



LIBRARY
New Delhi

Call No. _____

Acc. No. T-6275

DIRECT AND RESIDUAL EFFECT OF HERBICIDES ON SOYBEAN-WHEAT SEQUENCE

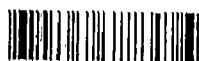
MEWA LAL KEWAT



T-6275

**DIVISION OF AGRONOMY
INDIAN AGRICULTURAL RESEARCH INSTITUTE
NEW DELHI-110 012**

T6275



IARI

1998

DIRECT AND RESIDUAL EFFECT OF HERBICIDES ON SOYBEAN-WHEAT SEQUENCE

Thesis

By

MEWA LAL KEWAT

Submitted to the Faculty of Post-Graduate School,
Indian Agricultural Research Institute, New Delhi,
in partial fulfilment of the requirements
for the award of the degree of

DOCTOR OF PHILOSOPHY

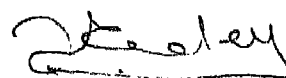
in

AGRONOMY

1 9 9 8

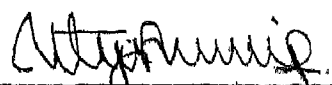
Approved by :

Chairman :

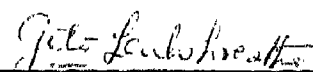


Dr. Jitendra Pandey

Members :



Dr. N.J. Yaduraju



Dr. Gita Kulshrestha



Dr. V.K. Gupta

Dr. Jitendra Pandey
Principal Scientist (Weed Control)

Division of Agronomy,
Indian Agricultural Research Institute,
New Delhi-110012., India.

CERTIFICATE

This is to certify that the thesis entitled "**Direct and residual effect of herbicides on soybean-wheat sequence**" submitted in partial fulfilment of the requirements for the award of the degree of **Doctor of Philosophy in Agronomy** of the Post Graduate School, Indian Agricultural Research Institute, New Delhi, is a record of *bona fide* research carried out by **Shri Mewa Lal Kewat**, under my guidance and supervision. No part of the thesis has been submitted for any other degree or diploma.

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

New Delhi

January 24, 1998



(**JITENDRA PANDEY**)
Chairman
Advisory committee

ACKNOWLEDGEMENTS

I sincerely express my deep sense of gratitude and indebtedness to **Dr. Jitendra Pandey**, Principal Scientist, **Division of Agronomy**, Indian Agricultural Research Institute, New Delhi and **Chairman** of my advisory committee, for suggesting the research problem, his vivacious guidance, valuable suggestions, keen and sustained interest and inferential critique during the entire span of this investigation and in preparation of this manuscript.

I am deeply indebted to **Dr. Gita Kulshrestha**, Principal Scientist, **Division of Agricultural Chemicals** and member of my advisory committee, for her valuable suggestions, guidance and extending necessary laboratory facilities for residue analysis.

I record my sincere thanks and gratefulness to other members of the advisory committee, **Dr. N.T. Yaduraju**, Senior Scientist, **Division of Agronomy** and **Dr. V.K. Gupta**, National Fellow, IASRI, New Delhi for their priceless counsels.

I humbly express my profound gratitude to **Dr. Mahendra Pal**, **Professor** and **Head, Division of Agronomy** for his kind encouragements, help and support during the entire course of my study at IARI.

I am very much grateful to **Dr. Rajendra Prasad**, **National Professor** and the then Head, Division of Agronomy, IARI for his scholarly guidance and enthusiastic incitement during the course of study.

I record my profound thanks to Dr. I.P.S. Ahlawat, Dr. R.P. Sharma, Dr. C.S. Saraf, Dr. R.C. Gautam, Dr. Ganga Saran, Dr. K.C. Gautam, Dr. R.K. Rai, Dr. H.K. Singh, Dr. Gajendra Giri, Dr. B.N. Mishra, Dr. N.K. Mohta, Dr. Y.S. Shivay, Dr. Ashok Kumar, Dr. K.N. Ahuja, Dr. R.P. Singh, Dr. Ranbir Singh, Dr. R.K. Chhillar and Sh. Ashok Verma for their help and encouragement in numerous ways. Thanks are also due to Sh. Shyam Lal Sharma, K.L. Gauba, Babu

Lal, Phula, Vijay Choudhary and Nathi Lal Sharma of the Division of Agronomy whose timely help made this pursuit a reality.

My heartily thanks are due to Dr. N.P.S. Agnihotri, Dr. Shashi Bala Singh, Dr. Madhuban Gopal, Sh. Pawan Kumar of the Division of Agricultural Chemicals for their kind cooperation during the study.

I express my deep sense of appreciation for the help rendered by Ravi Wanjari, Shanti Kumar Sharma, Vijay Khawale, Ramprakash, Padmavati, T.P. Saikia, Doyeli, Subhash Kalwe, Rameshwar, Amrendra Singh and Shashi Pant.

I am extremely grateful to the **Jawahar Lal Nehru Krishi Vishva Vidyalaya, Jabalpur** (Madhya Pradesh) for granting me study leave for pursuing the **Ph.D.** at **Indian Agricultural Research Institute, New Delhi.**

In retrospect, I find no word of appreciation to be appropriate to **Dr. K.L. Tiwari**, Professor and Head, and **Dr. R.S. Sharma**, Associate Professor, Department of Agronomy, College of Agriculture, **JNKVV, Jabalpur** for their inspiration and moral support.

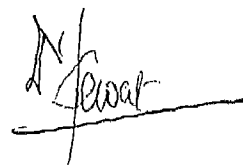
The Senior Research Fellowship awarded by the Indian Agricultural Research Institute, is duly acknowledged.

The typing work of this thesis was left in the competent hands of Sh. Alekh Narain and Anand Dubey, to whom I am greatly thankful.

Finally, I find no words to express my feelings to my parents, wife **Smt. Usha** and son **Mayank Raj, Ritu Raj** and **Rishav Raj**, Uncle and Aunt and younger brothers **Dr. R.R. Kewat** and **Rohani Prasad Kewat** and sister **Smt. Geeta Kewat** for their love, affection and inspiration in the achievement of this noble goal.

New Delhi

Date: 24th January, 1998



(MEWA LAL KEWAT)

CONTENTS

S.No.	Chapter	Page No.
1.	INTRODUCTION	... 1 - 4
2.	REVIEW OF LITERATURE	... 5 - 37
3.	MATERIALS AND METHODS	... 38 - 57
4.	RESULTS	... 58 - 119
5.	DISCUSSION ...	... 120 - 138
6.	SUMMARY AND CONCLUSION	... 139 - 145
	BIBLIOGRAPHY	... i - xvii
	APPENDICES	... I - IV

List of Tables contd...

Table No.	Title	Page
13.	Weed population (no. of plants/m ²) in soybean 110 DAS as affected by direct effect of pendimethalin and metribuzin in 1995-96	65
14.	Weed population (no. of plants/m ²) in soybean 110 DAS as affected by direct effect of pendimethalin and metribuzin in 1996-97	65
15.	Dry matter accumulation by weeds (g/m ²) in soybean 30, 60 and 110 DAS as affected by direct effect of pendimethalin and metribuzin in 1995-96	68
16.	Dry matter accumulation by weeds (g/m ²) in soybean 30, 60 and 110 DAS as affected by direct effect of pendimethalin and metribuzin in 1996-97	68
17.	Nitrogen, phosphorus and potassium content (%) in weeds at harvest (110 DAS) in soybean as affected by direct effect of pendimethalin and metribuzin	69
18.	Nitrogen, phosphorus and potassium depletion (kg/ha) by weeds in soybean as affected by direct effect of pendimethalin and metribuzin	70
19.	Soybean plant population (no. of plants/m) of 30 DAS and at harvest as affected by direct effect of pendimethalin and metribuzin	72
20.	Plant height (cm) of soybean 30, 60 DAS and at harvest as affected by direct effect of pendimethalin and metribuzin	73
21.	Number of trifoliolate leaves (nos./plant) in soybean as affected by direct effect of pendimethalin and metribuzin	74
22.	Dry matter production (g/plant) by soybean as affected by direct effect of pendimethalin and metribuzin	75
23.	Nodules numbers (no. of nodules/plant) and nodules dry weight (g) of soybean 60 DAS as affected by direct effect of pendimethalin and metribuzin	75

List of Tables contd...

Table No.	Title	Page
24.	Branches per plant (no. of branches/plant), pods per plant (no. of pods/plant), grains per pod (no. of grains/pod) and 1000-grain weight (g) of soybean as affected by direct effect of pendimethalin and metribuzin in 1995-96	76
25.	Branches per plant (no. of branches/plant), pods per plant (no. of pods/plant), grains per pod (no. of grains/pod) and 1000-grain weight (g) of soybean as affected by direct effect of pendimethalin and metribuzin in 1996-97	77
26.	Grain yield (q/ha), stover yield (q/ha) and harvest index (%) of soybean as influenced by direct effect of pendimethalin and metribuzin	78
27.	Nitrogen, phosphorus and potassium content (%) in soybean at harvest as affected by direct effect of pendimethalin and metribuzin in 1995-96	81
28.	Nitrogen, phosphorus and potassium content (%) in soybean at harvest as affected by direct effect of pendimethalin and metribuzin in 1996-97	81
29.	Nitrogen, phosphorus and potassium uptake (kg/ha) by soybean grain at harvest as affected by direct effect of pendimethalin and metribuzin	82
30.	Nitrogen, phosphorus and potassium uptake (kg/ha) by soybean stover at harvest as affected by direct effect of pendimethalin and metribuzin	82
31.	Total nitrogen, phosphorus and potassium uptake (kg/ha) by soybean (grain + stover) as affected by direct effect of pendimethalin and metribuzin	84
32.	Protein content (%) and protein yield (q/ha) of soybean as affected by direct effect of pendimethalin and metribuzin	86
33.	Oil content (%) and oil yield (q/ha) of soybean as affected by direct effect of pendimethalin and metribuzin	86

List of Tables contd...

Table No.	Title	Page
34.	Available nitrogen, phosphorus and potassium status (kg/ha) in soil after soybean harvest as affected by direct effect of pendimethalin and metribuzin	87
35.	Dry matter accumulation by oat (mg/pot) grown in soil collected from soybean (experiment) treated with pendimethalin and metribuzin	89
36.	Dry matter accumulation by wheat (mg/pot) grown in soil collected from soybean (experiment) treated with pendimethalin and metribuzin	89
37.	Pendimethalin and metribuzin residues ($\mu\text{g/g}$) in soil at different intervals (applied in <i>kharif</i> 1995)	91
38.	Pendimethalin and metribuzin residues ($\mu\text{g/g}$) in soil at different intervals (applied in <i>kharif</i> 1996)	91
39.	Correlation coefficient, rate constant, regression equation and half-life of herbicides (applied in <i>kharif</i> 1995)	93
40.	Correlation coefficient, rate constant, regression equation and half-life of herbicides (applied in <i>kharif</i> 1996)	93
41.	Herbicides residues ($\mu\text{g/g}$) in soybean grain	94
42.	Monocot and dicot population (no. of plants/ m^2) in wheat 45 DAS as affected by residual effect of pendimethalin and metribuzin and direct effect of isoproturon	96
43.	Total weed population (no. of plants/ m^2) in wheat at 45 DAS and at harvest as affected by residual effect of pendimethalin and metribuzin and direct effect of isoproturon	97
44.	Total weeds (no. of plants/ m^2) in wheat at harvest as affected by interaction between residual effect of pendimethalin and metribuzin and direct effect of isoproturon in 1996-97	98

List of Tables contd...

Table No.	Title	Page
45.	Dry matter accumulation by weeds (kg/ha) in wheat 45 DAS and at harvest as affected by residual effect of pendimethalin and metribuzin and direct effect of isoproturon	100
46.	Weed dry matter accumulation (kg/ha) in wheat at harvest as affected by interaction between residual effect of pendimethalin and metribuzin and direct effect of isoproturon in 1996-97	101
47.	Nitrogen, phosphorus and potassium content (%) in weeds in wheat at harvest as affected by residual effect of pendimethalin and metribuzin and direct effect of isoproturon	102
48.	Nitrogen, phosphorus and potassium depletion (kg/ha) by weeds in wheat at harvest as affected by residual effect of pendimethalin and metribuzin and direct effect of isoproturon	104
49.	Plant population (no. of plants/m) of wheat 15 DAS as affected by residual effect of pendimethalin and metribuzin and direct effect of isoproturon	106
50.	Plant height (cm) of wheat 45 DAS and at harvest as affected by residual effect of pendimethalin and metribuzin and direct effect of isoproturon	1-7
51.	Dry matter accumulation (g/plant) by wheat 30 and 60 DAS as affected by residual effect of pendimethalin and metribuzin and direct effect of isoproturon	108
52.	Number of tillers/m row length, spike length (cm). number of spikelets/spike and 1000-grain weight (g) of wheat as affected by residual effect of pendimethalin and metribuzin and direct effect of isoproturon in 1995-96	109
53.	Number of tillers/m row length, spike length (cm). number of spikelets/spike and 1000-grain weight (g) of wheat as affected by residual effect of pendimethalin and metribuzin and direct effect of isoproturon in 1996-97	110

List of Tables contd...

