71	4.02	3.31	4.57	2.82
C.D.(0.05)	1.04	2.06	12.86	9.61	13.26	8.00
C.V. %	15.00	11.10	12.80	8.77	11.96	10.51

of nitrogen by wheat crop was observed under unweeded control (T_{10}) during 2003-04, 2004-05 and in pooled results.

4.5.2 Phosphorus uptake by weeds and crop

The results on phosphorus uptake by weeds and crop as influenced due to different weed control treatments are presented in Table 4.13 and their analysis of variance is furnished in Appendix VI. The data are also graphically depicted in Fig. 4.9 and 4.10, respectively

Different weed management treatments influenced significantly on phosphorus uptake by weeds and crop during both the years and in the pooled results.

Significantly lower depletion was observed under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1) among different treatments during both the years and in pooled results, however, it was statistically at par with 2 hand weeding (T_8) during 2004-05 and with the treatments 2 hand weedings(T_8), fluchloralin 0.45 kg ha^{-1} pre-em. + 1 HW(T_4), metsulfuron 6 g ha^{-1} post-em. (T_5) and isoproturon 0.75 kg ha^{-1} pre-em. + 1 HW (T_2) in pooled results. The maximum uptake of phosphorus 7.19, 13.60 and 10.40 kg ha^{-1} by weeds was occurred under unweeded control (T_{10}) during 2003-04, 2004-05 and in pooled results, respectively.

The crop arrested significantly higher amount of phosphorus under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW(T_1) during both the year and in pooled results. However, it was at par with remaining treatments during 2003-04 and 2004-05 except 2,4-D (E.E.) 0.75 kg ha^{-1} post-em.(T_7) and except treatments 2,4-D (E.E.) 0.75 kg ha^{-1} post-em.(T_7) and fluchloralin 0.45 kg ha^{-1} pre-em. + 1 HW(T_4), respectively. While in the pooled results treatments metsulfuron 6 g ha^{-1} post-em.(T_5) and 2,4-D (S.S.) 0.96 kg ha^{-1} post-em.(T_6) remained at par with pendimethalin 1 kg ha^{-1} pre-em. + 1 HW(T_1). The lowest uptake of phosphorus by wheat crop was observed

Table 4.13. Effect of different treatments on P uptake by weeds and crop at harvest

Treatment	By weeds (kg ha^{-1})			By crop (kg ha^{-1})		
	2003-04	2004-05	Pooled	2003-04	2004-05	Pooled
T1	0.55	1.79	1.17	16.68	18.39	17.54
T2	2.59	4.30	3.45	15.44	16.21	15.82
T3	4.55	8.40	6.48	15.16	15.84	15.50
T4	1.37	5.19	3.28	16.05	14.77	15.41
T5	1.78	5.06	3.42	15.80	16.65	16.23
T6	1.85	7.14	4.50	16.55	16.54	16.55
T7	4.10	8.10	6.10	14.64	15.02	14.83
T8	2.60	3.30	2.95	15.18	16.07	15.62
T9	0.00	0.00	0.00	18.00	18.25	18.13
T10	7.19	13.60	10.40	11.83	9.89	10.86
S.Em.±	0.26	0.55	1.03	0.70	0.97	0.60
C.D.(0.05)	0.76	1.61	3.30	2.02	2.81	1.69
C.V. %	19.78	19.51	20.80	8.96	12.27	10.77

under unweeded control (T_{10}) during 2003-04, 2004-05 and in pooled results.

4.5.3 Potassium uptake by weeds and crop

The data on potassium uptake by weeds and crop as influenced due to different weed control treatments are presented in Table 4.14 and their analysis of variance is furnished in Appendix VI. The data are also graphically depicted in Fig. 4.9 and 4.10, respectively

Different weed management treatments exerted their significant effect on potassium uptake by weeds and crop during both the years and in the pooled results.

Different weed management treatments recorded significantly lower depletion of potassium by weeds as compared to unweeded control during 2003-04, 2004-05 and in pooled results. Significantly the lowest uptake was recorded under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1) in both the years as well as in the pooled results. However, statistically it remained at par with 2 hand weeding(T_8) during 2004-05 and with remaining treatments except, isoproturon 0.75 kg ha^{-1} post-em. (T_3) and 2,4-D (E.E.) 0.75 kg ha^{-1} post-em.(T_7) in the pooled results. The maximum loss of potassium 11.33, 23.56 and 17.44 kg ha^{-1} by weeds was occurred under unweeded control (T_{10}) during 2003-04, 2004-05 and in pooled results, respectively.

The crop benefited by significantly higher availability of potassium under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1) during both the years and in pooled, but it was at par with remaining treatments except 2,4-D (E.E.) 0.75 kg ha^{-1} post-em.(T_7) during 2003-04 and except treatments 2,4-D (E.E.) 0.75 kg ha^{-1} post-em.(T_7) and fluchloralin 0.45 kg ha^{-1} pre-em. + 1 HW(T_4) during 2004-05. In the pooled results treatments metsulfuron 6 g ha^{-1} post-em.(T_5) and 2,4-D (S.S.) 0.96 kg ha^{-1} post-em.

Table 4.14. Effect of different treatments on K uptake by weeds and crop at harvest

Treatment	By weeds (kg ha^{-1})			By crop (kg ha^{-1})		
	2003-04	**2004-05**	**Pooled**	**2003-04**	**2004-05**	**Pooled**
T1	0.84	2.72	1.78	64.55	71.17	67.86
T2	3.94	6.52	5.23	59.68	62.75	61.22
T3	6.91	12.96	9.93	58.61	61.19	59.90
T4	2.30	7.87	5.08	62.00	57.10	59.55
T5	2.71	7.67	5.19	61.14	64.33	62.73
T6	2.98	11.97	7.48	63.98	63.99	63.98
T7	6.23	13.79	10.01	56.67	58.25	57.46
T8	3.93	5.02	4.48	58.93	62.21	60.57
T9	0.00	0.00	0.00	69.59	70.68	70.13
T10	11.33	23.56	17.44	45.85	38.42	42.14
S.Em.±	0.48	1.16	1.91	2.64	3.72	2.28
C.D.(0.05)	1.38	3.36	6.13	7.65	10.79	6.46
C.V. %	23.12	25.13	26.55	8.77	12.19	10.64

(T_6) remained at par with pendimethalin 1 kg ha^{-1} pre-em. + 1 HW(T_1). The lowest uptake of potassium by wheat crop was observed under unweeded control (T_{10}) during 2003-04, 2004-05 and in pooled results.

4.6 ECONOMICS

The data on gross returns and net returns are presented in Table 4.15 and their analysis of variance is furnished in Appendix VII. The data are also graphically depicted in Fig.4.11

The data showed that being equivalent to weedfree, significantly higher gross returns of 34138 and 32750 Rs. ha^{-1} and was accrued under 2 hand weedings(T_8) during 2003-4 and in pooled, respectively. However, it was found at par with remaining treatments, except isoproturon 0.75 kg ha^{-1} pre-em. + 1 HW (T_2) during 2003-04. While in pooled results it was found at par with treatments, pendimethalin 1 kg ha^{-1} pre-em. + 1 HW(T1) and 2,4-D (S.S.) 0.96 kg ha^{-1} post-em.(T_6). During, 2004-05 the maximum gross returns was obtained under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW(T_1) However, it was found at par with remaining treatments, except isoproturon 0.75 kg ha^{-1} post-em. (T_3). Significantly the lowest gross returns of 25314, 16822 and 21068 Rs. ha^{-1} was accrued under unweeded control during 2003-04, 2004-05 and in pooled results, respectively.

The results indicated that significantly higher net returns of 22909 Rs. ha^{-1} was obtained under treatment 2,4-D (S.S.) 0.96 kg ha^{-1} post-em.(T_6) and it was found at par with isoproturon 0.75 kg ha^{-1} post-em.(T_3) during 2003-04. During 2004-05, the same treatment recorded significantly higher net returns, however it was statistically at par with rest of the treatments except unweeded control (T_{10}). In pooled,

Table 4.15. Economics of different treatments

Treatment	Gross returns (Rs ha^{-1})			Net returns (Rs ha^{-1})			Additional net returns over control (Rs ha^{-1})		
	2003-04	2004-05	Pooled	2003-04	2004-05	Pooled	2003-04	2004-05	Pooled
T1	33294	32202	32748	18774	18320	18547	4196	12399	8297
T2	29335	26600	27967	15489	13119	14304	911	7198	4054
T3	31150	25193	28171	19844	13722	16783	5266	7801	6533
T4	31702	26647	29175	17952	13053	15502	3374	7132	5252
T5	30405	27550	28977	18799	15779	17289	4221	9858	7039
T6	34135	30166	32151	22909	18775	20842	8331	12854	10592
T7	29844	26266	28055	18397	14654	16526	3819	8733	6276
T8	34138	31361	32750	18194	15461	16827	3616	9540	6577
T9	35956	33670	34813	19015	15792	17404	4437	9871	7154
T10	25314	16822	21068	14578	5921	10250	-	-	-
S.Em.±	1339	2055	1227	1257	2071	1211	-	-	-
C.D.(0.05)	3886	5965	3480	3648	6010	3437	-	-	-
C.V. %	8.50	14.87	11.73	13.79	18.65	16.96	-	-	-

significantly higher net returns of 20842 Rs. ha^{-1} was obtained under treatment 2,4-D (S.S.) 0.96 kg ha^{-1} post-em.(T_6) and it was found at par with pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1). Significantly the lowest net returns of 10250 Rs. ha^{-1} was realized under unweeded control.