Table No.	Title	Page
54.	Biological yield (q/ha), grain yield (q/ha) and harvest index (%) of wheat as affected by residual effect of pendimethalin and metribuzin and direct effect of isoproturon	112
55.	Nitrogen, phosphorus and potassium uptake (kg/ha) by wheat as affected by residual effect of pendimethalin and metribuzin and direct effect of isoproturon in 1995-96	114
56.	Nitrogen, phosphorus and potassium uptake (kg/ha) by wheat as affected by residual effect of pendimethalin and metribuzin and direct effect of isoproturon in 1996-97	115
57.	Total productivity of cropping system in terms of soybean equivalent (q/ha) as affected by residual effect of pendimethalin and metribuzin and direct effect of isoproturon	117
58.	Economics of cultivation under different treatments in soybean-wheat sequence	119

LIST OF FIGURES

Figure No.	Title	Between Page
1.	Mean weekly Meteorological data during Kharif and rabi, 1995-96	40 - 41
2.	Mean weekly meteorological data during <i>kharif</i> and <i>rabi</i> , 1996-97	40 - 41
3.	Plan and layout of the experiment in <i>kharif</i>	41 - 42
4.	Plan and layout of the experiment in <i>rabi</i>	41 - 42
5.	Emergence pattern of weeds in soybean as affected by direct effect of herbicides	60 - 61
6.	Dry matter accumulation by weeds in soybean as affected by direct effect of pendimethalin and metribuzin	68 - 69
7.	N, P and K depletion by weeds in soybean as affected by direct effect of pendimethalin and metribuzin	70 - 71
8.	Grain and stover yield of soybean as influenced by direct effect of pendimethalin and metribuzin	78 - 79
9a.	N, P and K uptake by soybean grain as affected by direct effect of pendimethalin and metribuzin	82 - 83
9b.	N, P and K uptake by soybean stover as affected by direct effect of pendimethalin and metribuzin	82 - 83
10.	Dry matter accumulation by oat and wheat grown in soil collected from soybean (experiment) treated with pendimethalin	89 - 90

List of figures contd...

Figure No.	Title	Between Page
	and metribuzin	
11.	Per cent dissipation of pendimethalin and metribuzin in soil at different intervals	91 - 92
12.	Log (Residues ($\mu\text{g/g}$) $\times$ 10] residues of pendimethalin and metribuzin in soil at different intervals	93 - 94
13.	Dry matter accumulation by weeds in wheat 45 DAS and at harvest as affected by residual effect of pendimethalin and metribuzin and direct effect of isoproturon	100 -101
14.	N, P and K depletion by weeds in wheat at harvest as affected by residual effect of pendimethalin and metribuzin and direct effect of isoproturon	104 - 105
15.	Biological and grain yield of wheat as affected by residual effect of pendimethalin and metribuzin and direct effect of isoproturon	112 - 113
16.	N, P and K uptake (kg/ha) by wheat grain as affected by residual effect of pendimethalin and metribuzin and direct effect of isoproturon	115 - 116

INTRODUCTION

India has made impressive progress in agriculture during the last three decades, culminating in self-sufficiency in cereals and surplus in vegetable crops, but made tardy progress in oilseeds and pulses. Despite a record production of about 191.1 million tonnes foodgrains, the per caput availability of cereals has inched up by 39 per cent between 1951 and 1995. Contrary to this, per capita availability of pulses declined by 39 per cent over the same period (Rajagopalan, 1996) and availability of oilseeds is also deplorable. Owing to non availability of protein and oil, large poverty stricken population is suffering from maladies of malnutrition (Paroda, 1996). It is, therefore, of utmost importance to increase the productivity of these crops to make oil and protein available to larger population. Rainfed conditions and poor soil fertility in which these crops are grown are the major constraints in their productivity. In addition to these another potent factor that limits the productivity is heavy weed infestation (Chhokar *et al.*, 1995)

Continuous cropping of rice and wheat in sequence in conventional and non-conventional areas has created the problem of nutrients imbalance in feeding zone leading to lower response to applied fertilizers and decline in crop yields. Besides aforesaid problems, this has led to perceptible change in weed flora. Unbeaten weeds *Echinochloa colonum* (L.) Link., *Cyperus rotundus* L. in rice and *Phalaris minor* Retz. and *Avena ludoviciana* Dur. in wheat are rampant and are causing substantial reduction in crops yield if not controlled in time (Pandey *et al.*, 1980). Although losses inflicted in crop yields are variable, an average yield loss

T- 6275

of 15-40% is quite common in rice and wheat. In extreme cases, the loss is hundred per cent. Thus, it is essential to integrate cereal, pulses and oilseed crops in cropping sequence to attain a sustainable crop ecosystem and to keep the trend of production of these crops ascending.

Substitution of soybean in sequence with short to medium duration varieties of wider adoptability with relatively better tolerance to excess as well as low soil moisture stress before wheat bring about improvement in soil fertility and crop productivity (Bansil, 1997). Soybean *per se* is biologically very productive, energy efficient and environmentally more compatible than many conventional crops viz. rice, sorghum and maize in double cropping system with rice and wheat (Sawarkar *et al.*, 1995).

Soybean, both an oilseed (20%) and a pulse crop (over 40% protein), ranks third in oilseed production (4.60 million tonnes) in India with an area of more than 4.57 million hectares, which continues to expand by half a million hectares per annum. However, the average productivity has remained low (1 tonne / ha) as against the world average of more than 1.8 tonnes/ha. Wheat a major *rabi* cereal crop occupies about 24.6 million hectares annually with an average productivity of only 2.7 tonnes per hectare against its yield potential of 5 tonnes per hectare (Economic survey, 1996-97). Of the several factors, crop-weed competition is the most important one responsible for low productivity of the crops. Early slow crop growth and adequate soil moisture provide unique opportunity to weeds to ensconce and exploit the soybean-wheat habitat. The weeds not only divest the crop of vital growth factors viz., nutrients, space, light and moisture but also hinder the germination and growth of crops by liberating the allelo compounds in the soil and thereby resulting in heavy

yield losses ranging from 35 to 55 per cent in soybean (Saraswat and Mishra, 1996; Tiwari and Kurchania, 1990) and 30 to 40 per cent in wheat (Pandey *et al.*, 1992 and Panwar *et al.*, 1993). Thus, it is imperative to device effective control measures to get rid of weed notoriety in soybean-wheat sequence.

Weed control is achieved through judicious management using good crop agronomy and a variety of weed control practices. These may include a range of cultural and physical techniques. In recent past remarkable adaption of potent tool herbicide for destruction of weeds has brought remarkable increase in efficiency of inputs and production of crops.

Pendimethalin and metribuzin are most potent and widely used herbicides in soybean, though they persist in soil depending on the dose, edaphic and agroclimatic conditions (Kulshrestha and Singh, 1992). Therefore, it is note worthy to understand the process of residue build up and its dissipation in soils to advocate ameliorative measures. Similarly isoproturon is also a wide spectrum herbicide for weed control in wheat.

Knowledge on direct and residual effects of herbicide in cropping sequence is of great importance, where succeeding crop follow preceding crop in quick succession and herbicide residues left over may effect the succeeding sensitive crop in rotation (Walsh *et al.*, 1993). Earlier studies carried out by Kulshrestha, *et al.*, 1977; Sharma and Sandhu, 1985; and Saikia, 1997 at different locations, established that atrazine applied to maize had no residual effect on succeeding wheat, oat, peas, berseem, linseed, lentil, radish, chickpea, mustard and turnip, grown in succession. But, the information on residual effect of pendimethalin and metribuzin is meagre in literature.

Keeping the above in mind the present study entitled “**Direct and residual effect of herbicides on soybean-wheat sequence**” was carried out at the Indian Agricultural Research Institute, New Delhi with the following objectives.

1. To measure direct effect of herbicides on crops and weeds.
2. To investigate residual effect of herbicides on succeeding wheat crop.
3. To study the nutrient uptake by crops and weeds.
4. To suggest economically viable weed control measures for crop grown in sequence.

REVIEW OF LITERATURE

An attempt has been made in this chapter to review the available literature pertaining to the direct and residual effect of herbicides on Soybean - Wheat sequence. The reported literature relating to residual effects of herbicides applied to soybean on the weed flora of succeeding wheat crop is very meager and hence major thrust has been made on the work done on weed flora, crop - weed competition, methods of weed control, direct as well as residual effects of herbicides on weeds and crops, herbicide dissipation and persistence in the soybean - wheat ecosystem.

2.1. SOYBEAN

2.1.1 Weed Species : In Madhya Pradesh in Sagar and Jabalpur districts in soybean ecosystem weed species that occur in fields are *Echinochloa crus-galli*, *Panicum maximum*, *Digitaria adscendens*, *Cyperus iria*, *Caesulia axillaris*, *Commelina bengalensis*, *Celosia argentia*, *Eclipta alba*, *Phasalis minima*, *Euphorbia geniculata*, *Corchorus acutangulus* and *Acalypha indica*. The former three grassy weeds are common and constitute near 40 per cent. Among the dicots only *Celosia argentia* is predominant (Kuramawanshi et al., 1995 and Sharma et al., 1995). In Chhattisgarh region monocot weeds viz. *Echinochloa colonum*, *Echinochloa crus-galli*, *Fimbristylis miliacea* and *Cyperus iria* constitute around 74 per cent and of about 26 per cent dicot weeds mainly *Phyllanthus niruri* and *Eclipta alba* appear 80 days after sowing (Chandrakar and Urkurkar, 1993). In Vidarbha region of Maharashtra in

clay soil *Digera arvensis*, *Celosia argentic* and *Euphorbia geniculata* amongst dicot and *Cyperus rotundus*, *Poa annua*, *Denebera reflexa* among monocots are widely prevalent (Patil et al., 1996). At Bangalore in red sandy loam soils the major weed species that were observed in the experimental field were *Cyperus rotundus*, *Digitaria marginata*, *Dactyloctenium aegyptium*, *Echinochloa colonum* among monocots; *Cenebera didyme*, *Acanthospermum hispidum*, *Amaranthus viridis*, *Emilia sanchyfolia*, among dicots in monsoon season while during summer season *Gomphrena decumbens* and *Phyllanthus niruri*, were dominant in soybean fields besides *Cyperus rotundus*, *D. marginata*, *D.aegyptium* and *A. hispidum*. In both the seasons the relative density of weeds was 50 per cent monocots, 35 to 40 per cent dicots and 10 to 15 per cent sedges (Muniyappa et al.,1986). In Haryana, *Echinochloa colonum*, *Trianthema portulacastrum*, *Celosia argentic* were rampant and constituted 52.2, 14.3, and 14.3 per cent respectively, of the total weed flora. Besides, *Digera arvensis*, *Cyperus rotundus*, *Physalis minima* and *Dactyloctenium aegyptium* also occurred (Chhokar et al., 1995). Arya (1995) studied the weed flora in *kharif* season under high and mid hill conditions of north - western Himalayas and reported that *Cyperus rotundus* had maximum frequency in valley (72.7%), mid hill south (76.3%) and mid hill north aspect (73.3%) and occurred in almost all the crop. *Galinsoga parviflora* was most frequent (65.2%) in high hills, but the density/m² and relative dominance were highest of *Oxalis latifolia* in almost all the agroecological situations and in most of the *kharif* crops including soybean. Under rainfed low hill conditions of Nainital in Uttar Pradesh *Echinochloa colona*, *Eleusine indica*, *Digitaria sanguinalis*, *Galinsoga parviflora*, *Oxalis latifolia*,

Cyperus spp. and *Commelina benghalensis* invade soybean (Singh *et al.*, 1995). At Palampur, Rana and Angiras (1996) observed preponderance of *Cyperus* spp. (59.8%), *Panicum dichotomiflorum* (21.4%) and *Aeschynomene indica* (1.6%) besides small population of *Ageratum conyzoides* in soybean. At Ludhiana (Punjab) *Trianthema portulacastrum*, *Digera arvensis*, *Eleusine aegypticum* and *Cyperus rotundus* commonly occurred. *Euphorbia hirta*, *Amaranthus viridis*, *Digitaria sanguinalis* and *Bulbostylis barbata* also invade but their density remain low (Singh *et al.*, 1995). At New Delhi important weed species that plague soybean are *Digitaria adscendens*, *Trianthema portulacastrum*, *Digera arvensis*, *Dactyloctenium aegyptium*, *Phyllanthus niruri* and *Cyperus rotundus*. Of these former two are regrant (Pandey *et al.*, 1996). At Jabalpur (M.P.) Tiwari *et al.* (1996) observed dominance of *Echinochloa crus-galli*, *Digitaria adscendens*, *Cynodon dactylon* among grasses, while *Commelina communis*, *Cyanotis axillaris*, *Phyllanthus fraternus*, *Eclipta alba*, *Alysicarpus vaginalis* and *Corchorus olitorius* among the broad leaf weeds in soybean-wheat cropping sequence. But *Echinochloa crus-galli* and *Cyperus iria* were opulant. In Bundelkhand region of Uttar Pradesh, *Echinochloa colona*, *Dactyloctenium aegyptium*, *Euphorbia hirta*, *Cyperus rotundus*, *Digera arvensis* and *Phyllanthus niruri* are prevalent in soybean - wheat cropping sequence (Tiwari *et al.*, 1994).