The maximum additional net returns of 8331, 12854 and 10592 Rs. ha^{-1} over unweeded control was realized under 2,4-D (S.S.) 0.96 kg ha^{-1} post-em.(T_6) during both the years as well as in pooled results. However, the next beneficial treatment was isoproturon 0.75 kg ha^{-1} post-em.(T_3) during 2003-04, pendimethalin 1 kg ha^{-1} pre-em. + 1 HW(T_1) during 2004-05 and in pooled results.

4.7 BIOASSAY STUDIES

4.7.1 Pot study

4.7.1.1 Indicator plant - Mustard

The results on persistence effect of different herbicides applied in wheat crop on germination, plant height and dry matter production of mustard (indicator plant) recorded at 30 and 60 DAS are presented in Table 4.16 and 4.17 and their analysis of variance is furnished in Appendix VIII.

The results reveal that persistence effect of different herbicides applied in wheat crop was found non-significant on germination, plant height and dry matter production of mustard during both the years and in the pooled results. The results clearly indicate that there was no any persistence effect of different herbicides on mustard at 30 DAS.

The data show that persistence effect of different herbicides applied in wheat crop was found non-significant on germination, plant height and dry matter production of mustard during both the years and in

Table 4.16. Persistence effect of different herbicides on bioassay parameters of mustard at 30 DAS

Treatment	**Germination (%)**			**Plant height (cm)**			**Dry matter (g 5 plant^{-1})**		
	2003-04	**2004-05**	**Pooled**	**2003-04**	**2004-05**	**Pooled**	**2003-04**	**2004-05**	**Pooled**
T1	55.00	74.00	64.50	4.73	4.00	4.36	0.32	0.33	0.32
T2	60.00	71.00	65.50	4.00	4.63	4.31	0.32	0.31	0.31
T3	57.00	65.00	61.00	4.78	4.00	4.39	0.31	0.32	0.31
T4	58.00	69.00	63.50	4.44	4.55	4.49	0.30	0.37	0.34
T5	54.00	64.00	59.00	4.60	4.03	4.31	0.32	0.32	0.32
T6	53.00	66.00	59.50	3.98	4.50	4.24	0.30	0.32	0.31
T7	54.00	66.00	60.00	4.00	4.05	4.03	0.32	0.36	0.34
T8	61.00	73.00	67.00	4.54	4.63	4.58	0.35	0.32	0.34
T9	61.00	69.00	65.00	4.54	4.73	4.63	0.36	0.36	0.36
T10	60.00	71.00	65.50	4.6	4.55	4.58	0.36	0.31	0.33
S.Em.±	4.38	3.21	2.71	0.24	0.23	0.24	0.02	0.02	0.01
C.D.(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
C.V %	15.29	9.33	12.18	10.88	10.50	10.69	9.88	13.28	11.73

Table 4.17. Persistence effect of different herbicides on bioassay parameters of mustard at 60 DAS

Treatment	Germination (%)			Plant height (cm)			Dry matter (g 5 plant^{-1})		
	2003-04	2004-05	Pooled	2003-04	2004-05	Pooled	2003-04	2004-05	Pooled
T1	62.00	77.00	69.50	7.43	7.55	7.49	0.50	0.58	0.54
T2	63.00	81.00	72.00	7.48	7.55	7.51	0.56	0.55	0.55
T3	60.00	68.00	64.00	7.53	7.63	7.58	0.55	0.53	0.54
T4	62.00	74.00	68.00	7.50	7.58	7.54	0.54	0.51	0.52
T5	59.00	73.00	66.00	7.43	7.50	7.46	0.57	0.55	0.56
T6	60.00	75.00	67.50	7.63	7.73	7.68	0.58	0.56	0.57
T7	61.00	74.00	67.50	7.63	7.73	7.68	0.57	0.55	0.56
T8	63.00	79.00	71.00	7.43	7.53	7.48	0.59	0.56	0.57
T9	65.00	74.00	69.50	7.28	7.40	7.34	0.58	0.55	0.56
T10	64.00	77.00	70.50	7.53	7.65	7.59	0.58	0.56	0.57
S.Em.±	3.17	2.69	2.08	0.27	0.21	0.17	0.02	0.01	0.01
C.D.(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
C.V %	10.23	7.16	8.57	7.33	5.43	6.44	6.71	5.02	5.94

the pooled results. The results clearly indicate that there was no any persistence effect of different herbicides on mustard at 60 DAS.

4.7.1.2 Indicator plant - Sorghum

The data on persistence effect of different herbicides applied in wheat crop on germination, plant height and dry matter production of sorghum (indicator plant) recorded at 30 and 60 DAS are presented in Table 4.18 and 4.19 and their analysis of variance is furnished in Appendix IX. The data are also graphically depicted in Fig.4.12

A perusal of data revealed that different treatments influenced significantly on germination, plant height as well as dry matter production of sorghum. Pre-emergence application of pendimethalin 1 kg ha^{-1}(T_1), isoproturon 0.75 kg ha^{-1} (T_2) and fluchloralin 0.45 kg ha^{-1} (T_4) showed significant persistence effect and reduced germination, plant height and dry matter production over control as well as other treatments at 30 DAS.

Different treatments failed to cause their significant effect on germination, plant height as well as dry matter production of sorghum at 60 DAS. The results reveal that persistence effect of different herbicides applied to wheat crop was found non-significant on germination, plant height and dry matter production of sorghum during both the years and in the pooled results. The results clearly show that persistence effect of different herbicides on sorghum was disappear at 60 DAS which was found significant at 30 DAS.

4.7.1.3 Indicator plant - Cucumber

The results on persistence of different herbicides applied to wheat crop on germination, plant height and dry matter production of cucumber

Table 4.18. Persistence effect of different herbicides on bioassay parameters of sorghum at 30 DAS

Treatment	Germination (%)			Plant height (cm)			Dry matter (g 5 plant^{-1})		
	2003-04	2004-05	Pooled	2003-04	2004-05	Pooled	2003-04	2004-05	Pooled
T1	37.50	36.25	36.88	5.63	5.58	5.60	0.18	0.17	0.17
T2	31.25	32.50	31.88	5.93	5.98	5.95	0.18	0.18	0.18
T3	65.00	46.25	55.63	11.05	11.20	11.13	0.34	0.33	0.34
T4	38.75	32.50	35.63	5.15	5.25	5.20	0.19	0.17	0.18
T5	65.00	42.50	53.75	10.68	11.68	11.18	0.37	0.34	0.35
T6	61.25	43.75	52.50	10.95	11.90	11.43	0.35	0.31	0.33
T7	61.25	47.50	54.38	11.00	11.88	11.44	0.33	0.34	0.33
T8	65.00	50.00	57.50	11.43	11.43	11.43	0.34	0.36	0.35
T9	70.00	48.75	59.38	11.80	12.13	11.96	0.37	0.33	0.35
T10	71.25	48.75	60.00	11.65	12.13	11.89	0.37	0.36	0.36
S.Em.	4.22	3.42	4.37	0.28	0.29	0.20	0.01	0.02	0.01
C.D.(0.05)	12.24	9.94	13.98	0.82	0.83	0.57	0.04	0.05	0.03
C.V %	14.90	15.98	15.45	5.93	5.78	5.85	9.17	12.39	10.85

Table 4.19. Persistence effect of different herbicides on bioassay parameters of sorghum at 60 DAS

Treatments	**Germination (%)**			**Plant height (cm)**			**Dry matter (g 5 plant^{-1})**		
	2003-04	**2004-05**	**Pooled**	**2003-04**	**2004-05**	**Pooled**	**2003-04**	**2004-05**	**Pooled**
T1	57.50	47.50	52.50	12.95	13.88	13.41	0.53	0.51	0.52
T2	61.25	45.00	53.13	14.03	12.45	13.24	0.52	0.56	0.54
T3	61.25	45.00	53.13	14.63	14.45	14.54	0.51	0.54	0.52
T4	72.50	41.25	56.88	14.48	14.28	14.38	0.53	0.55	0.54
T5	67.50	40.00	53.75	13.28	13.75	13.51	0.55	0.52	0.54
T6	63.75	42.50	53.13	13.88	12.78	13.33	0.57	0.55	0.56
T7	68.75	51.25	60.00	13.48	12.98	13.23	0.57	0.51	0.54
T8	67.50	52.50	60.00	14.40	13.90	14.15	0.59	0.56	0.58
T9	66.25	51.25	58.75	13.71	14.30	14.01	0.59	0.57	0.58
T10	71.25	52.50	61.88	15.05	12.96	14.01	0.56	0.55	0.55
S.Em.±	3.75	3.47	2.55	0.51	0.54	0.37	0.02	0.02	0.01
C.D.(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
C.V %	**11.39**	**14.80**	**12.82**	**7.28**	**7.93**	**7.60**	**7.61**	**6.75**	**7.21**

(indicator plant) recorded at 30 and 60 DAS are presented in Table 4.20 and 4.21 and their analysis of variance is furnished in Appendix X.

The data show that persistence effect of different herbicides applied in wheat crop was found non-significant on germination, plant height and dry matter production of cucumber at 30 DAS during both the years and in the pooled results. The results clearly show that there was no any persistence effect of different herbicides on cucumber at 30 DAS.

The results indicate that persistence effect of different herbicides applied in wheat crop was found non-significant on germination, plant height and dry matter production of cucumber at 60 DAS during both the years and in the pooled results. The results clearly indicate that there was no any persistence effect of different herbicides on cucumber at 60 DAS.

4.7.2 Post-harvest field study

4.7.2.1 Effect on germination

The results on residual effect of different weed management treatments employed in wheat crop on germination of succeeding groundnut, greengram, cotton and pearlmillet crop are presented in Table 4.22 & 4.23 and their analysis of variance is furnished in Appendix XI.

The results reveal that carry over effect of different herbicides applied in wheat crop was found non-significant on germination of groundnut, greengram, cotton and pearlmillet crop recorded at 10 DAS after harvesting of wheat in the same plots during both the years and in the pooled results. The results clearly indicate that there was no any residual phytotoxic effect in the soil after harvesting of wheat crop.

Table 4.20. Persistence effect of different herbicides on bioassay parameters of cucumber at 30 DAS

Treatment	Germination (%)			Plant height (cm)			Dry matter (g 5 plant^{-1})		
	2003-04	2004-05	Pooled	2003-04	2004-05	Pooled	2003-04	2004-05	Pooled
T1	52.50	57.50	55.00	4.23	4.25	4.24	0.42	0.46	0.44
T2	62.50	50.00	56.25	4.30	4.28	4.29	0.44	0.42	0.43
T3	50.00	47.50	48.75	4.35	4.40	4.38	0.44	0.48	0.46
T4	55.00	50.00	52.50	4.28	4.25	4.26	0.43	0.42	0.42
T5	52.50	52.50	52.50	3.85	4.08	3.96	0.44	0.41	0.43
T6	55.00	52.50	53.75	3.95	3.98	3.96	0.44	0.42	0.43
T7	57.50	47.50	52.50	4.00	4.08	4.04	0.42	0.43	0.42
T8	47.50	60.00	53.75	4.20	4.35	4.28	0.48	0.39	0.44
T9	62.50	57.50	60.00	4.53	4.60	4.56	0.46	0.47	0.46
T10	62.50	60.00	61.25	4.28	4.23	4.25	0.48	0.46	0.47
S.Em.±	3.85	3.52	2.61	0.20	0.19	0.14	0.02	0.02	0.01
C.D.(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
C.V %	13.80	13.17	13.5	9.73	8.88	9.31	7.64	9.19	8.44

Table 4.21. Persistence effect of different herbicides on bioassay parameters of cucumber at 60 DAS

Treatment	Germination (%)			Plant height (cm)			Dry matter (g 5 plant^{-1})		
	2003-04	2004-05	Pooled	2003-04	2004-05	Pooled	2003-04	2004-05	Pooled
T1	52.50	67.50	60.00	5.83	5.70	5.77	0.66	0.64	0.65
T2	72.50	57.50	65.00	6.08	5.93	6.00	0.66	0.63	0.65
T3	55.00	62.50	58.75	6.44	5.90	6.17	0.67	0.65	0.66
T4	60.00	65.00	62.50	6.40	5.65	6.03	0.65	0.63	0.64
T5	55.00	57.50	56.25	5.93	5.88	5.90	0.67	0.66	0.66
T6	55.00	55.00	55.00	6.14	5.88	6.01	0.68	0.67	0.67
T7	65.00	65.00	65.00	6.38	5.80	6.09	0.68	0.66	0.67
T8	57.50	65.00	61.25	6.33	5.93	6.13	0.70	0.69	0.69
T9	62.50	60.00	61.25	6.31	6.08	6.19	0.71	0.70	0.71
T10	67.50	67.50	67.50	6.33	6.10	6.21	0.71	0.69	0.70
S.Em.±	4.82	3.08	2.86	0.17	0.14	0.11	0.02	0.02	0.02
C.D.(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
C.V %	15.99	9.91	13.21	5.41	4.61	5.05	6.44	7.49	6.97

Table 4.22. Residual effect of different treatments on germination of groundnut and greengram at 10 DAS after harvest of wheat

Treatment	Groundnut (%)			Greengram (%)		
	2003-04	**2004-05**	**Pooled**	**2003-04**	**2004-05**	**Pooled**
T1	72.50	79.17	75.83	81.00	87.00	84.00
T2	55.00	67.50	61.25	75.00	79.00	77.00
T3	70.83	70.00	70.42	84.00	88.00	86.00
T4	75.00	78.33	76.67	86.00	90.50	88.25
T5	65.00	65.00	65.00	78.50	80.50	79.50
T6	67.50	67.50	67.50	82.50	88.50	85.50
T7	65.00	65.83	65.42	80.00	86.00	83.00
T8	76.67	80.00	78.33	78.50	81.50	80.00
T9	73.33	80.00	76.67	71.50	75.50	73.50
T10	65.83	72.50	69.17	68.50	72.50	70.50
S.Em.±	7.70	7.69	5.44	5.83	6.15	4.24
C.D.(0.05)	NS	NS	NS	NS	NS	NS
C.V. %	22.43	21.19	21.79	14.83	15.84	13.52

Table 4.23. Residual effect of different treatments on germination of cotton and pearlmillet at 10 DAS after harvest of wheat

Treatment	Cotton (%)			Pearlmillet (%)		
	2003-04	2004-05	Pooled	2003-04	2004-05	Pooled
T1	68.75	71.25	70.00	55.50	57.50	56.50
T2	78.75	80.00	79.38	65.00	51.00	58.00
T3	72.50	73.75	73.13	51.00	59.00	55.00
T4	71.25	75.00	73.13	62.50	61.50	62.00
T5	65.00	68.75	66.88	51.50	52.50	52.00
T6	71.25	72.50	71.88	66.50	64.00	65.25
T7	71.25	82.50	76.88	62.50	64.00	63.25
T8	67.50	67.50	67.50	57.50	56.00	56.75
T9	65.00	76.25	70.63	53.50	52.00	52.75
T10	55.00	62.50	58.75	52.50	51.00	51.75
S.Em.±	5.76	5.70	4.05	5.15	4.75	3.50
C.D.(0.05)	NS	NS	NS	NS	NS	NS
C.V. %	16.80	15.62	16.19	17.83	16.71	17.29

4.7.2.2 Effect on plant height

The data on residual effect of different weed management treatments employed in wheat crop on plant height of succeeding groundnut, greengram, cotton and pearlmillet crop are presented in Table 4.24 & 4.25 and their analysis of variance is furnished in Appendix XII.

The results reveal that carry over effect of different herbicides applied in wheat crop was found non-significant on plant height of groundnut, greengram, cotton and pearlmillet crop recorded at 30 DAS after harvesting wheat in the same plots during both the years and in the pooled results. The results clearly indicate that there was no any residual adverse effect on plant height of succeeding crops.

4.7.2.3 Effect on dry matter production

The results on residual effect of different weed management treatments employed in wheat crop on dry matter production of succeeding groundnut, greengram, cotton and pearlmillet crop are presented in Table 4.26 & 4.27 and their analysis of variance is furnished in Appendix XIII.

The results reveal that carry over effect of different herbicides applied in wheat crop was found non-significant on dry matter production of groundnut, greengram, cotton and pearlmillet crop recorded at 30 DAS after harvesting wheat in the same plots during both the years and in the pooled results. The results clearly indicate that there was no any residual phytotoxic effect in the soil after harvesting wheat crop.

4.8 CORRELATION STUDIES

The relationship between the grain yield of wheat and other important growth and yield attributing characters, weed parameters and nutrient uptake have been studied. The data on correlation coefficient (r), coefficient of determination (R^2) are furnished in Table 4.28.

Table 4.24 Residual effect of different treatments on plant height of groundnut and greengram at 30 DAS after harvest of wheat

Treatment	Groundnut (cm)			Greengram (cm)		
	2003-04	2004-05	Pooled	2003-04	2004-05	Pooled
T1	4.65	5.25	4.95	8.10	6.85	7.48
T2	5.25	5.50	5.38	7.60	7.85	7.73
T3	5.10	5.20	5.15	7.00	7.25	7.13
T4	5.15	4.75	4.95	7.63	7.85	7.74
T5	5.45	5.50	5.48	6.75	8.35	7.55
T6	4.95	5.05	5.00	7.25	7.50	7.38
T7	4.85	4.95	4.90	7.50	7.55	7.53
T8	5.25	5.25	5.25	6.98	7.03	7.00
T9	5.15	5.25	5.20	6.75	6.75	6.75
T10	5.05	5.15	5.10	6.60	6.85	6.73
S.Em.±	0.19	0.22	0.15	0.32	0.42	0.27
C.D.(0.05)	NS	NS	NS	NS	NS	NS
C.V. %	7.47	8.62	8.07	8.94	11.47	10.31

Table 4.25. Residual effect of different treatments on plant height of cotton and pearlmillet at 30 DAS after harvest of wheat