2.2. CROP-WEED COMPETITION

2.2.1. Critical period of crop-weed competition : Durigan *et al.* (1983) reported that in soybean the critical period varied with seasons, soil and climate as well as types of weed species that infest the crop. Singh

and Kolar (1994) noted maximum reduction in seed yield (18%) when weeding delayed from 30 to 45 days after sowing (DAS) indicating this period as most critical for crop-weed competition. Chhokar *et al.*, (1995) found in rainy season weed free environment between 28 to 40 DAS imperative to produce yields equivalent to season-long weed free plots and indicated if the chemical means are to be adopted for control of weeds, the herbicides should have residual effect so as to last atleast upto the end of this critical period. Ponnuswamy *et al.*, (1996) noted first 15 to 60 the most critical period of crop-weed competition, while Varshney (1989) found first 20 to 40 DAS most vital for weed removal. Similar was the observation of Maniyappa *et al.*, (1986) they recorded significant reduction in the yield when first weeding was delayed upto 40 to 60 days. Soybean yielded more than 1.4 t/ha when weeds are absent 20 DAS or when plots were kept free from weeds between 20 and 40 DAS (Tjitorsemito, 1991).

2.2.2. Competition for nutrient : Unchecked weed growth depletes nearly 35.9, 10.6, 56.1 and 54.1 kg each of N, P, K and Ca/ha, respectively (Singh and Mani 1977). Chhokar *et al.* (1997) observed that weeds till 60 DAS depleted 52.2 kg N and 9.3 kg K /ha. Singh and Sharma (1989) noted that grasses in weedy check plots removed 52.66, 10.66, 63.74 kg/ha N, P and K, whereas broad leaved weeds removed only 4.81, 0.78, 2.67 kg/ha of N, P and K respectively. Pandey *et al.* (1981) reported that in *kharif* weeds remove 41.69, 19.97 and 66.77 kg N, P and K /ha besides 117.6, 44.8, 189.7 and 4765 g each of Zn, Cu, Mn and Fe/ha respectively.

2.2.3 Competition for moisture : Munger (1986) found higher photosynthetic rates in *Abutilon theophrasti* Medic (Velvet leaf) than those of soybean under normal water supply, whereas under water stressed condition it declined sharply in former than in latter and also indicated that reduction in yield of soybean was due to interspecific competition for limited growth resources than water. Moderately heavy infestation of *Sorghum halepense* reduces soybean yields by 59 per cent where available soil moisture becomes critical (Williams and Hayes, 1982). Young (1981) reported that the competitive effects of *Agropyron repens* was reduced with plentiful supply of water in soybeans. But Cordes and Bauman (1984) did not find *Ipomoea hederacea* more competitive at reproduction stage of soybean for light and moisture than other growth factors.

2.2.4. Competition for light : Cordes and Bauman (1984) did not find any effective competition for light during vegetative stage at any density of *Ipomoea hederacea* and soybean. On the contrary Thomas and Lindert (1986) noted that fast growing weeds *Amaranthus spinosus*, *A. hybridus*, *Nicandra physalodes* and *Eleusine indica* had a marked effect on soybean yield mainly due to competition for light. Regnier and Stoller (1989) reported that *Xanthium strumarium* had more leaves within the soybean canopy than that of *Datura stramonium* and *Abutilon theophrasti* at each light level.

2.2.5. Effect of weed competition on soybean yield : Muniyappa *et al.* (1986) reported that seed yield was reduced by 53 per cent due to weed competition in unweeded control as compared to weed free plots which received three weedings 20, 40, and 60 DAS (3804 kg/ha). They

also indicated that effect of weeds on crop yield reduction was visible in monsoon (71%) than in summer (35%). Varshney (1989) noted 55 per cent reduction due to unchecked weeds. At Jabalpur, Jain and Tiwari (1992) observed reduction in seed yield to the tune 43%, when soybean was dominated by grass weeds. Where-as yield reduction was between 0.7 to 17 per cent only when herbicides were applied to reduce the weed menace. Singh and Singh (1992) made observation if 65 lakh weeds dominated by *Echinochloa colounm* (75%) compete till the harvest of the crop a reduction in yield occurs by 67 per cent. Singh and Bajpai (1994) noted that in Chhattisgarh region of Madhya Pradesh season-long association of weeds with soybean, at a density of 673 plants/m² resulted in yield loss of 16.9 q/ha. Singh and Kolar (1994) at Ludhiana (Punjab), found one-fourth (30.8%), reduction in crop yield due to weed competition for initial 4 weeks and more than half with 6 weeks (71.6%). Kurmawanshi *et al.* (1995) reported that in presence of grassy, broadleaf and minor weeds at a relative density of 62, 31 and 7 per cent, respectively, yield reduction was 46.5 per cent when weeds were allowed to grow during critical growth stage. Singh *et al.* (1995) under rainfed low hill condition of Uttar Pradesh did not find noticeable reduction in yield at lesser densities of 25-36 plants/m² but recorded higher reduction in yield (71%) at density of 191 plants/m². Jain and Tiwari (1995) found significant loss in crop yield (77%) when sown without killing the first flush of weeds. But percentage reduction in yield scale down to 61 per cent when sown after killing first flush of weeds and 48 per cent after killing first and second flushes of weeds. At IARI, New Delhi Pandey *et al.* (1996) noted significant reduction in yield (84%) with 10, 13, 49, 9 and 8 plants/m² of *Digeria*

arvensis, *Trianthema portulacastrum*, *Digitaria adscendens*, *Dactyloctenium aegyptium* and *Cyperus rotundus*, respectively, and they also estimated a loss of 0.46 kg of soybean grain per kilogram of weeds on dry weight. Chhokar *et al.* (1996) observed 48.2 and 63 per cent reduction in seed yield at weed densities of 239 and 360 plants/m² respectively. At Palampur, Rana and Angiras (1996) reported that competition between soybean and weeds viz. (*Cyperus rotundus*, *Panicum dichotomiflorum*, *Aeschynomene indica* etc.) brought about 75 per cent reduction in yield. In Minnesota, Young *et al.* (1982) found 19 and 55 per cent reduction in soybean yield at 520 and 910 shoots/m² of *Agropyron repense*, respectively, but insignificant reduction at 96 and 160 shoots/m². Wiley *et al.* (1984) reported that *Abutilon theophrasti* at 40 plants/m² lowered yield by 50 per cent in wide row crops (76 cm) and 41 per cent in narrow row crops (25 cm). In Nebraska, Hayden and Martin (1986) noted 6, 22 and 33 per cent reduction in soybean yield at 2, 6 and 12 plants/11.3 m long row of *Abutilon theophrasti* but 11, 23 and 33 per cent, when it competed for 6, 8 weeks and full season respectively. Shurtleff and Coble (1985) reported that *Amaranthus retroflexus* at 16 plants/10m long row reduced soybean seed yield by 22 per cent whereas Hayden and Martin (1986) noted 11, 15 and 22 per cent reduction with 2, 6 and 12 plants/11.3 m long row.

2.3 METHODS OF WEED CONTROL

2.3.1 Manual weeding : Controlling weeds by hand reduces the weed growth and result in higher grain yield (Jain *et al.*, 1988 and Tiwari *et al.*, 1988). Shishodia *et al.* (1988) found hand weeding exclusively

better than herbicides both pre or post emergence for controlling weeds in rainfed low hill conditions of Uttar Pradesh. Chandrakar and Urkurkar (1993) registered higher grain yield (13.13q/ha) with two hand weeding (30 & 50 DAS) as compared to sole or when herbicides were supplemented with one hand weeding in clay soil of Chhathisgarh region. Singh *et al.* (1992) and Chhokar *et al.* (1991) found highest weed control efficiency with manual weeding (at 30 and 45 DAS) and when pendimethalin was supplemented with one hand weeding or hoeing at 30 DAS. At New Delhi, Pandey *et al.* (1996) recorded highest yield of soybean (16.2 q/ha) with two hand weeding and it proved superior to herbicide treatments. Nimje (1996) reported that hand weeding provided a weed free environment in the early stages to some extent but it was not economically viable because of low return per rupee investment. Kurmawansi *et al.* (1995) found at least three hand weeding essential to get rid of weed growth but it proved more expensive than herbicides.

Manual weeding provides excellent control of monocot and dicot weeds in soybean-wheat sequence (Tewari *et al.*, 1992). Tiwari *et al.*, (1996) found maximum yields of both soybean and wheat with hand weeding in a soybean- wheat cropping system at Jabalpur

2.3.2. Chemical Weed Control

2.3.2.1. Effect of pendimethalin on weeds : Pre-emergence application of pendimethalin or fluchloralin or oxadiazon has been found to be effective in controlling almost all the weeds associated with soybean at Jabalpur (Lokras *et al.*, 1985). Singh and Singh (1987) reported pendimethalin more efficient than methabenzthiazuran in paralysing the weed growth in soybean at Pantnagar. At Mandsaur (M.P.) pendimethalin at 1.5 kg/ha

reduced the weed biomass and caused more increase in yield even to that of hand weeding (Jain *et al.*, 1991). Shekara and Nanjappa (1993) also found pendimethalin very effective in reducing weed menace in soybean. Tiwari *et al.* (1994) observed pendimethalin and alachlor at 1.5 kg that equally efficient in curtailing the weed biomass production in Bundelkhand region of Uttar Pradesh.

Pendimethalin application at pre-sowing brought about 93 to 100 per cent control of *Abutilon theophrasti* both under narrow and widely spaced soybean whereas at pre-emergence only 76 to 99 per cent (Watteyne and Burnside, 1983). Hunt and Arnold (1981) observed 58 to 85 per cent control of *Sorghum halepense* with pre-sowing application of pendimethalin at 1.68 kg/ha, whereas Konstantinovic *et al.* (1984) did not find any control at 6 kg/ha in chesnut meadow soil. Pandey *et al.* (1996) reported that pendimethalin and fluchloralin each at 1.0 kg/ha gave better control of *Trianthema portulacastrum*, *Digitaria adscendens*, *Dactyloctenium aegyptium* and *Cyperus rotundus* but failed to control *Digera arvensis* at IARI, New Delhi. At Hisar, Chhokar *et al.* (1996) found excellent control of weed species like *Echinochloa colonum*, *Trianthema portulacastrum* and *Celosia argentia* with trifluralin and pendimethalin each at 1.0 kg/ha, when both were supplemented with one hand hoeing than their separate application.

2.3.2.2 Effect of pendimethalin on yield attributes : At Jabalpur (M.P.) Lokras *et al.* (1985) recorded higher values of yield attributes like branches/plant, pods/plant and 1000 grain weight with pendimethalin, fluchloralin, metalochhor and hand weeding than that of unweeded check. Tiwari *et al.* (1988) found increase in number of seeds/plant. Singh *et al.* (1994)

recorded with pendimethalin at 0.5 kg/ha supplemented with one hand weeding 40 DAS higher number of pods and thousand seed weight as compared to oxyfluorfen and weedy check. Pandey *et al.* (1996) registered increase in plant height, grain weight/pod and 1000 grain weight with pendimethalin and fluchloralin as compared to weedy check. Patil *et al.* (1996) recorded higher numbers of pods/plant with application of pendimethalin or oxadiazon than plots without herbicides.