Treatment	Cotton (cm)			Pearlmillet (cm)		
	2003-04	**2004-05**	**Pooled**	**2003-04**	**2004-05**	**Pooled**
T1	8.35	8.93	8.64	8.35	8.85	8.60
T2	8.85	9.60	9.23	7.55	8.05	7.80
T3	9.00	9.40	9.20	8.65	8.90	8.78
T4	8.00	8.30	8.15	7.70	7.95	7.83
T5	7.80	8.30	8.05	7.70	8.20	7.95
T6	8.40	8.90	8.65	10.00	10.50	10.25
T7	7.90	8.35	8.13	8.68	9.40	9.04
T8	9.45	8.00	8.73	8.90	9.40	9.15
T9	7.65	9.75	8.70	9.63	10.38	10.00
T10	7.10	7.35	7.23	6.75	7.25	7.00
S.Em.±	0.50	0.81	0.48	1.09	1.39	0.88
C.D.(0.05)	NS	NS	NS	NS	NS	NS
C.V. %	12.07	18.63	15.87	19.94	21.20	20.86

Table 4.26. Residual effect of different treatments on dry matter of groundnut and greengram at 30 DAS after harvest of wheat

Treatment	Groundnut (g plant^{-1})			Greengram (g plant^{-1})		
	2003-04	2004-05	Pooled	2003-04	2004-05	Pooled
T1	0.92	1.28	1.10	0.52	0.64	0.58
T2	1.02	1.05	1.03	0.58	0.54	0.56
T3	0.93	0.89	0.91	0.60	0.46	0.53
T4	1.02	1.10	1.06	0.43	0.63	0.53
T5	1.02	1.09	1.06	0.57	0.49	0.53
T6	1.06	1.14	1.10	0.48	0.58	0.53
T7	1.15	0.90	1.03	0.40	0.49	0.44
T8	1.17	1.15	1.16	0.48	0.41	0.44
T9	1.10	1.21	1.16	0.48	0.44	0.46
T10	0.97	0.93	0.95	0.38	0.40	0.39
S.Em.±	0.07	0.10	0.06	0.05	0.07	0.04
C.D.(0.05)	NS	NS	NS	NS	NS	NS
C.V. %	13.32	17.70	15.75	20.72	21.59	20.84

Table 4.27. Residual effect of different treatments on dry matter of cotton and pearlmillet at 30 DAS after harvest of wheat

Treatment	Cotton (g plant^{-1})			Pearlmillet (g plant^{-1})		
	2003-04	2004-05	Pooled	2003-04	2004-05	Pooled
T1	0.94	1.00	0.97	0.49	0.37	0.43
T2	1.00	0.99	0.99	0.48	0.45	0.46
T3	0.98	0.98	0.98	0.48	0.45	0.46
T4	1.03	0.94	0.99	0.40	0.47	0.43
T5	1.00	0.99	1.00	0.44	0.41	0.42
T6	1.02	1.01	1.02	0.46	0.43	0.45
T7	1.13	1.05	1.09	0.38	0.36	0.37
T8	1.03	1.01	1.02	0.45	0.42	0.44
T9	1.01	1.03	1.02	0.45	0.43	0.44
T10	0.93	0.95	0.94	0.38	0.36	0.37
S.Em.$\pm$	0.04	0.04	0.03	0.03	0.03	0.02
C.D.(0.05)	NS	NS	NS	NS	NS	NS
C.V. %	8.57	8.74	8.65	14.91	15.92	15.40

Results revealed that plant height, leaf area index, total and productive tillers, spikelets per spike, grain weight, test weight showed positive and significant correlation with grain yield of wheat. Weed parameters viz., weed population, dry weight of weeds, weed index exhibited negative significant correlation with grain yield. While, weed control efficiency and herbicidal efficiency index showed positive and significant correlation with grain yield. The nutrient(NPK) uptake by weeds exhibited negative significant relationship with grain yield, on the other hand crop exhibited positive significant relationship with grain yield.

The positive relationship between grain yield and K uptake by crop was the highest (0.9237) followed by N uptake by crop (0.9232), P uptake by crop (0.9216), grain weight per plant (0.9044), spikelet per spike (0.8978), plant height (0.8932), weed control efficiency (0.8880), productive tillers (0.8260), total tillers (0.8172), test weight (0.8058), leaf area index (0.7991) and herbicidal efficiency index (0.7363) which attributed correspondingly 85.32, 85.24, 84.93, 81.79, 80.81, 79.79, 78.85, 68.23, 66.78, 64.93, 63.85 and 54.22 % variation in grain yield. The negative relationship between grain yield and weed index was the highest (-0.9975) followed by P uptake by weeds (-0.8959), K uptake by weeds (-0.8911), dry weight of weeds (-0.8844), N uptake by weeds (-0.8843) and weed population (-0.8137) which attributed correspondingly 99.50, 80.27, 79.40, 78.22, 78.20 and 66.21 % variation in grain yield.

Table 4.28. Correlation coefficient (*r*), coefficient of determination (R^2) of grain yield (dependent variable) with individual growth and yield attributes, weed parameters and nutrient uptake

Independent variable	***r***	R^2	**a**	**b**
Plant height (cm) at harvest	0.8932**	79.79	-5894.62	129.3568
LAI at 50 % flowering	0.7991**	63.85	1688.36	598.4033
Total tillers at harvest	0.8172**	66.78	-1773.65	104.8731
Productive tillers at harvest	0.8260**	68.23	-147.89	81.1141
Spikelet per spike at harvest	0.8978**	80.61	-2341.03	386.2688
Grain weight (g/plant	0.9044**	81.79	610.70	614.0097
Test weight (g)	0.8058**	64.93	-475.39	101.0728
Weed population at harvest	-0.8137**	66.21	3798.30	-15.0888
Dry weight of weeds (kg ha^{-1})	-0.8844**	78.22	3891.56	-1.0667
Weed Index (%)	-0.9975**	99.50	4010.30	-38.6106
Weed Control Efficiency (%)	0.8880**	78.85	2542.86	13.7352
Herbicidal Efficiency Index (%)	0.7363*	54.22	3253.53	116.8408
N uptake by weeds (kg ha^{-1})	-0.8843**	78.20	3888.96	-51.9390
N uptake by crop (kg ha^{-1})	0.9232**	85.24	86.94	44.0595
P uptake by weeds (kg ha^{-1})	-0.8959**	80.27	4004.57	-136.8300
P uptake by crop (kg ha^{-1})	0.9216**	84.93	131.86	210.9681
K uptake by weeds (kg ha^{-1})	-0.8911**	79.40	3974.14	-81.1834
K uptake by crop (kg ha^{-1})	0.9237**	85.32	105.17	54.9613

* Significant at 5 % level of significance
** Significant at 1 % level of significance

CHAPTER V
DISCUSSION

During the course of presenting results of experiment entitled "Efficacy of herbicides in wheat (*Triticum aestivum* L.) and assessment of their persistence through bioassay technique" in the preceding chapter, many significant variations among different treatments were recorded. In this chapter, it is contemplated to discuss the variations observed in growth, yield attributes, yield and nutrient uptake by crop and weeds, weed population, dry weight of weeds and persistence of different herbicides through bioassay. It has been attempted to establish cause and effect relationship based on the results of the present investigation duly supported by available evidences and relevant literature.

The weather condition during the winter season of 2003-04 and 2004-05 (Tables 3.1 and 3.2) was more or less congenial for satisfactory growth and development of wheat crop under irrigated conditions. As a result, the growth of wheat crop was normal and hence, whatever, variations observed in the present investigation are therefore attributed to different treatments exercised in this experiment. The results obtained in the investigation are discussed in the following major heads.

5.1 Growth parameters

5.2 Yield attributes

5.3 Yield

5.4 Weed study

5.5 Nutrient uptake by weeds and crop

5.6 Economics

5.7 Bioassay studies

5.1 Growth parameters

Wheat exhibits determinate growth habit. The plant growth is the function of photosynthetic activity of the plant and their capacity to utilize available nutrients.

Plant population at 20 DAS and at harvest (Table 4.1) was not significantly influenced by different treatments. This indicated that application of different herbicides has no adverse effect on wheat crop.

Growth parameters viz., plant height and LAI were significantly influenced by weed management treatments (Table 4.2) and their maximum values were recorded under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1) but remained at par with fluchloralin 0.45 kg ha^{-1} pre-em. + 1 HW (T_4) and metsulfuron 6 g ha^{-1} post-em. (T_5). While incase of leaf area index, it remained consistence with rest of the treatments, except isoproturon 0.75 kg ha^{-1} pre-em. + 1 HW (T_2). It was due to favourable environment in the root zone resulting in absorption of more water and nutrients and good control of weeds which resulted in to less weed crop competition throughout the growth stage of crop. Thus, enhance availability of nutrients, water, light and space which might have accelerated the photosynthetic rate, there by increasing the supply of carbohydrates, resulted in increase in plant height and leaf area. This finding corroborates the results on plant height with those of Walia *et al*. (1997) and Sardana *et al*. (2001) and incase of leaf area index with the results reported by Pandey and Kumar (2005).