2.3.2.3. Effect of pendimethalin on growth and yield : Dubey *et al.* (1984) reported that pendimethalin at 1.0 kg/ha supplemented with one hand weeding gave highest soybean seed yield (2.3 t/ha). Similarly Dubey *et al.* (1988) concluded from their study that pendimethalin alone at 1.0 kg/ha gave remarkable control of weeds and caused maximum increase in yield. Singh and Singh (1987) noted significantly higher grain yield with pendimethalin (2.0 to 3.0 kg/ha), fluchloralin and hand weeding twice than methabenzthiazuron (1.0 to 2.0 kg/ha) and weedy check. Jain *et al.* (1991) recorded 58 per cent higher grain yield with pendimethalin as compared to weedy check (9.89 q/ha). Pandey *et al.* (1996) reported that in weedy check, grain yield was only 2.6 q/ha whereas in pendimethalin it was 5.5 q/ha. There was an increase of 111.5 per cent. Chhokar *et al.* (1996) recorded markedly higher yield with pendimethalin combined with 2 hand hoeing 20 and 35 DAS or 2 hand weedings 20 and 40 DAS and both yielded comparable to weed free check (33.3 q/ha).

Boilick *et al.* (1988) reported that incorporation of pendimethalin at 1.1, 1.7, 2.2 kg/ha delayed emergence and injured soybean seedlings but inhibitory effect did not influence seed formation and yield of soybean. Higgins *et al.* (1985) found less than 20 per cent plant injury due to

pendimethalin when it was applied as pre-emergence at 1.12 or 2.24 kg/ha. But Doublias (1990) reported severe phytotoxic symptoms in soybean at 1.65 kg/ha.

2.3.2.4 Effect of pendimethalin on nutrients content and uptake by soybean : Shekara and Nanjappa (1993) reported that pendimethalin facilitated an increase in N, P and K uptake to the extent of 83, 71 and 209 per cent respectively, against weedy check in which depletion was only 49.5, 3.45, 10.15 kg each of N, P and K/ha respectively. Singh *et al.* (1994) reported that pendimethalin at 0.5 kg + 1 hand weeding 40 DAS resulted in similar uptake of N, P and K to that of hand weeding twice 30 and 60 DAS. At Hisar, Chhokar *et al.* (1997) found reduction in the depletion of major nutrient by weeds (barnyard grass, horse purslane, quail grass) in pendimethalin (1.0kg/ha) followed by one hand hoeing (35 DAS) and concomitant increase in N (86.2 kg) and P (9.0 kg/ha) uptake by the crop over weedy check. Chin (1991) also found increase in NPK content and total uptake of these nutrients by soybean grain and straw with pendimethalin alone or its combined application with imazethapyr.

2.3.2.5. Effect of metribuzin on weeds : In a trial at Jabalpur Lokras *et al.* (1985) noted that pre-emergence application of metribuzin at 0.5 kg/ha reduced the weed population and biomass significantly over bentazon and unweeded check up to 50 DAS. In Wisconsin, studies of Halstead and Harvey (1986) reveals that metribuzin at 0.21 to 0.43 kg/ha controls weeds sufficient enough to effect increase in crop yield. Similarly Singh *et al.* (1991) noted acceptable control of weeds with metribuzin at 0.5 kg/ha and found better than other herbicides. Agrawal *et al.* (1995)

observed metribuzin most potent in reducing weed density of seven most damaging weeds *Echinochloa crus-galli*, *Caesulia axillaris*, *Eragrostis* spp., *Phyllanthus niruri*, *Cyperus rotundus*, *Cyperus iria* and *Ageratum conyzoides*. Vencill *et al.* (1995) found effective control of sicklepod (*Cassia obtusifolia*) and morningglory (*Ipomoea* spp.) with metribuzin pre-broadcast than applied pre-banded.

Jain *et al.*, (1988) observed the efficacy of herbicides in controlling weeds in the order of oxadiazon > fluchloralin > metribuzin > fluazifop-butyl. Whereas, Tiwari *et al.* (1994) found alachlor, pendimethalin and metribuzin identically equal in effecting decrease in weed population. Singh and Singh (1992) observed fluchloralin at 1.0 kg/ha, metribuzin at 0.75 to 1.0 kg/ha and acifluorfen at 2.0 kg/ha highly effective in reducing the weed population and dry weight of weeds.

Hamill *et al.* (1995) reported that one cultivation combined with metribuzin 0.42 kg/ha not only provided effective control of weeds but also maintained reliable economic return over the years. Where as Etheridge *et al.* (1996) found with the combinations of imazaquin + metribuzin average 90 per cent control of sicklepod (*Senna obtusifolia*) 6 weeks after planting.

2.3.2.6. Effect of metribuzin on growth, yield attributes and yield :

Pre-sowing incorporation of pendimethalin and trifluralin each at 1.68 kg/ha significantly reduce the crop stand but pre-emergence applied herbicides alachlor at 3.36 kg/ha linuron at 1.12 kg/ha and metribuzin at 0.42 kg/ha have no adverse effect on soybean and give effective control of weeds (Melville *et al.*, 1979). Metribuzin at 0.8 kg/ha (pre-emergence) and fluchloralin at 0.75 kg/ha (PPI) are very potent herbicide and have longer

effect but former adversely affects soybean (Rafael *et al.*, 1976). Lokras *et al.* (1985) reported that metribuzin at 0.5 kg/ha at pre-emergence, hand weeding once and twice effected similar increase in branches/plant, pods/plant, seed index, crop dry weight and finally grain yield. Jain *et al.* (1988) recorded with metribuzin at 0.5 kg/ha higher seed per plant, 100 seed weight, branches/plant, pods/plant, seeds/pod and grain yield. Increase was comparable to oxadiazon and fluchloralin each at 1.0 kg/ha. Jain and Tiwari (1992) recorded comparatively higher increase in filled pods/plant, seed yield/plant and 1000 grain weight with metribuzin at 0.5 kg/ha compared to oxyfluorfen and fluchloralin but found equal to oxadiazon at 1.0 kg/ha.

Dubey, *et al.* (1984) registered significantly higher grain yields with fluchloralin (2.26 t/ha) and metribuzin (2.11 t/ha). Tiwari *et al.* (1988) noted increase in seed yields with herbicides including metribuzin at 0.35 kg/ha over control values of 3467 kg/ha. The increase was from 3482-3652 kg/ha. The maximum increase was caused by methabenzthiazuron (3905 kg/ha) at 1.0 kg/ha. Whereas, Singh *et al.* (1991) recorded highest grain yield (19.53 q/ha) with metribuzin at 0.5 kg/ha. In Chhattisgarh region Singh and Singh (1992) noted effective control of weeds and increase in soybean yield with fluchloralin at 1.0 kg/ha followed by metribuzin at 0.75 kg/ha and linuron at 1.5 kg/ha. Tiwari *et al.* (1994) reported that metribuzin at 0.5 kg/ha at pre-emergence gave sufficiently enough control of weeds to cause an increase in yield comparable to hand weeding twice (6.24 q/ha).

2.3.2.7. Effect of metribuzin on nutrient uptake : Jain *et al.* (1995) reported that oxadiazon (1.0 kg/ha), metribuzin (0.5 kg/ha) and fluchloralin

(1.0 kg/ha) resulted in higher uptake of N, P and K by soybean and loss of these nutrients was only marginal under these treatments. But soybean with unchecked weed growth depleted only 93.0, 7.4 and 15.0 kg/ha each of N, P and K, respectively. Singh and Nepalia (1997) observed that in metribuzin treated plots crop removed 111, 12 and 56 kg/ha each of N, P and K but when supplemented with 1 hand weeding 30 DAS removal was 135, 14 and 76 kg/ha each of N, P and K respectively. Whereas in weed infested plots removal was only 21, 2 and 11 kg/ha N, P and K respectively.

2.4 WHEAT

2.4.1. Weed Species : It is established from weed survey studies of wheat fields that in Punjab nearly 52 weed species infest the wheat and of which 6 are monocot and 46 dicot, belonging to 16 families. *Phalaris minor*, *Avena ludoviciana*, *Melilotus indica*, *Chenopodium album* and *Medicago denticulata* are most common. Besides *Poa annua*, *Polypogon monspeliensis*, *Lolium temulentum*, *Silene conoideae*, *Rumex dentatus*, *Lathyrus aphaca* and *Lepidium sativa* also occurs. Among grassy weeds *Phalaris minor* and *Avena ludoviciana* are rampant in almost all districts. However in some parts of the state *Cirsium arvense* and *Convolvulus arvensis* are dominant (Singh et al., 1993). In Hisar, Singh (1995) surveyed distribution pattern of weeds in wheat field in all the districts and observed the dominance of grass weeds *Avena ludoviciana*, and *Phalaris minor*, *Polypogon monspeliensis* in the eastern zone, *Chenopodium album*, *Asphodelus tenuifolius*, *Trigonella polycerata* and *Fumaria parviflora* in western zone, *Medicago denticulata*, *Rumex maritimum*, *Cirsium arvense*, *Melilotus indica* and *Convolvulus*

arvensis had in the eastern zone (lightsoil) and *Sisymbrium irio*, *Euphorbia dracunculoides*, *Sapponaria vaccaria*, *Desmostachya bipinnata*, *Zizyphus rotundifolia* and *Aerva javanica* in western zone. In Kashmir valley, from floristic analysis of rabi crop weeds it is established that maximum number of weeds numbering around 78 are associated with wheat crop with the dominance of Poaceae (13 sp.), followed by Brassicaceae (11 sp.), Asteraceae and Fabaceae (9 sp. each). Among the weeds of wheat fields, frequency of *Cynodon dactylon* (100%), *Lotus coruiculatus* (50%), *Sorghum halepense* (42%), *Convolvulus arvensis* (50%), and *Poa annua* (50%) is higher as compared to other weeds (Zafar Reshi et al., 1987) At Jharnapani in Nagaland, *Phalaris minor*, *Polygonum spp.*, *Fumaria parviflora*, *Melilotus alba*, *Anagallis arvensis*, *Vicia Sativa*, *Vicia hirsuta* and *Setaria gluaca* are the predominant weeds (Dwivedi and Patel, 1987) At Palampur (HP), the dominant weed species that invade the crop are *Phalaris minor*, *Avena fatua*, *Lolium temulatum* and *Vicia sativa* (Angiras and Sharma, 1993), whereas under high hill temperate zone weed species particularly *Amaranthus viridis*, *Polygonum alatum*, *Digitaria sanguinalis* and *Galinsoga parviflora* infest the wheat crop severely (Sekhar et al., 1989). Pandey et al. (1996); and Sharma and Pandey (1997) reported preponderance of *Phalaris minor*, *Avena fatua* among the grass weeds and *Fumaria parviflora*, *Chenopodium album*, *Melilotus indica* and *Anagallis arvensis* among the broad-leaved weeds in wheat in the ascending order of intensity at New Delhi. Besides, *Convolvulus arvensis* also occurs in small numbers. Under low hill and valley Situation of Utter Pradesh, *Chenopodium album*, *Oxalis corniculata*, *Galinsoga parviflora*, *Stellaria media*, *Melilotus indica* and *Polygonum plebanum* are

the ruling weeds in the experimental field (Singh, 1996). At Varanasi (U.P.), the dominant weed species that plague wheat crop are *Avena fatua* (11.5%), *Phalaris minor* (17%), *Chenopodium album* (16.5%), *Melilotus indica* (52%), *Cynodon dactylon* (16.1%) and *Cyperus rotundus* (17.3%) (Singh and Reddy, 1988). In Madhya Pradesh at Sehore, Tiwari (1986) observed preponderance of *Chenopodium album*, *Melilotus alba*, *Sonchus arvensis*, *Argemone mexicana* and *Vicia sativa* in irrigated wheat, while *chenopodium album*, *Convolvulus arvensis*, *Launea aspeniifolia*, *Sonchus arvensis* and *Argemone mexicana* in rainfed wheat. At Jabalpur, Tiwari and Bisen (1985) noted the dominance of *Phalaris minor* (615/m²), followed by *Chenopodium album* (146), *Portulaca oleracea* (80), *Trifolium flagiferum* (48), *Melilotus spp.* (43), *Rumex dentatus* (10) *Solanum nigrum* (5) and *Paspalum distichum*. At Anand in Gujarat, Patel and Upadhyay (1990) found dominance of *Cyperus rotundus*, *Cynodon dactylon*, *Digitaria adscendens*, *Eragrostis tenella* among the monocots and *Chenopodium album*, *Digera arvensis*, *Chenopodium murale*, *Portulaca oleracea*, *Boerhavia diffusa*, *Tribulus terrestris* and *Melilotus alba* among the dicots in wheat in irrigated condition in loamy sand soil. At Akola (Maharashtra), the dominant weed species that occurs in wheat field in descending order are *Cyperus rotundus* 36.5%, *Panicum spp.* 18.8%, *Cynodon dactylon* 8.2, *Parthenium hysterophorus* 7.0%, *Digera arvensis* 6.1%, *Amaranthus sp.* 5.7% and *Cardiospermum helicarpium* 4.8% (Jadhao and Nalamwar, 1993). Weed flora survey was made during *kharif* and *rabi* season in Telangana region of Andhra Pradesh by Kondap *et al.* (1987). They reported that 41 weed species were associated with wheat, which accounted 28% of the total weeds of the area. The dominant

weeds were *Lagasea mollis*, *Tridax procumbens*, *Chloris barbata*, *Dactyloctenium aegyptium* and *Panicum* sp. At Bhubaneswar, Orissa, 15 weed species belonging to 15 genera and 7 families infest the crop in moderately acidic sandy loam soil. *Cynodon dactylon*, *Dactyloctenium aegyptium*, *Digitaria ciliaris*, *Echinochloa colonum*, *Eleusine indica*, *Paspalum scrobiculatum*, *Cyperus rotundus* *Fimbristylis miliacea* among the monocots and *Acanthospermum hispidum*, *Ageratum conyzoides*, *Cleome viscosa*, *Commelina bengalensis*, *Croton sparsiflorus*, *Physalis minima* and *Phyllanthus niruri* among the dicots are common in wheat crop (Panda et al., 1996).

Tiwari et al. (1996) observed dominance of *Chenopodium album*, *Melilotus alba*, *Anagalis arvensis*, *Phalaris minor*, *Digitaria adscendens*, *Medicago hispida*, *Medicago denticulata*, *Chicorium intybus*, *Indigofera cordifolia* and *Cyperus rotundus* when wheat was preceded by soybean. While Nandal and Singh (1994) found preponderance of *Phalaris minor*, *Lolium temuletum*, *Vicia sativa* and *Avena fatua* when wheat was followed by rice.

2.4.2. Crop-weed competition

2.4.2.1 Critical period of crop-weed competition : Saeed et al. (1987) reported that for obtaining satisfactory yield level of wheat, the crop needed weed free condition for initial 30 to 45 days but it varied in wheat crop depending upon agroecosystem (i.e. irrigated or rainfed) type and intensity of weed and their time of occurrence. In Bangladesh Rahaman et al. (1990) obtained high yield of wheat when weeds were present for no longer than 5 DAS or when plots were kept weed free for at least 30 DAS, signifying a critical period for weed management between 2 to

4 week after sowing when crop was dominated by *Chenopodium album*, *Digitaria sanguinalis*, *Cynodon dactylon*, *Dactyloctenium aegyptium* and *Oldenlandia corymbora*. While Alam *et al.* (1994) registered maximum loss in seed yield when weeding was delayed from 35 to 50 DAS indicating this period the most critical for crop-weed competition in wheat cultivar Balaka in Bangladesh. In Gujarat, Barevadia *et al.*, (1993) reported that wheat crop could tolerate weed competition until 30 DAS without significant reduction in grain yield and remarkable reduction when weeds were allowed to grow between 30 to 45 DAS. At Jorhat (Assam) Gogoi *et al.* (1993) also observed that in rainfed wheat unchecked weed growth or weed free condition for 15 DAS did not cause significant reduction or increase in crop yield but increasing the weed free period to 45 or 60 DAS resulted in higher grain yield comparable to that of season-long weed free condition and finally reported that the period between 15 to 45 DAS was most critical.

2.4.2.2 Competition for nutrients : Weeds usually absorb mineral nutrient faster than many of the crop plants and accumulate them in their tissues in relatively larger amounts and therefore, derive greater benefit (Gupta, 1984). Shahi (1978) reported that *Chenopodium album* removed on an average more than 32 kg N/ha in rainfed wheat in India. At Hisar Yadav *et al.* (1986) found *Phalaris minor* among the different weeds exerted maximum pressure and alone depleted 47.4 kg N, 8.4 kg P and 47.0 kg K/ha whereas dicot weeds *Chenopodium album*, *Lathyrus aphaca* and *Vicia sativa* depleted 10.0, 0.7, 9.7, 10.9, 4.6, 5.8, and 5.2, 2.8, 3.5 kg NPK/ha, respectively. Bhagwati *et al.* (1989) estimate revealed that the removal of nitrogen by wild oats 180

plants/m² was 31.3 kg N/ha whereas it was only 11.9 kg N/ha by total weed density of 282 plants/m² of dicots. Malik *et al.* (1995) reported that an intense growth of mainly dicot weeds deprived the crop of about 58 kg N, 16 kg P and 88 kg K/ha. In the same year Malik *et al.*, noted that a weed free crop removed only 126.3 kg N, 30.7 kg P and 226.9 kg K/ha as against 129.4, 28.7 and 188.6 kg N,P and K/ha, respectively, by weed infested crop.

2.4.2.3 Competition for moisture : Weed-crop competition for soil moisture is particularly apparent in arid and semi arid areas where it is already limited (Gupta, 1993). Sahi (1978) determined the consumptive use of water of *Chenopodium album* as 550 mm as against 479 mm of wheat crop. He stated further that weeds removed moisture evenly from 40 to 90 cm soil depth while the major uptake of moisture by wheat was limited to the top 15 cm of soil. Bowler (1975) reported that wild oats had greater water use efficiency as compared to wheat. In arid zone, Lof (1976) found annual grass *Hordeum murinum* which is economical in its water use was suppressed by *Phalaris minor* which consumed most available water and nitrogen. Wimschneider *et al.* (1990) observed disproportionately higher competition between wild oats and spring wheat under higher fertility levels and the effect was more acute in the case of temporary drought. From Ludhiana (Punjab) Singh and Kolar (1992) reported that wheat utilised nitrogen more efficiently than wild oats under limited moisture condition whereas under normal irrigation the reverse was true, implying that the advantage of weed control measures was more under normal irrigation than under limited irrigation.

2.4.2.4 Competition for Light : Light competition may commence very early in the crop season if a dense weed growth smothers the crop-seedlings (Gupta, 1984). Gill and Mehra (1981) found that two or three gene dwarf genotypes proved very favourable for the growth and development of *Phalaris minor* resulting in one and half to twice the weight of weeds growing in association with tall cultivars of wheat at harvest and this increase in dry matter was attributed due to higher light transmission by the semi-dwarf and dwarf wheat cultivars.

2.5 METHODS OF WEED CONTROL

2.5.1. Manual weeding : At Akola, Jadhao and Nalambar (1993) registered exclusively higher grain yield (33.05 q/ha) with two handweeding (30 & 60 DAS) in irrigated wheat owing to significant reduction in dominant weeds *Cyperus rotundus*, *Panicum spp.* and *Cynodon dactylon*. Vaishya and Kumar (1993) recorded about 38 per cent extra yield over weedy check with two hand weeding given 20 and 40 DAS. Lal *et al.*, (1996) found highest weed control efficiency (53%) with manual weeding and black polythene covering. At IARI Pandey *et al.* (1996) recorded lower weed population and weed dry weight in hand weeding and markedly higher yield as compare to single or combined application of herbicides. Singh (1996) observed that hand weeding twice (30 and 45 DAS) and pendimethalin were more efficient in reducing the weed growth. The former caused 72 per cent and latter 76 per cent reduction in weed growth respectively. Contrary to this, Angiras and Sharma (1993) found hand weeding ineffective when grassy weeds like *Phalaris minor*, *Avena fatua* and *Lodium temulantum* were present in wheat. At Ludhiana (Punjab) Brar and Walia (1993) also found hand weeding ineffective in curbing

Phalaris minor population as compared to herbicides because of morphological similarity. Sharma and Pandey (1997) observed hand weeding effective during early stages but ineffective against late emerging weeds in the season.

2.5.2. Chemical weed control

2.5.2.1. Effect of isoproturon on weeds : Porwal and Gupta (1987) reported that isoproturon at 0.75 kg/ha as post emergence 30 DAS gave effective control of annual broad leaved weeds *Chenopodium album*, *C. Murale*, *Spergula arvensis*, *Fumaria parviflora*, *Melilotus indica* and grassy weeds *Phalaris minor* and *Avena fatua* but failed to control perennial broad leaved weed *Convolvulus arvensis* at Udaipur. Sekhar *et al.* (1989) recorded under high hill temperat zone of H.P. with post emergence application of isoproturon at 1.25 kg/ha lower density of major weeds *Amaranthus viridis*, *Polygonum barbatum*, *Digitaria sanguinalis* *Galinsoga parviflora* to the tune of 44, 37, 73 and 50 per cent, respectively. At Jabalpur , Tiwari *et al.* (1988) got excellent control of *Phalaris minor*, *Chenopodium album*, *Indigofera sp.*, *Medicago denticulata*, *Rumex dentatus* and *Sonchus arvensis* with pre-emergence application of isoproturon at 1.0 kg/ha, but when it was applied at same rate as post emergence controlled only *Phalaris minor*, *Chichory intybus*, *Rumex dentatus* and *Sonchus arvensis*. At Hisar, Panwar *et al.* (1988) in their studies found enough control of pre-dominant weeds *Chenopodium album*, *Phalaris minor* and *Avena ludoviciana* and increase in crop yield with isoproturon and it proved better than dicamba. At Luchiana (Punjab) Brar and Walia (1993) observed isoproturon at 0.75 - 0.94 kg/ha and metoxuron at 1.0, 1.2 and 1.5 kg/ha equally effective and comparable

with recommended application of isoproturon at 0.94 kg/ha after first irrigation with respect to weed control potential and grain yield increase as these values were at par with each other. Walla *et al.* (1996) noted the efficacy of herbicides in the order of tralkoxydim 0.35 kg > isoproturon 0.56 kg > diclofop-methyl 1.0 kg/ha against wild oats applied as post emergence.

Sharma and Pandey (1997) recorded significantly lower fresh weight of both Haryana and Delhi biotypes of *Phalaris minor* at 1.5 kg/ha applied either as pre or post emergence. But the magnitude of decrease in plant height and fresh weight of Haryana biotype was comparatively lesser than that of Delhi biotype.

Singh *et al.* (1993) and Panwar *et al.* (1995) found isoproturon more effective against *Phalaris minor* than tralkoxydim and got excellent control of weeds with combined application of isoproturon at 0.5 kg + tralkoxydim at 0.20 kg/ha. Panwar *et al.* (1993) recorded significant reduction in weed density of *Phalaris minor* (small canary grass) and *Chenopodium album* (lambs quarter) as well as total weed biomass with mixtures of isoproturon at 0.75 kg + fluroxypyr at 0.15 or 0.20 kg/ha and potential control of wild oats.

2.5.2.2. Effect of isoproturon on growth, yield attributes and yield:

In silty clay calcareous soil at Pusa (Bihar), application of isoproturon 30 DAS, caused substantial improvement in the number of effective tillers/m², length of ear, weight of ear, grains/ear, test weight and grain yield of wheat (Singh *et al.*, 1989). Malik *et al.* (1989) observed beneficial effect of isoproturon alone or with surfactant on effective tillers/m row length and grain yield in sandy loam soil at Hisar. Satao and Podole

(1994) found pre-emergence isoproturon at 1.0 kg/ha equivalent to isoproturon 1.0 kg/ha + 1 hand weeding (25 DAS) in respect of functional leaves/plant, leaf area/plant 40 DAS and higher number of effective tillers/m row length at harvest. On the contrary, Dwivedi *et al.*, (1996) did not find any beneficial effect of isoproturon alone or in combination with 2,4-D on plant height and number of tillers/m², but observed significant increase in the yield due to marked reduction in weed biomass in Chhattisgarh region.

Kumar and Singh (1997) reported that application of isoproturon at 1.0 kg/ha 28 DAS caused increase in grain yield to the tune of 92 per cent (47.27 q/ha) over weedy check (24.56 q/ha) and increase was lower only by 10 per cent than that of weed free check (Naik *et al.*, 1997). In Jammu region, post emergence (30-35 DAS) spray of isoproturon at 0.75 kg/ha alone or in combination with 2,4-D (0.5 kg/ha) and nitrogen in two or three splits produced in 2.3 to 2.4 times higher grain yield than weedy check (Azad and Singh, 1997). Bhagwati *et al.* (1989) observed at lower population level of 180 plants/m² of wild oats, markedly lower response to added nitrogen (3.9 kg grain/kg N), as compared to broad leaved weeds + wild oats (30.4 kg/ha N) and remarkable lower than broad leaved weeds of 282 plants/m² (53.6 kg/kg N). Contrary to this, Sharma and Pandey (1997) did not find effective control of weeds and significant increase in yield (25.0 q/ha) over weedy check (28.0 q/ha) when isoproturon was applied before first irrigation. In the year 1996 Pandey *et al.*, registered 12 per cent increase in grain yield with pre-emergence application isoproturon.