5.2 Yield attributes

Different treatment exerted their significant effect on various yield attributes viz., total and productive tillers (Table 4.3), number of spikelets per spike and grain weight per plant (Table 4.4), test weight (Table 4.5). The maximum total tillers was recorded under metsulfuron 6 g ha^{-1} post-em. (T_5) but remained at par with rest of the treatments, except unweeded control(T_{10}). Significantly higher productive tillers obtained under weedfree treatment (T_9) and remained at par with pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1) and metsulfuron 6 g ha^{-1} post-em. (T_5). The maximum number of spikelets per spike and test weight were observed under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1). However, it did not differ significantly to the rest of the treatments, except unweeded control (T_{10}). Incase of grain weight per plant, it was recorded higher by pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1) and was equivalent to weedfree. Increased values in these yield attributes might have been on account of the overall improvement in vegetative growth which favorably influenced the tillering, flowering and fruiting and ultimately resulted into increased grain weight per plant and test weight. These findings are in close vicinity of those of Singh and Saha (2001), Yadav *et al*. (2001) and Jat *et al*. (2003) in respect to number of tillers, Sardana *et al*. (2001), Singh and Saha (2001), Sharma and Thakur (2002), Singh and Ali (2004) and Singh and Singh (2004) incase of spikelet and Pandey *et al*. (2000), Yadav *et al*. (2001), Jat *et al*. (2003), Singh and Ali (2004) and Singh and Singh (2004) regarding to test weight.

5.3 Yield

An appraisal of data on grain and straw yield (Table 4.6) reveals that different weed management treatments influenced the yield of wheat significantly. Among the different treatments significantly the highest grain yield was recorded under 2 hand weedings (T_8) and statistically it was similar to pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1) and 2,4-D (S.S.) 0.96 kg ha^{-1} post-em. (T_6) and they all found equivalent to weedfree. The magnitude of increases in average grain yield under weedfree (T_9), 2 hand weedings (T_8), pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1) and 2,4-D (S.S.) 0.96 kg ha^{-1} post-em.(T_6) over unweeded control (T_{10}) were 65.25, 55.52 , 55.40 and 52.66 per cent, respectively.

Pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1) produced significantly higher straw yield and was remained at par with the treatments metsulfuron 6 g ha^{-1} post-em. (T_5), isoproturon 0.75 kg ha^{-1} pre-em. + 1 HW (T_2), 2,4-D (S.S.) 0.96 kg ha^{-1} post-em. (T_6), 2 hand weedings (T_8) and isoproturon 0.75 kg ha^{-1} post-em. (T_3) and they all found equivalent to weedfree. The magnitude of increases in average straw yield under weedfree (T_9), pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1), metsulfuron 6 g ha^{-1} post-em. (T_5), isoproturon 0.75 kg ha^{-1} pre-em. + 1 HW (T_2), 2,4-D (S.S.) 0.96 kg ha^{-1} post-em. (T_6), 2 hand weedings (T_8) and isoproturon 0.75 kg ha^{-1} post-em. (T_3) over unweeded control (T_{10}) were 66.30, 58.18, 56.81, 54.53, 49.75, 49.75 and 47.43 per cent, respectively.

The higher grain yield obtained under weedfree (T_9), 2 hand weedings (T_8), pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1) and 2,4-D (S.S.) 0.96 kg ha^{-1} post-em. (T_6) and higher straw yield produced under weedfree (T_9), pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1), metsulfuron 6 g ha^{-1} post-em. (T_5), isoproturon 0.75 kg ha^{-1} pre-em. + 1 HW (T_2), 2,4-D (S.S.) 0.96 kg ha^{-1} post-em. (T_6), 2 hand weedings (T_8) and isoproturon 0.75 kg ha^{-1} post-em. (T_3) could attributed to lower weed population (Table 4.7 and 4.8), dry weight of weeds (Table 4.10) and weed index which were negatively correlated with grain yield while higher weed control efficiency and herbicidal efficiency index (Table 4.11) were found positively correlated with the grain yield (Table 4.28), ultimately reduced the crop-weed competition and plants had not to face stress of either nutrients, moisture, light and space as compared to under heavy weed infestation (Table 4.12, 4.13 & 4.14). These helped the plant to put optimum growth in terms of plant height and leaf area index (Table 4.2). Further, it also enhanced photosynthetic activity and partitioning of assimilates, resulting in improved yield attributes viz., total and productive tillers, spikelet per spike, grain weight per plant and test weight(Table 4.3, 4.4 & 4.5) which were positively correlated with grain yield(Table 4.28), evidently resulted in higher yields under above mentioned treatments. These findings are in agreement with those of Singh (1997) and Nayak *et al*. (2003) who obtained the maximum grain yield with 2 hand weeding. Sukhadia *et al*. (2000) and Singh and Singh (2004) reported the highest grain yield with pendimethalin 1 kg ha^{-1} pre-em. supplemented by one hand weeding. Poonia *et al*. (2001), Pandey *et al*. (2001), Jat *et al*. (2003), Singh *et al* (2004) and Singh and Singh (2004) observed maximum grain yield of wheat with post-emergence application of 2,4-D. Similarly the maximum straw yield with various weed management treatments have been reported by Sukhadia *et al*. (2000), Pandey *et al*. (2001), Poonia *et al*. (2001), Jat *et al*. (2003), Jat *et al*. (2004) and Singh and Ali (2004).

5.4 Weed study

Weed population at 20, 40 and 60 DAS and at harvest

Different weed management treatments marked their significant effect on weed count recorded at 20, 40 and 60 DAS and at harvest (Table 4.7 and 4.8). Among different treatments, pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1) proved the most effective to reduce the weed population. However, it remained at par with isoproturon 0.75 kg ha^{-1} pre-em. + 1 HW (T_2) when recorded at 20 DAS, while with treatments isoproturon 0.75 kg ha^{-1} pre-em. + 1 HW (T_2) and fluchloralin 0.45 kg ha^{-1} pre-em. + 1 HW (T_4) when recorded at 40 and 60 DAS as well as at harvest. These treatments found equivalent effective to that of weedfree. This might be due to the effective weed control at early stage of crop growth by herbicide application and later weeds through hand weeding. The highest weed count was observed under treatment unweeded control (T_{10}) which was due to absence of weed control practices. Effectiveness of pre-emergence application of pendimethalin along with one hand weeding have been reported by Pandey *et al*. (1997), Sukhadia *et al*. (2000), Chopra *et al*. (2001) and Singh and Singh (2004) and pre-emergence application of isoproturon found more effective than pendimethalin by Bhan and Dixit (1998) at Jabalpur (MP).

Population of individual weed species

Different weed management treatments significantly reduced the population of *Brachiaria* spp., *Asphodelus tenuifolius*, *Indigofera glandulosa* and *Digera arvensis* as compared to unweeded control which recorded the maximum population of the respective weed species (Table 4.9). Metsulfuron 6 g ha^{-1} post-em. (T_5) failed to control *Brachiaria* spp. because basically metsulfuron controls broad leaf weeds. Isoproturon 0.75 kg ha^{-1} pre-em. + 1 HW (T_2), isoproturon 0.75 kg ha^{-1} post-em. (T_3) and fluchloralin 0.45 kg ha^{-1} pre-em. + 1 HW (T_4) failed to control *Asphodelus tenuifolius*. Primarily, isoproturon is narrow spectrum herbicide and it is effective against grassy weeds particularly *Phalaris minor* and *Avena fatua* and few broad leaf weeds while fluchloralin is used in various field crops for selective control of many annual broad leaf weeds and grasses. The population of *Cyperus rotundus* did not influence due to different treatments. This may be due to perennial nature and under ground net-work of this weed. Effectiveness of various herbicides against different weed species in wheat crop have reported by Chopra *et al*. (2001) and Sharma and Thakur (2002).

Dry weight of weeds

Dry weight of weeds was significantly influenced by weed management treatments (Table 4.10). Among different treatments, pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1) proved superior to reduce dry weed weight and equivalent to weedfree. However, rest of the treatments were also found equally effective to restrict dry weight of weeds, except isoproturon 0.75 kg ha^{-1} post-em. (T_3). Significantly the highest dry weight of weeds was observed under unweeded control. Reduction in dry weight of weeds under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1), 2 hand weedings (T_8), fluchloralin 0.45 kg ha^{-1} pre-em. + 1 HW (T_4), metsulfuron 6 g ha^{-1} post-em. (T_5), isoproturon 0.75 kg ha^{-1} pre-em. + 1 HW (T_2), 2,4-D (S.S.) 0.96 kg ha^{-1} post-em. (T_6) and 2,4-D (E.E.) 0.75 kg ha^{-1} post-em. (T_7) over unweeded control was 92.10, 80.06, 77.40, 76.94, 76.77, 66.85 and 55.36 per cent, respectively. This was due to lower weed population recorded under these treatments could be attributed to the effective weed control at early stage by herbicides application and later through hand weeding. The findings corroborate with those of Sukhadia *et al*. (2000), Chopra *et al*. (2001), Poonia *et al*. (2001), Sardana *et al*. (2001), Singh and Saha (2001), Singh and Singh (2002), Nayak *et al*. (2003) and Prashad *et al*. (2005).