2.5.2.3. Effect of isoproturon on nutrient uptake : At Hisar Bhagwati *et al.* (1989) reported that in weedy check wheat removed 41.0 kg N/ha as compared to 50.5 kg N/ha where weeds growth was arrested with sole application of isoproturon at 1.0 kg/ha (post) or with combined application of isoproturon at 0.5 kg/ha and 2,4-D at 36 DAS. Similarly Malik *et al.* (1995) observed better utilization of major nutrients by wheat in plots treated with isoproturon alone at 1.0 kg/ha or when it was combined with 2,4-D. The corresponding values under these treatments were about 40, 11 71 and 47, 14, 82 kg of N, P and K kg/ha higher respectively, than the weedy check. Again Malik *et al.* (1995) reported that uptake of nutrients under combined application of isoproturon 1000 g/ha + tribenuron (7.5 g/ha) was 120.8, 28.0 and 205.4 kg N, P and K/ha, respectively, similar to that of weed free. The increase in uptake was 92, 125 and 75 per cent of N, P and K, respectively, than weedy check.

2.6. EFFECT OF HERBICIDES ON SYMBIOTIC NITROGEN FIXATION

Tora and Zambrano (1976) reported that in a slightly alkaline clay soil nodules in soybeans were reduced by 13, 8, 2, 0.5 and 1 per cent in prometryne at 0.75 kg/ha, diuron at 1.6 kg/ha, metribuzin at 0.35 kg/ha, alachlor at 2 kg/ha and alachlor at 1.0 + linuron at 0.5 kg/ha applied as pre-emergence, respectively, but little higher by 28 per cent with bentazone at post emergence 45 DAS alone. Dry weight of nodules was found to be lower with pre-emergence treatments than with post-emergence bentazone. The highest nodules number was recorded in alachlor (2.4 kg/ha) treated plots. Similar was the observation of Deuber and Signori (1980). They observed reduction in nodules number with

vernolate (3.6 kg/ha) both in Clayey and Silty loam soils, dry weight with metribuzin (0.63 kg/ha) in the clay and with pendimethalin (1.5 kg/ha) in the silty soil. These treatment did not have any stimulatory effect. Deuber *et al.* (1981) in field trials in clay and heavy clay soils did not find harmful effect on nodule when pendimethalin applied as pre-emergence, but observed decrease in another experiment with pendimethalin, trifluralin and vernolate. Decrease in number of nodules and their dry weight was also observed by Bollich *et al.* (1988) but they did not find any adverse effect on N_2 fixation with the application of trifluralin and pendimethalin. At Jabalpur, Lokras *et al.* (1985) recorded higher number of nodules with metalochlor (66.8) followed by metribuzin (51.2) and slighter lower nodules/plant in metribuzin at 0.5 kg/ha or pendimethalin at 1.0 kg/ha applied as pre-emergence. Praharaj and Dhingra's in 1995 from their field studies reported that pendimethalin at 0.5 kg/ha had no adverse effect on the nodulation and nitrogenase activity but it altered the efficiency of rhizobial inoculants in terms of biological nitrogen fixation in soybean.

2.7 RESIDUAL EFFECT OF HERBICIDES

2.7.1. Pendimethalin : Gautam's (1990) studies revealed that metribuzin, pendimethalin and oxadiazon applied to potato had no residual effect on succeeding wheat crop. Thomas *et al.* (1994) reported that residues from fluchloralin at 0.75 kg/ha, pendimethlin at 1.0 kg/ha, and haloxyfop-methyl at 0.30 kg/ha significantly reduced broad leaf and grass weed populations in preceding pigeonpea-cowpea intercropping system, without causing any significant reduction in crop yield of wheat in succession. Tiwari *et al.* (1994) reported that increasing rate of pendimethalin from 1.0 to 1.5 kg/ha caused increase in soybean yield but affected yield of succeeding

wheat crop as evidence from lower grain yield (21.2 q/ha) under pendimethalin at 1.5 kg/ha but proved beneficial to wheat (yield 23.1 q/ha) when applied at 1.0 kg/ha. Patel and Barevadia (1997) found fluchloralin, pendimethalin and oxadiazon applied to soybean safe to succeeding wheat, maize, mustard gram and sorghum. The former two affected sorghum plant height by 19.6 and 22.3 per cent at 0.75 kg/ha application, respectively.

2.7.2 Metribuzin : Aman and Hosmani (1978) observed metribuzin, alachlor and nitrofen applied to soybean fairly safe to succeeding bengalgram, safflower, wheat and cotton, but bhendi and *rabi* sorghum were affected due to the residual effect of herbicides. In the same year, Mani from IARI (New Delhi) reported that none of the six herbicides including metribuzin (at 0.5 kg/ha) applied as pre-emergence to potato with the exception of basalini affected the grain yield of succeeding wheat grown as a relay crop. Lal (1990) at Shimla, also did not find any adverse effect on the *zaid* pulse black gram when metribuzin was applied to potato in *rabi* at 0.5, 0.75 and 1.0 kg/ha. However, weed population in the potato and following blackgram decreased indicating its persistence in soil. Similar was the observation of Tiwari *et al.* (1994) at Belatal Uttar Pradesh, they found ascending rates of metribuzin from 0.5 to 0.8 kg/ha beneficial to soybean but proved detrimental to succeeding wheat crop at higher rate as its yield was 21.5 q/ha as against 24.3 q/ha at 0.5 kg/ha as pre-emergence.

2.8 PERSISTENCE OF HERBICIDES IN SOILS

2.8.1. Pendimethalin : Walker and Brown (1982) reported that 25% of original value of pendimethalin remain biologically active in soil even after 140 days of its application at 1.2 and 4.0 kg/ha in soybean. Berayon and Mercadod (1983) applied pendimethalin at 1.5, 3.0 and 6.0 kg/ha in Guadalupe clay, Lipa clay loam and Taal fine sandy loam in the Philippines and observed that its herbicidal activity was lost rapidly in soil after 20 to 50 days of application. Higher residual activity was present in clay loam soil than clay or fine sandy loam after 50 and 110 days of application. Similarly Singh *et al.* (1994) found initial dissipation rate more acute during first 40 days in which more than 60 per cent degradate and rate slowed down after 80 days and at 240 days 90 per cent was dissipated. Parochetti and Dec's (1978) studies revealed that thermo-decomposition of pendimethalin was only 10 per cent as compared to 30 per cent of fluchloralin. Walker and Bond (1977) found increase in half life of pendimethalin from 99 to 409 days in sandy loam soil at 75% field capacity with corresponding decrease in temperature from 30 to 10 °C . But Zimdahl *et al.* (1984) and Savage, (1978) reported faster degradation of pendimethalin with increase in temperature and moisture level. Kulshrestha and Singh (1992) observed rapid loss of pendimethalin in flooded soil (half life; 35 days) compared to non-flooded soil. In former half life was only 35 days whereas in latter 53 days. Jayakumar *et al.* (1992) found variation in degradation time of pendimethalin in different soils and estimated the half lives of pendimethalin in alluvial, black and red soils were 26, 20 and 16 days and the persistence up to 10, 60 and 50 days respectively. Yadav *et al.* (1993) found half

life 76, 92 and 122 days and 12.0, 24.8 and 36.5 per cent of the initial concentration in wheat 200 days after application at 6, 4 and 2 irrigations, respectively, signifying not to include sensitive crops in the rotation where pendimethalin has been used in the preceding crop.

2.8.2 Metribuzin : Surface applied metribuzin dissipated rapidly during the first 5 to 7 days period with a half life values ranging from 4 to 5 days and decreased drastically thereafter, but erection of artificial cover after application or shallow incorporation increased the half life of herbicide approximately 2.5 to 3 fold, evidencing volatilization or photodecomposition of surface applied metribuzin (Savage, 1980 and David *et al.*, 1986). Similar results were also reported by Jensen *et al.* (1989). Incubation studies by Savage (1977) indicated that metribuzin was degraded more rapidly in non-autoclaved field soil and soil enriched with glucose than in air dried soil for 1 year or autoclaved soil. However, degradation of metribuzin is more rapid at 30 °C than at 20 °C and microbial activity apparently is important in the degradation of metribuzin in soil.

2.8.3 Isoproturon : The isoproturon is lost rapidly from top soils with a half life of 12 days and degradation is decreased by a factor of 2 to 10 in deeper soil layers (Nordmeyer and Pestemer, 1995). Kulshrestha, (1983) reported that isoproturon persisted more in dry conditions ($t_{1/2}$ - 43 days) than moist conditions ($t_{1/2}$ 25 days) and its degradation in moist soil was temperature dependent. Degradation was rapid at higher temperature than at mean temperature (30 q 1xC). Similarly the half life of isoproturon in aqueous medium decreased with an increase in pH from 54 to 70% depending upon pH, it hydrolysed in 10 weeks (Kulshrestha, 1982).

Randhawa and Sandhu (1989) reported higher half life (50 days) of isoproturon when applied at 0.94 kg/ha. It was not detected in the soil at 140 DAS. Similar was the observation of Singh and Vaishay (1992) they did not find its persistence beyond 60 days when applied at 1.0 kg/ha. Covering surface with rice straw after isoproturon application minimises its loss due to photodecomposition and enhances half life from 18 to 21 days (Yadav and Malik, 1988).

2.9 RESIDUE ANALYSIS

2.9.1 Chemical Method

2.9.1.1 Pendimethalin : Pendimethalin residues from soil are extracted either a mixture of hexane : acetone in the ratio of 3:1 v/v (Savage, 1978, Savage and Jordan, 1980) or acetonitrile:Water:glacial acetic acid 80:20:2.5 v/v/v (Smith *et al.* 1995) or 10% methanol in chloroform (Padmavati *et al.*, 1997). Dekkar and Johnson, 1976 and Day, 1978 purified methanol extract of dinitroanilines; thereafter extracts was passed through chromatography columns using alumina for the oryzalin, and florisil for the ethalfluralin. In all these studies, quantitative measurement of the residues was done by using liquid gas chromatography having electron capture detector (ECD). Kulshrestha and Yaduraju (1987), Kulshrestha and Singh (1992) and Padmavati *et al.* (1997) also used gas liquid chromatography fixed with ^{63}Ni for pendimethalin estimation and obtained average recovery ranging between 80 to 90 per cent..

2.9.1.2 Metribuzin : Thornton *et al.* (1975) analysed metribuzin and its metabolites in crops after separating the compounds on a column of 5% OV-225 on chromosorb W (HP) using GLC with ECD. In 1977

Thornton and Stanley refined technique which is used to estimate residue in both soil and plant. In plant for measuring the residue refluxing with water-acetonitrile (1:4 v/v) is done followed by filtration and filtrate solution is evaporated until only water remains. This is used to separate metribuzin and metabolites from each other by liquid-liquid partitioning and cleaned up on gas chromatography columns. Cleaned sample is injected in gas liquid chromatograph for quantification on a 5% OV-225 column with electron-capture detector. For analysing residue in soil refluxing is done with water-acetonitrile. Free residues are separated from the solids by filtration and afterward partitioned thrice with chloroform. This extract is cleaned up on a florosil column using benzene-acetonitrile (99:1) prior to gas chromatographic analysis. Whereas, Savage (1977) extracted residues by shaking with acetone. Then suspensions were filtered through fritted glass filters using vacuum and 1 ml aliquots of the filtrate were injected into a gas chromatograph equipped with a ^{63}Ni electron-capture detector. Inlet, column and detector temperatures were 210, 185 and 225°C, respectively.

2.9.2 Bioassay method : Bioassays in which sensitive crops are used to determine the residual toxicity of various herbicides. Cultivated oats (*Avena sativa* L.) is being used as test crop because its root and shoot growth responds reasonably well to ureas, carbamates and triazines, thus, implying good detector for a large proportion of soil active herbicides (Hance and Mckone, 1976). The other test crops for metribuzin were cucumber (Savage, 1977) and cowpea (Gill *et al*, 1982). Jayakumar *et al*. (1988) observed that cucumber was found to be sensitive to herbicide residues of fluchloralin (1.0 kg/ha), oxadiazon (0.5, 1.0 and 1.5 kg/ha),

oxyfluorfen (0.1, 0.15 and 0.2 kg/ha) and pendimethalin (1.25 kg/ha) whereas finger millet, fox tail millet and mungbean showed no sensitivity to above herbicides. While Dhawan and Malik (1992) detected the residues of pendimethalin in soil by bioassay method using sorghum as test plant. Their study revealed that pendimethalin concentrations upto 6 ppm caused 50% inhibition in the germination even after 150 days of incubation, but lower concentration caused lesser inhibition. On the contrary, Subbaiah *et al.* (1994) reported that maize shoot weight inhibition was more suitable for detecting pendimethalin residue followed by cucumber root or shoot length inhibition. Ankegowda (1996) identified maize root growth bioassay for pendimethalin residues in the soil profile, especially to predict the potential for damage to sensitive follow up crops. Studies of Padmavati *et al.* (1994) indicated that germination was affected beyond 0.1 ppm pendimethalin in ragi, 0.5 ppm in korra, bajra and wheat, and beyond 2 ppm in maize sunflower and green gram and they suggested ragi and korra ideal crops for bioassays to detect pendimethalin. Based on plant height of cucumber they postulated pendimethalin at 1.25 kg/ha left 2.810 ppm of residue in the post harvest soil.