Weed index, Weed control efficiency and Herbicidal efficiency index

Different weed management treatments exerted their remarkable effect on weed index, weed control efficiency and herbicide efficiency index (Table 4.11). Among different weed management treatments, the lowest weed index was recorded under treatment 2 hand weedings (T_8) with 4.01% closely followed by pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1) with 5.93 % and 2,4-D (S.S.) 0.96 kg ha^{-1} post-em. (T_6) with 8 %. Owing to effective control of weeds resulted into minimum loss in yield under these treatments. The highest weed control efficiency (92.02 %) was registered under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1). This is due to lower weed population and lower dry matter production of weeds during initial stage by pre-emergence application of this herbicide and control of later weeds through hand weeding provide weedfree and congenial environment to the crop. The lowest weed control efficiency (36.91%) was observed under isoproturon 0.75 kg ha^{-1} post-em. (T_3). All over India, isoproturon as post-emergence is recommended for the control grassy weeds particularly *Phalaris minor* and *Avena fatua* which are not exist in this area. The highest herbicidal efficiency index of 9.05 % was recorded under treatment pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1) which reflect effectiveness of this treatment. The lowest herbicidal efficiency index of 0.74 % was observed under treatment isoproturon 0.75 kg ha^{-1} post-em. (T_3) and closely followed by treatment 2,4-D (E.E.) 0.75 kg ha^{-1} post-em. (T_7) with herbicidal efficiency index of 0.99 %. The findings are corroborate with those of Pandey *et al*. (1997), Jain *et al*. (1998), Bhan and Dixit (1998), Sukhadia *et al*. (2000), Poonia *et al*. (2001), Singh and Saha (2001), Nayak *et al*. (2003) and Singh and Ali (2004).

5.5 Nutrient uptake by weeds and crop

Nitrogen, phosphorus and potassium (Tables 4.12, 4.13 & 4.14) uptake by weeds was significantly higher under unweeded control (T_{10}). Among different treatments, the minimum loss of nutrients by weeds was under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1). Restriction in loss of nutrients by weeds diverted to significantly higher nutrients uptake by the crop (Tables 4.12, 4.13 & 4.14) under this treatment. However, statistically it was similar to 2,4-D (S.S.) 0.96 kg ha^{-1} post-em. (T_6) and metsulfuron 6 g ha^{-1} post-em. (T_5). These treatments were also found equivalent to weedfree. Weed control measures significantly boosted the uptake of N, P and K by wheat crop over control (T_{10}). This was due to minimum nutrient uptake by weeds ultimately decrease dry matter production of weeds and provide more nutrients to crop which reflected in increasing productivity of wheat (Tables 4.10 & 4.6). The results could be supported by studies of Pandey *et al*. (2001), Singh and Saha (2001) and Jat *et al*. (2004).

5.6 Economics

The economics of different treatments presented in Table 4.15 indicated that maximum gross returns of 32750 Rs. ha^{-1} was accrued under 2 hand weedings(T_8) which was closely followed by pendimethalin 1 kg ha^{-1} pre-em. + 1 HW(32748 Rs. ha^{-1}) and 2,4-D (S.S.) 0.96 kg ha^{-1} post-em. (32151 Rs. ha^{-1}). Significantly the lowest gross returns of 21068 Rs. ha^{-1} was accrued under unweeded control. Remarkably the highest net returns of 20842 Rs. ha^{-1} was obtained under treatment 2,4-D (S.S.) 0.96 kg ha^{-1} post-em.(T_6) and it was found at par with pendimethalin 1 kg ha^{-1} pre-em. + 1 HW (T_1). Significantly the lowest net returns of 10250 Rs. ha^{-1} was realized under unweeded control. The maximum additional net returns of 10592 Rs. ha^{-1} over unweeded control was realized under 2,4-D (S.S.) 0.96 kg ha^{-1} post-em.(T_6). However, the next beneficial treatment was pendimethalin 1 kg ha^{-1}

pre-em. + 1 HW(T_1) which might be due to effective and efficient control of weeds under this treatment. The highest benefit under 2,4-D (S.S.) 0.96 kg ha^{-1} post-em.(T_6) might be due effective control of weeds and lower cost of herbicide. The results substantiated the finding of Sukhadia *et al*. (2000), Yadav *et al*. (2001) and Singh and Singh (2004).

5.7 Bioassay studies

Bioassay is a major tool for quantitative and qualitative determination of herbicide residual effect. In this method, the property of a chemical is measured in terms of some biological responses. Sensitive plant species called as indicator or test species are used for conducting bioassay. The major advantage of this technique is that the procedure followed is generally more economical, easy to perform and costly equipment are not required. The indicator plant is grown in a field or pot and is compared with that of similar plant grown in untreated soil.

Effect on indicator plant – mustard and cucumber

The data showed that persistence effect of different herbicides applied in wheat crop was found non-significant on germination, plant height and dry matter production of mustard (Tables 4.16 & 4.17) and cucumber (Tables 4.20 & 4.21) at 30 as well as at 60 DAS. The results clearly indicate that there was no any persistence effect of different herbicides viz. pendimethalin 1 kg ha^{-1} pre-em. , isoproturon 0.75 kg ha^{-1} pre- and post-emergence, fluchloralin 0.45 kg ha^{-1} pre-em., metsulfuron 6 g ha^{-1} post-em. 2,4-D (S.S.) 0.96 kg ha^{-1} post-em. and 2,4-D (E.E.) 0.75 kg ha^{-1} post-em. on mustard as well as cucumber at 30 as well as 60 DAS. Particularly, these indicator plants were used to detect the presence of residue of metsulfuron and 2,4-D. Rao (2001) reported that metsulfuron is moderately persistent in soil with half life of 30 days, with a range of 1- 6 weeks, while 2,4-D has persistence of 1-4 weeks and field half life of 10 days. The results supported by those of Singh and Vaishya (1993), Walia *et al*. (2000) and Walia *et al*. (2002).

Effect on indicator plant – sorghum

A perusal of data revealed that different treatments influenced significantly on germination, plant height as well as dry matter production of sorghum at 30 DAS (Table 4.18). Pre-emergence application of pendimethalin 1 kg ha^{-1}, isoproturon 0.75 kg ha^{-1} and fluchloralin 0.45 kg ha^{-1} showed significant persistence effect and reduced germination, plant height and dry matter production significantly over control as well as other treatments. While at 60 DAS (Table 4.19) different treatments failed to cause their significant effect on germination, plant height as well as dry matter production of sorghum. The results clearly show that persistence effect of different herbicides on sorghum was disappeared at 60 DAS which was found significant at 30 DAS. Thus, it seems that pendimethalin 1 kg ha^{-1}, isoproturon 0.75 kg ha^{-1} and fluchloralin 0.45 kg ha^{-1} remained biologically active up to 30 DAS in medium black calcareous soil of South Saurashtra region. Field half life of pendimethalin has been observed up to 25 to 44 days in different types of soil in India (Rao, 2001). Residue of isoproturon was disappeared at 60 days when applied at 0.47 kg ha^{-1}(Walia *et al*., 2002). Basically, grasses are more sensitive to pre-emergence application of these herbicides, therefore sorghum was used as indicator plant for these herbicides. The results also confirms the finding of Kulshrestha and

Yaduraju (1987), Yadav *et al*. (1993), Pahwa and Bajaj (1997) and Bhan and Kewat (2002).

Effect on succeeding crops

The carry over effect of different herbicides applied in wheat crop was found non-significant on germination (10 DAS), plant height (30 DAS) and dry matter production of succeeding crops i.e. groundnut, greengram, cotton and pearlmillet (Tables 4.22 to 4.26). The results clearly indicate that different herbicides viz. pendimethalin 1 kg ha^{-1} pre-em., isoproturon 0.75 kg ha^{-1} pre- and post-emergence, fluchloralin 0.45 kg ha^{-1} pre-em., metsulfuron 6 g ha^{-1} post-em., 2,4-D (S.S.) 0.96 kg ha^{-1} post-em. and 2,4-D (E.E.) 0.75 kg ha^{-1} post-em. did not left their residual phytotoxic effect in the soil after harvesting wheat crop on succeeding groundnut, greengram, cotton and pearlmillet crop. Sharma and Angiras (1996) observed that the residue of pendimethalin 1.5 kg ha^{-1} pre-emergence applied in wheat was only 0.001 ppm in soil after harvest of wheat through bioassay using oat as indicator plant. Singh and Ali (2004) found that post-em. application of metsulfuron methyl at 3 to 5 g ha^{-1} and 2,4-D 0.75 kg ha^{-1} did not leave any residual toxicity to the succeeding soybean crop. Yadav *et al.* (2004) studied residual impact of various herbicides applied in wheat on succeeding *kharif* season crops and reported that metsulfuron (4 and 8 g ha^{-1}), 2,4-D (0.5 & 1 kg ha^{-1}), isoproturon (1 kg ha^{-1}) and pendimethalin (1.5 kg ha^{-1}) applied in wheat did not exhibit any adverse effect on mungbean, maize, cowpea, pigeonpea, pearlmillet and cotton.

CHAPTER VI

SUMMARY AND CONCLUSION

An experiment was conducted at Instructional Farm, Junagadh Agricultural University, Junagadh on “Efficacy of herbicides in wheat (*Triticum aestivum* L.) and assessment of their persistence through bioassay technique.” during the *rabi* season of 2003-04 and 2004-05. Ten treatments comprising of different pre- and post-emergence herbicides, combination of herbicide with hand weeding, two hand weedings, weed free and unweeded control.

The experimental findings in detail and their cause and effect relation description have been given in the previous IV and V chapters . The salient features of finding are summarized on the basis of pooled results as under

(1) Initial and final plant population was not affected significantly by the different weed management treatments. Pre- and post-emergence application of herbicides included in this investigation were found safe for wheat crop.

(2) Plant height was significantly higher under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW, fluchloralin 0.45 kg ha^{-1} pre-em. + 1 HW, and metsulfuron 6 g ha^{-1} post-em. over rest of the treatments as well as unweeded control and remained equivalent to weedfree.

(3) Significantly the highest leaf area index was observed under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW and remained at par with rest of the treatments except isoproturon 0.75 kg ha^{-1} pre-em. + 1 HW and unweeded control.

(4) Being at par among themselves, all the treatments produced significantly higher total tillers over unweeded control. Among different treatments, significantly higher number of productive tillers was recorded under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW and metsulfuron 6 g ha^{-1} post-em. and found equivalent to weedfree.

(5) All the treatments being at par among themselves and produced significantly higher spikelets over unweeded control.

(6) Among different treatments, significantly the higher grain weight per plant was observed under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW which was at par with 2,4-D (SS) 0.96 kg ha^{-1} post-emergence and found equivalent to weedfree.

(7) The maximum test weight was recorded under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW and remained at par with rest of the treatments except isoproturon 0.75 kg ha^{-1} pre-em. + 1 HW and unweeded control.

(9) Producing equivalent yield to weedfree, the maximum grain yield was obtained under treatment 2 hand weeding and statistically it was at par with pendimethalin 1 kg ha^{-1} pre-em. + 1 HW and 2,4-D (S.S.) 0.96 kg ha^{-1} post-emergence.

(10) Significantly higher straw yield was obtained under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW and found statistically at par with the rest of the treatments except fluchloralin 0.45 kg ha^{-1} pre-em. + 1 HW, 2,4-D (E.E.) 0.75 kg ha^{-1} post-em. and unweeded control.

(11) Being equivalent effective to weedfree, pendimethalin 1 kg ha^{-1} pre-em. + 1 HW proved the most effective to reduce the weed population. However, it remained at par with isoproturon 0.75 kg ha^{-1} pre-em. + 1 HW when it recorded at 20 DAS, while with treatments isoproturon

0.75 kg ha^{-1} pre-em. + 1 HW and fluchloralin 0.45 kg ha^{-1} pre-em. + 1 HW when it recorded at 40 and 60 DAS as well as at harvest. The maximum weed population were recorded under unweeded control at 20, 40, 60 DAS and harvest.

(12) Different weed management treatments significantly reduced density of *Brachiaria* spp., *Asphodelus tenuifolius*, *Indigofera glandulosa* and *Digera arvensis* as compared to unweeded control which recorded the maximum population of the respective weed species.

(13) Among different treatments, pendimethalin 1 kg ha^{-1} pre-em. + 1 HW at 30 DAS proved superior effective to reduce dry weed weight and proved equivalent to weedfree which also reflected in higher weed control efficiency (92.02 %), higher herbicidal efficiency index (9.05 %) and lower weed index (5.93 %). However, rest of the treatments were also found equivalent effective to restrict dry weight of weeds, except isoproturon 0.75 kg ha^{-1} post-emergence.

(14) Nitrogen, phosphorus and potassium uptake by weeds was significantly higher under unweeded control. The minimum loss of nutrients by weeds was under pendimethalin 1 kg ha^{-1} pre-em. + 1 HW. Restriction in loss of nutrients diverted to significantly higher nutrients uptake by the crop under this treatment. However, statistically it was similar to 2,4-D (S.S.) 0.96 kg ha^{-1} post-em. and metsulfuron 6 g ha^{-1} post-emergence. These treatments were also found equivalent to weedfree.

(15) Recording equivalent gross returns to weedfree, the maximum gross returns was accrued under 2 hand weedings which was at par with pendimethalin 1 kg ha^{-1} pre-em. + 1 HW and 2,4-D (S.S.) 0.96 kg ha^{-1}

post-emergence. While significantly the highest net returns was obtained under 2,4-D (S.S.) 0.96 kg ha^{-1} post-em. and it was found at par with pendimethalin 1 kg ha^{-1} pre-em. + 1 HW. The lowest gross and net returns was obtained under unweeded control.

(16) The persistence effect of different herbicides applied in wheat crop was found non-significant on germination, plant height and dry matter production of mustard and cucumber at 30 as well as at 60 DAS and significant on sorghum at 30 DAS.

(17) Different herbicides did not left their residual phytotoxic effect in the soil after harvesting wheat crop as it is proved through non-significant effect on germination, plant height and dry matter production of succeeding groundnut, greengram, cotton and pearlmillet crops.

CONCLUSION

Based on the pooled results of two years' experimentation, it is concluded that potential production and profit can be achieved by post-emergence application of 2,4-D (S.S.) @ 0.96 kg ha^{-1} at 30 DAS using spray volume of 500 liters. Pre-emergence application of pendimethalin 1 kg ha^{-1} supplemented by one hand weeding at 30 DAS also emerged out best treatments for minimizing weed problem in wheat. Application of pendimethalin 1 kg ha^{-1}, isoproturon 0.75 kg ha^{-1} and fluchloralin 0.45 kg ha^{-1} as pre-emergence showed significant persistence effect up to 30 DAS, though it disappear at 60 DAS as indicated by sorghum bioassay. While mustard and cucumber bioassay did not show any significant persistent effect. There is no residual toxicity of pendimethalin 1 kg ha^{-1} pre-em., isoproturon 0.75 kg ha^{-1} pre- and post-emergence, fluchloralin 0.45 kg ha^{-1} pre-em., metsulfuron 6 g ha^{-1} post-em., 2,4-D (S.S.) 0.96 kg ha^{-1} post-em. and 2,4-D (E.E.) 0.75 kg ha^{-1} post-emergence was observed after harvesting wheat crop and it is found safe to grow groundnut, greengram, cotton and pearlmillet as succeeding crop.

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* original not seen

Appendix-I. Analysis of variance (mean sum of squares) for plant population, plant height and leaf area index

Source of variance	d.f.	Plant population		Plant height	Leaf area index
		Initial	Final		
2003-04					
Replication	3	50.32	53.22	3.30	1.39
Treatment	9	21.44	27.24	20.76**	1.40**
Error	27	89.05	93.65	6.86	0.54
2004-05					
Replication	3	92.00	99.56	122.06	1.27
Treatment	9	40.42	44.84	70.64**	1.72**
Error	27	50.18	52.84	8.25	0.27
Pooled					
R / Y	6	76.39	55.89	63	1.331
Y	1	252.05	288.80	1598**	4.775**
Treatment	9	52.52	52.52	77**	2.859**
Y x T	9	19.55	19.55	14	0.259
Error	54	73.24	73.24	8	0.403

Appendix-II. Analysis of variance (mean sum of squares) for yield attributes

Source of variance	d.f.	Total tillers	Productive tillers	Spikelets per spike	Grain weight per plant
2003-04					
Replication	3	71.37	8.83	0.73	0.31
Treatment	9	40.82	84.33**	2.01**	1.75**
Error	27	38.09	32.15	0.17	0.13
2004-05					
Replication	3	267.49	376.49	1.08	0.73
Treatment	9	108.67**	106.80**	7.91**	1.75**
Error	27	12.27	12.90	0.45	0.13
Pooled					
R / Y	6	169	193	0.904	0.521
Y	1	1163**	357**	1.740	3.828**
Treatment	9	99**	168**	8.690**	3.507**
Y x T	9	51	23	1.230	0.001
Error	54	25	23	0.310	0.126

* Significant at 5 % level of significance, ** Significant at 1 % level of significance.

Appendix-III. Analysis of variance (mean sum of squares) for test weight and yield of wheat

Source of variance	d.f.	Test weight	Grain yield	Straw yield
2003-04				
Replication	3	0.11	290877.91	68872.89
Treatment	9	0.51**	505387.90**	849683.74**
Error	27	0.07	99812.02	297890.31
2004-05				
Replication	3	0.11	8503879.80	1637955.59
Treatment	9	0.51**	1229416.00**	1489270.09**
Error	27	0.07	232158.14	377286.80
Pooled				
R / Y	6	0.112	4397379	853414.240
Y	1	5.000**	4218381**	1138142.933**
Treatment	9	1.024**	1611236**	2004039.270**
Y x T	9	0.001	123568	334914.553
Error	54	0.070	165985	337588.558

Appendix-IV. Analysis of variance (mean sum of squares) for weed population and dry weight of weeds

Source of variance	d.f.	Weed population				Dry weight of weeds
		20 DAS	40 DAS	60 DAS	Harvest	
2003-04						
Replication	3	1.57	0.40	0.81	0.81	4957.01
Treatment	9	16.70**	23.09**	22.52**	22.52**	142094.81**
Error	27	1.66	1.49	1.72	1.72	3032.05
2004-05						
Replication	3	1.72	2.02	3.89	3.89	25720.16
Treatment	9	25.14**	42.51**	36.60**	36.60**	1268213.16**
Error	27	0.81	0.57	0.39	0.39	20044.26
Pooled						
R / Y	6	1.643	1.210	2.347	2.08	15338.585
Y	1	36.078**	22.505*	23.718*	23.43*	3051155.026*
Treatment	9	39.545**	62.538**	56.855**	50.32**	1108301.686*
Y x T	9	2.287	3.054	2.261	2.45	302006.279*
Error	54	1.236	1.029	1.055	0.86	11538.158

Appendix-V. Analysis of variance (mean sum of squares) for population of different weed species