2.10 ECONOMICS

2.10.1 Economics of herbicides application in soybean : At Jabalpur, Jain *et al.* (1988) found metribuzin at 0.5 kg/ha most practical and economical in realising higher net return. Net return under it and hand weeding once was Rs 5570/ha and Rs 3759/ha, respectively, signifying it more economical. Jain and Tiwari (1992) at Jabalpur calculated economic returns under different herbicide treatments and recorded highest net return of Rs 1750 with oxadiazon at 1.0 kg/ha followed by Rs. 1258

with metribuzin at 0.5 kg/ha. Net return under these treatments was more than recorded under fluchloralin at 1.0 kg/ha.

Patil *et al.* (1986) found pendimethalin and oxadiazon each at 1.0 kg/ha equally effective in realising higher gross monetary return followed by fluchloralin and both the former herbicides gave almost two times more gross monetary return over weedy check (Rs. 6813/ha). Tiwari *et al.* (1994) also found application of metribuzin at 0.5 kg/ha, alachlor and pendimethalin each at 1.5 kg/ha as pre-emergence, more remunerative than manual weeding owing to increase in labour wages.

2.10.2 Economics of herbicide application in wheat : Porwal and Gupta (1987) found isoproturon alone (0.75 kg/ha) or in combination with 2,4-D (0.5 kg/ha) more remunerative than hand weeding, with an additional income of Rs. 1283 and 2693 per ha over conventional hand weeding which garner additional return of Rs. 858/ha only. Patel and Upadhyay (1990) did not find pendimethalin and isoproturon economical compared to 2,4-D.

2.11 Weed Shift

It is evident from the Appendix IV that there is shift in weed flora and dominance. In year 1962 grass weeds namely *Avena* sp. and *Phalaris minor* were not recorded in wheat (Mukhopadhyay *et al.*, 1962), while in year 1975 dominance of *Phalaris minor* and *Avena* sp. was observed by Gautam and Mani at New Delhi. Of the various dicot weed species *Chenopodium album* occurrence and preponderance continues till today.

From Malwa region of Madhya Pradesh Jain *et al.* (1972) reported the occurrence of *Corchorus acutangulus*, *Digera arvensis*, *Euphorbia*

hypertifolia, *Leucas cephalotes*, *Portulaca quadrifida*, *Phyllathus niruri* and *Setaria glauca* weed species in Soybean. While Jain *et al.* (1991) did not find *Leucas cephalotes* and *Portulaca quadrifida* but found occurrence of *Paspalum* sp. and *Panicum* sp., signifying the shift in weed flora (Appendix IV).

MATERIALS AND METHODS

The investigation entitled “**Direct and residual effect of herbicides on soybean wheat sequence**” was carried out during *kharif* and *rabi* seasons of 1995-96 and 1996-97. The details of the materials used and methods followed during the course of experiment are cited in this chapter.

3.1 GENERAL DETAILS

3.1.1. Experimental site and location : The experiment was conducted during 1995-96 and 1996-97, at the research farm of the Division of Agronomy, Indian Agricultural Research Institute, New Delhi, Mid Block-3A, situated at 28°35' N latitude and 77° 12' E longitude and at an attitude of 228 m above mean sea level.

3.1.2. Soil of the experimental field : The Soil of the experimental area was of ‘Yamuna alluvium’ in origin having sandy loam in texture in the upper 30 cm layer and loam beyond that (*Typic Ustochrepts*, order Inceptisole). The area was with even topography and well drained. The soil was slightly alkaline in reaction and non-saline. It was medium in available phosphorus, potassium and low in nitrogen. The important physico-chemical properties of the top 0-15 cm soil layer of the experimental area determined before the start of the experiment are given in the Table 1.

3.1.3. Climate and Weather : The climate of Delhi region is of sub-tropical and semi-arid type with hot and dry summer and cold winter. Delhi comes under Trans-Gangetic plains agro-climatic zone. Historically, the mean maximum and minimum air temperatures show considerable fluctuations

Table 1. Important Physical and Chemical Properties of the Soil.

Properties	Values	Method used
A) Mechanical Composition		
Coarse sand (%)	00.60	International Pipette
Fine sand (%)	60.40	method (Piper, 1966)
Silt (%)	21.80	
Clay (%)	17.20	
B) Chemical composition		
Available nitrogen (kg ha ⁻¹)	198.50	Modified kjeldahl method (Jackson, 1967)
Available phosphorus (kg ha ⁻¹)	15.60	Olsen's method (Olsen <i>et. al.</i> , 1954)
Available potassium (kg ha ⁻¹)	231.60	Flame photometer (Jackson, 1967)
pH (1:2.5, soil : water ratio)	7.90	Beckman glass electrode (Jackson, 1967)
Electrical conductivity (dSm ⁻¹)	0.43	Solu-bridge (Jackson, 1967)

during summer and winter. May and June are the hottest months with the maximum temperature ranging between 41 to 46°C; while the coldest month is January with minimum temperature approaching 2°C. The average annual precipitation is about 710 mm, of which about 85% is received during a short span of three months between July to September. Rains are scanty during winter but a few showers are normally received during January-February. The annual pan evaporation is about 850 mm. The mean daily open pan evaporation reaches as high as 16 mm in June

and as low as 1 mm in January. The relative humidity reaches maximum in January and minimum in March.

The weather data during the crop growing seasons recorded at the meteorological observatory, IARI, New Delhi, are given in **Appendix I** and Figure 1 and 2.

3.1.4. Cropping history of the field : The cropping history of the experimental fields is given in Table 2.

Table 2. Cropping history of the field

Year	<i>Kharif</i>	<i>Rabi</i>
	June - October	November - April
1992-93	Fallow	Wheat
1993-94	Fallow	Wheat
1994-95	Fallow	Wheat
1995-96	Present experiment	Present experiment
1996-97	Present experiment	Present experiment

3.2. EXPERIMENTAL DETAILS

The experiment was laidout in naturally infested field. The details of the experiment are given below.

3.2.1. Treatments : There are six weed control treatments applied in soybean in *kharif* season. While in *rabi* each soybean plot was divided into three sub plots. Wheat was sown in each plot to which three weed control treatments were allotted just to study the residual effect of pendimethalin and metribuzin applied to soybean crop. Thus, in all, there were 18 treatment combinations in *rabi* .