Source of variance	d.f.	Population				
		Brachiaria spp.	*Asphodelus tenuifolius*	*Indigofera glandulosa*	*Digera arvensis*	*Cyperus rotundus*
Pooled						
R / Y	6	0.99	0.30	0.79	0.068	0.42
Y	1	17.80**	1.06**	0.78**	0.016**	1.40**
Treatment	9	47.16**	0.90**	1.25**	0.476**	0.48
Y x T	9	2.22	0.38	0.14	0.038	0.41
Error	54	1.15	0.31	0.16	0.052	0.32

Appendix-VI. Analysis of variance (mean sum of squares) for NPK uptake by weed and crop

Source of variance	d.f.	N uptake		P uptake		K uptake	
		Weed	Crop	Weed	Crop	Weed	Crop
2003-04							
Replication	3	0.45	46.04	0.32	4.22	1.31	44.84
Treatment	9	58.35**	142.77**	18.15**	10.47**	43.82**	154.76*
Error	27	0.51	20.81	0.28	1.94	0.91	27.78
2004-05							
Replication	3	6.06	106.11	1.12	75.87	5.83	165.08
Treatment	9	538.05**	305.22**	59.41**	22.57**	179.73*	335.20
Error	27	2.01	48.94	1.23	3.74	5.35	55.29
Pooled							
R / Y	6	3.255	79.29	0.720	10.047	3.57	64.956
Y	1	1274.76*	16.88**	183.5**	1.06**	518.12**	16.55**
Treatment	9	467.199*	682.66**	69.03**	29.67**	194.22**	439.5**
Y x T	9	129.198	77.00	8.524	3.366	29.33	50.490
Error	54	1.261	63.67	0.754	2.840	3.13	41.532

Appendix-VII. Analysis of variance (mean sum of squares) for gross and net returns

Source of variance	d.f.	Gross returns	Net returns
2003-04			
Replication	3	21148801.44	16105329.42
Treatment	9	37349650.43**	20630727.90**
Error	27	7173168.09	6320721.14
2004-05			
Replication	3	62023771.15	64432818.82
Treatment	9	90832172.18**	51245975.29**
Error	27	16897762.12	17159115.14
Pooled			
R / Y	6	32069325	33021675.12
Y	1	301064485**	284339103.80**
Treatment	9	119082387**	61779266.52**
Y x T	9	9099436	10097436.66
Error	54	12035465	11739918.14

Appendix-VIII. Analysis of variance (mean sum of squares) for germination, plant height and dry matter production of mustard

Source of variance	d.f.	30 DAS			60 DAS		
		Germin-ation	Plant height	Dry matter	Germin-ation	Plant height	Dry matter
2003-04							
Replication	3	6.80	0.737	0.001	32.40	0.47	0.007
Treatment	9	39.16	0.383	0.002	14.62	0.04	0.003
Error	27	76.73	0.231	0.001	40.10	0.30	0.001
2004-05							
Replication	3	53.33	0.168	0.001	13.87	0.25	0.001
Treatment	9	47.82	0.370	0.002	51.38	0.04	0.002
Error	27	41.19	0.210	0.002	28.98	0.17	0.001
Pooled							
R / Y	6	30.07	0.452	0.001	23.133	0.36	0.004
Y	1	2645.0*	0.058	0.001	3537.8*	0.20	0.003
Treatment	9	67.76	0.275	0.002	47.311	0.08	0.002
Y x T	9	19.22	0.479	0.002	18.689	0.00	0.002
Error	54	58.96	0.221	0.001	34.541	0.24	0.001

Appendix-IX. Analysis of variance (mean sum of squares) for germination, plant height and dry matter production of sorghum

Source of variance	d.f.	30 DAS			60 DAS		
		Germin-ation	Plant height	Dry matter	Germin-ation	Plant height	Dry matter
2003-04							
Replication	3	382.29	0.076	0.002	15.83	3.76	0.002
Treatment	9	877.85**	30.42**	0.027**	90.56	1.72	0.002
Error	27	71.18	0.319	0.001	56.11	1.04	0.002
2004-05							
Replication	3	8.96	0.214	0.004	68.96	1.61	0.001
Treatment	9	183.40**	35.86**	0.026**	92.01	2.07	0.002
Error	27	46.92	0.328	0.001	48.13	1.16	0.001
Pooled							
R / Y	6	195.63	0.145	0.003	42.396	2.68	0.001
Y	1	3781.25**	3.003*	0.002	7125.31*	3.44*	0.009*
Treatment	9	908.47**	65.95**	0.052**	103.090	1.94	0.003
Y x T	9	152.78	0.341	0.001	79.479	1.85	0.001
Error	54	59.05	0.323	0.001	52.118	1.10	0.002

Appendix-X. Analysis of variance (mean sum of squares) for germination, plant height and dry matter production of cucumber

Source of variance	d.f.	30 DAS			60 DAS		
		Germin-ation	Plant height	Dry matter	Germin-ation	Plant height	Dry matter
2003-04							
Replication	3	42.50	0.122	0.002	22.50	0.57	0.005
Treatment	9	116.94	0.167	0.002	169.17	0.18	0.002
Error	27	59.17	0.166	0.001	92.87	0.11	0.002
2004-05							
Replication	3	170.00	0.035	0.003	49.17	0.18	0.006
Treatment	9	95.56	0.130	0.003	80.28	0.08	0.002
Error	27	49.63	0.142	0.002	38.06	0.07	0.002
Pooled							
R / Y	6	106.25	0.078	0.003	35.833	0.38	0.006
Y	1	101.25	0.055	0.001	80.000	2.21	0.006
Treatment	9	133.47	0.283	0.002	125.000	0.16	0.004
Y x T	9	79.03	0.014	0.003	124.444	0.10	0.000
Error	54	54.40	0.154	0.001	65.463	0.09	0.002

Appendix-XI. Analysis of variance (mean sum of squares) for germination of different crop in post harvest study

Source of variance	d.f.	Germination			
		Groundnut	Greengram	Cotton	Pearlmillet
2003-04					
Replication	3	231.85	20.37	85.63	25.87
Treatment	9	163.70	120.99	156.18	137.60
Error	27	237.20	135.77	132.85	106.16
2004-05					
Replication	3	300.28	81.47	21.67	45.43
Treatment	9	154.60	483.96	140.56	106.90
Error	27	236.49	543.10	130.00	90.25
Pooled					
R / Y	6	266.065	26.92	53.646	35.650
Y	1	306.806	378.45*	382.813*	18.050
Treatment	9	282.793	262.94	261.840	184.006
Y x T	9	35.509	3.56	34.896	60.494
Error	54	236.847	143.55	131.424	98.206

Appendix-XII. Analysis of variance (mean sum of squares) for plant height of different crop in post harvest study

Source of variance	d.f.	Plant height			
		Groundnut	Greengram	Cotton	Pearlmillet
2003-04					
Replication	3	0.89	0.17	1.61	9.32
Treatment	9	0.20	0.93	5.14	4.15
Error	27	0.14	0.42	6.66	6.67
2004-05					
Replication	3	1.79	0.37	5.32	10.61
Treatment	9	0.21	1.12	7.15	5.14
Error	27	0.20	0.72	3.67	7.66
Pooled					
R / Y	6	1.340	0.274	8.00	0.21
Y	1	0.200	0.561	4.95	3.83*
Treatment	9	0.297	1.133	8.37	2.87
Y x T	9	0.119	0.922	0.05	1.45
Error	54	0.172	0.566	6.21	1.81

Appendix-XIII. Analysis of variance (mean sum of squares) for dry matter production of different crop in post harvest study

Source of variance	d.f.	Dry matter production			
		Groundnut	Greengram	Cotton	Pearlmillet
2003-04					
Replication	3	0.01	0.07	0.012	0.01
Treatment	9	0.03	0.02	0.012	0.01
Error	27	0.02	0.01	0.007	0.00
2004-05					
Replication	3	0.04	0.22	0.007	0.01
Treatment	9	0.07	0.03	0.030	0.01
Error	27	0.04	0.02	0.019	0.00
Pooled					
R / Y	6	0.022	0.143	0.010	0.009
Y	1	0.030	0.004	0.016	0.015*
Treatment	9	0.052	0.030	0.036	0.009
Y x T	9	0.047	0.024	0.006	0.004
Error	54	0.028	0.015	0.013	0.004

Appendix XIV : Cost of cultivation for wheat

Particulars	Cost of cultivation (Rs ha^{-1})	
	2003-04	2004-05
1. Preparatory tillage	1325	1400
2. Seed and Sowing	1900	1900
3. Fertilizers	2280	2295
4. Irrigation	1600	1660
5. Harvesting & Threshing	2655	2655
6. Other cost (@ 10 %)	976	991
Total	10736	10901

Price of treatment inputs

1. Stomp (30 % EC)	Rs. 360 / lit.
2. Isoguard (75 % WP)	Rs. 300 / kg
3. Basalin (45 % EC)	Rs. 430 / lit.
4. Algrip (20 % WP)	Rs. 160 / 8 gram
5. Fernoxone (80 % WP)	Rs. 185 / kg
6. Agrodon (34 % EC)	Rs. 200 / lit.
7. Labour rate : Common	Rs. 50 / day
: Spraying	Rs. 86.70 / day

Market price of produce

1. Wheat grain	Rs. 8.50 / kg
2. Wheat straw	Rs. 0.10 / kg