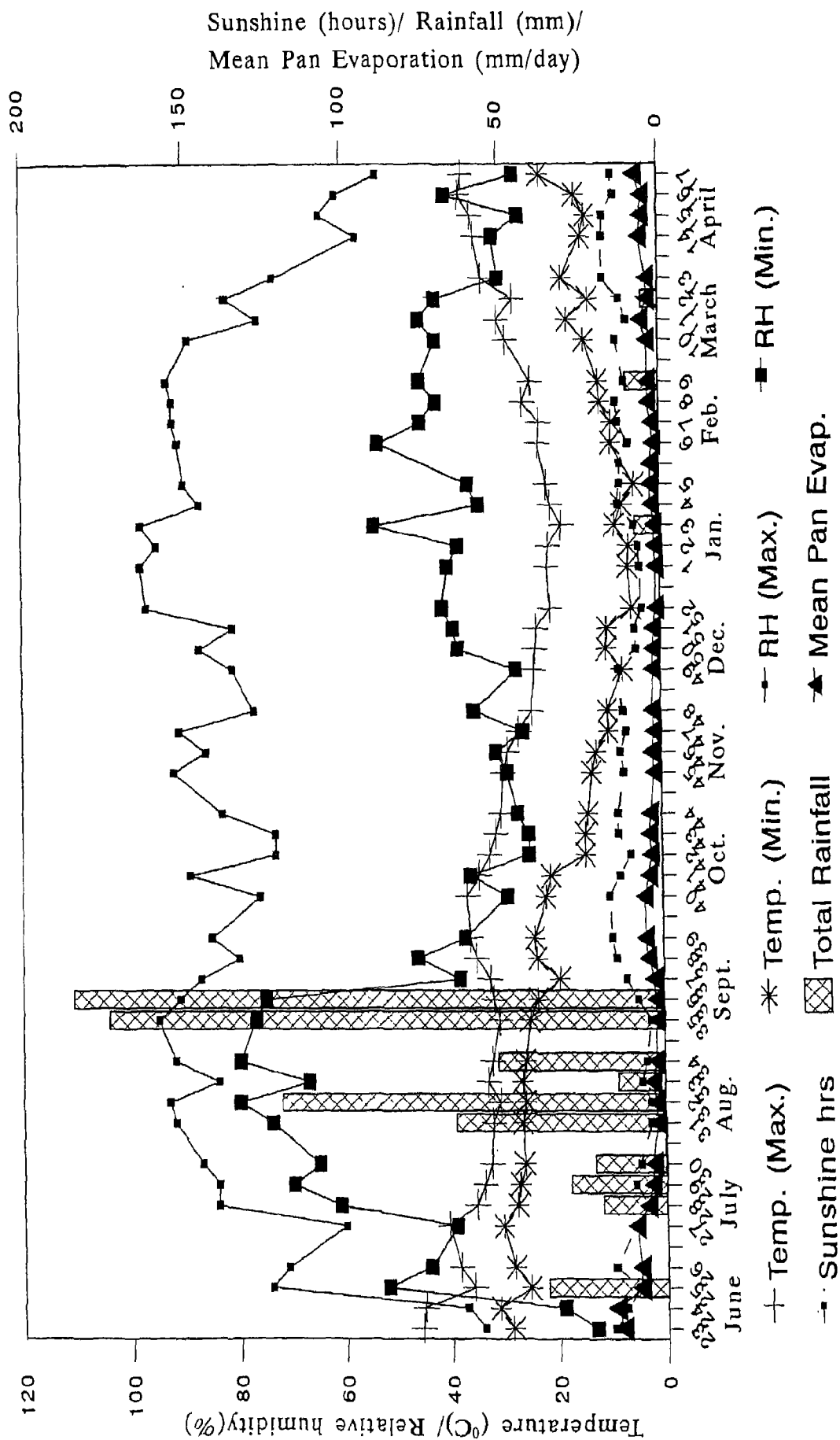


Fig.1. Mean weekly meteorological data during *kharif* and *rabi*, 1995-96

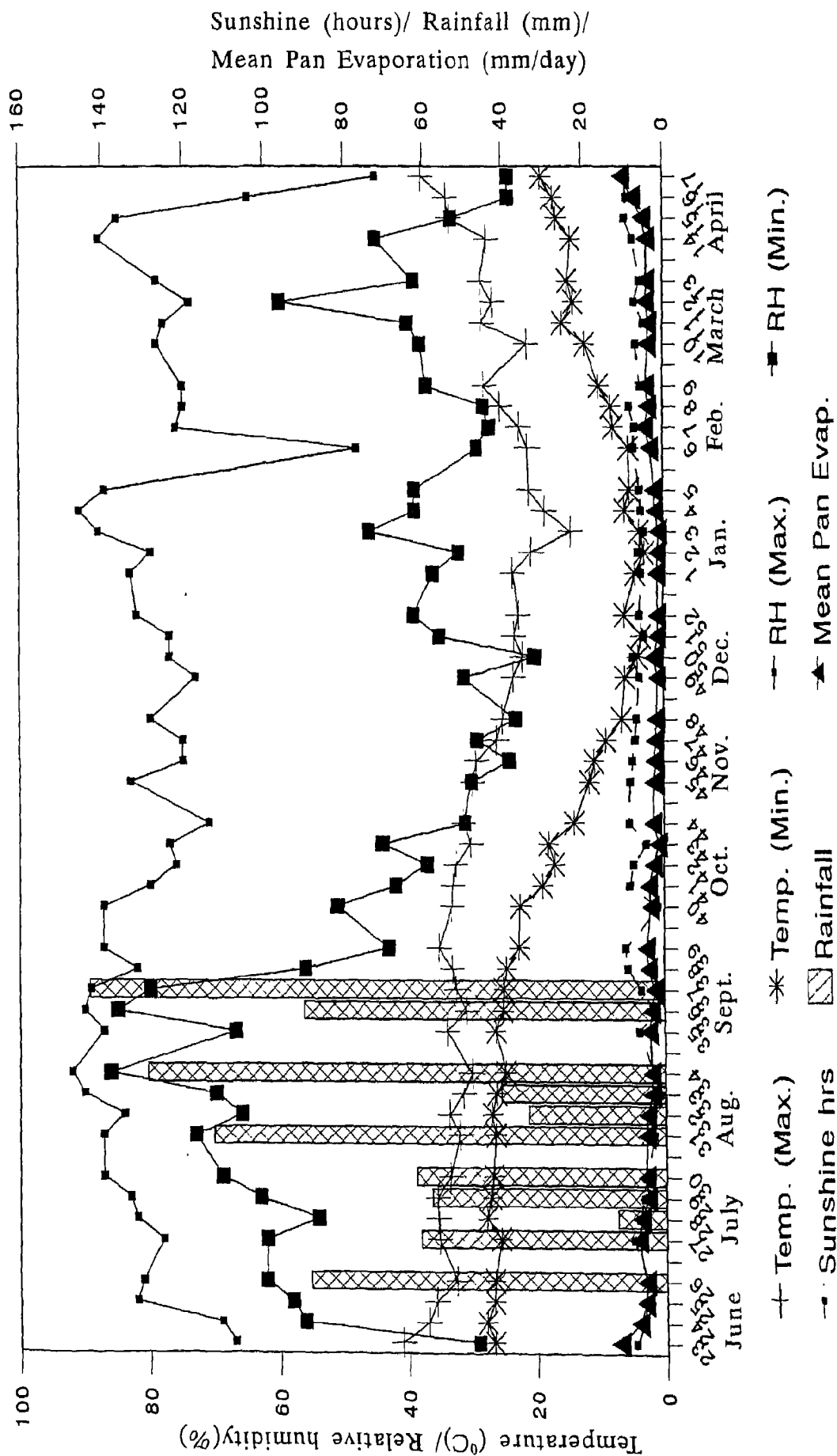


Fig.2. Mean weekly meteorological data during *kharif* and *rabi*, 1996-97

3.2.1.1. Kharif - Soybean

- T1 Pendimethalin @ 1.0 kg a.i./ha pre-emergence (Pre-em.)
- T2 Pendimethalin @ 1.5 kg a.i./ha pre-emergence (Pre-em.)
- T3 Metribuzin @ 0.5 kg a.i./ha pre-emergence (Pre-em.)
- T4 Metribuzin @ 0.75 kg a.i./ha pre-emergence (Pre-em.)
- T5 Hand weeding at 20 and 40 days after sowing (DAS)
- T6 Weedy check (no weeding)

3.2.1.2. Rabi - Wheat

- W1 Isoproturon @ 0.75 kg a.i./ha pre-emergence (Pre-em.)
- W2 Hand weeding at 30 days after sowing (DAS)
- W3 Weedy check (no weeding)

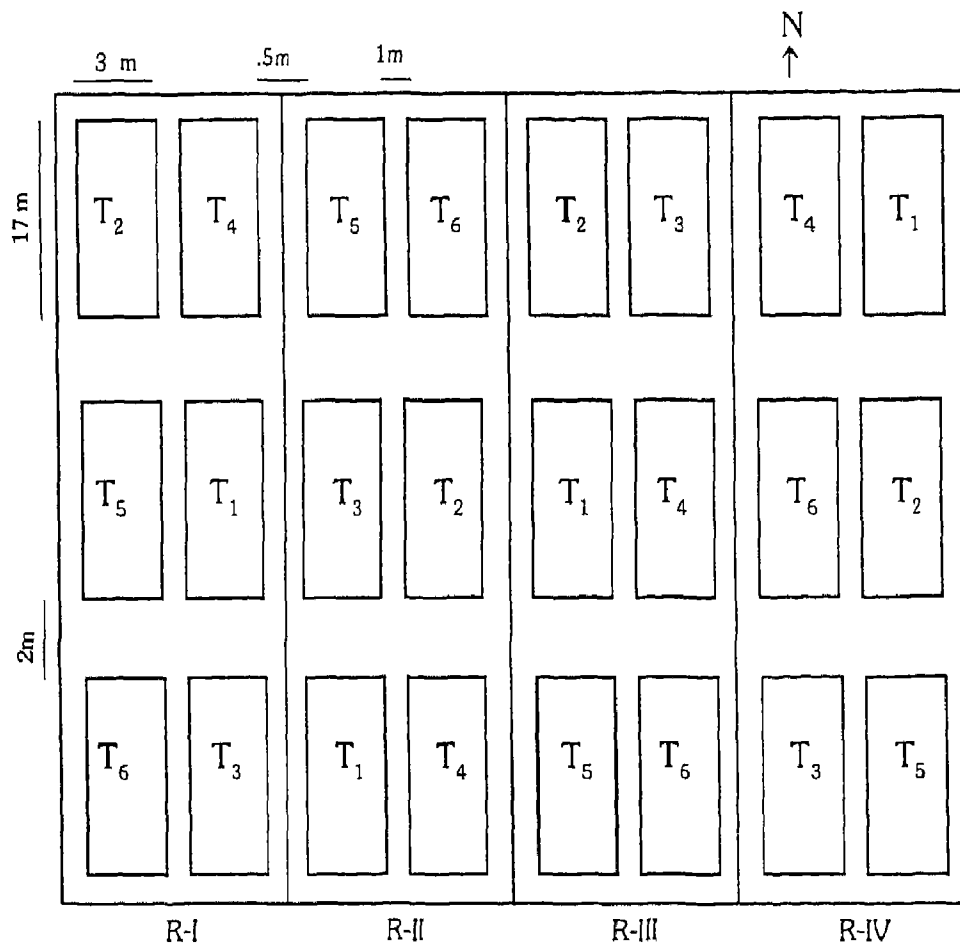
3.2.2. Experimental design and layout

3.2.2.1. **Design** : The experiment was laid out in randomized block design with four replications in kharif while in rabi, the design was a split plot design and treatments were replicated four times. In rabi each kharif soybean plot was divided into three plots and wheat was sown. In these plots, weed control treatments viz. isoproturon @ 0.75 kg a.i./ha, hand weeding once and weedy check were super-imposed randomly to assess the direct and residual effect of each treatment.

3.2.2.2. Layout

Total number of plots	(i) Kharif : 24
	(ii) Rabi : 72
Gross plot size	(i) Kharif : 17 m x 3m = 51.00m ²
	(ii) Rabi : 5 m x 2.99 m = 14.95 m ²
Net plot size	(i) Kharif : 16 m x 2.60 m = 41.60 m ²
	(ii) Rabi : 4 m x 2.53 m = 10.12 m ²

Fig3. Plan and layout of the experiment in *kharif*



Design : RBD

Replication : 4

Crop : Soybean (PUSA-22)

Treatments

T₁ : Pendimethalin @ 1.0 kg/ha

T₂ : Pendimethalin @ 1.5 kg/ha

T₃ : Metribuzin @ 0.5 kg/ha

T₄ : Metribuzin @ 0.75 kg/ha

T₅ : Hand weeding 20 & 40 DAS

T₆ : Weedy check

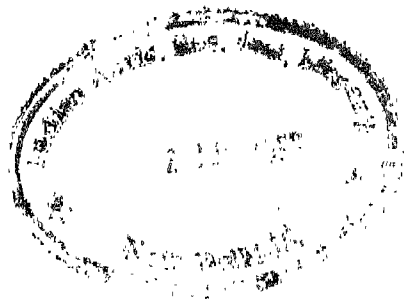
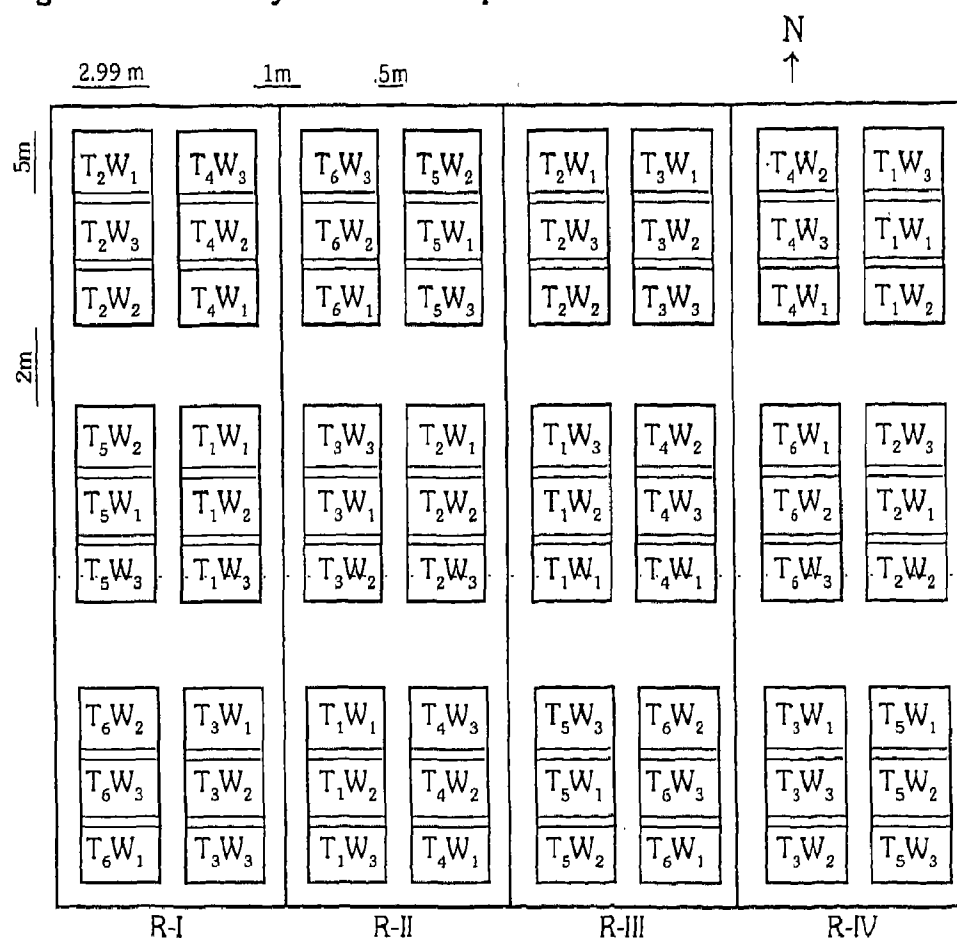


Fig4. Plan and layout of the experiment in *rabi*



Design : Split-plot
Replication : 4
Crop : Wheat
Treatments : **Mainplots** : *kharif* treatments
T₁ : Pendimethalin @ 1.0 kg/ha
T₂ : Pendimethalin @ 1.5 kg/ha
T₃ : Metribuzin @ 0.5 kg/ha
T₄ : Metribuzin @ 0.75 kg/ha
T₅ : Hand weeding 20 & 40 DAS
T₆ : Weed check
Sub plots : *Rabi* treatments
W₁ : Isoproturon 0.75 kg/ha
W₁ : Hand weeding 30 DAS
W₃ : Weedy check

Spacing between rows of soybean : 0.30 m

Spacing between rows of wheat : 0.23 m

The plan of layout of the experiment is depicted in Figure 3 and 4.

3.3 DESCRIPTION OF CROP CULTIVARS

3.3.1. Soybean (Pusa - 22) : It was developed at IARI, New Delhi , from a cross between Punjab 1 x Clark-63 and released for general cultivation in 1983 for northern plain zone, north east zone and parts of central zone. It matures in 110-120 days. It is a compact plant type with average plant height of 90-100cm and bear purple flowers and tawny pubescence. The seeds are creamy in colour with brown helium. The 100 seed weight ranges between 12-13g and yield potential ranges between 25-30 quintals per hectare with an oil content 20-21 per cent. It is tolerant to yellow mosaic, resistant to bacterial pustules, rhizoctonia wilt and alternaria blight.

3.3.2 Wheat (HD-2329) : It is a derivative of crosses amongst HD 1962/E4870/K65/3/HD-1663/UP-262 and was developed at IARI, New Delhi and recommended for general cultivation in Rajasthan, Delhi, Eastern U.P., Bihar, Haryana and Punjab. It matures in about 135-146 days under Delhi conditions with mean plant height of 94 cm and heading completes in 98 days. Seeds are medium bold (37g/1000 seeds) with hard texture. It has an yield potential over 65 quintals per hectare.

3.4. CHEMICAL NATURE OF HERBICIDES

3.4.1. Pendimethalin : It is a primarily a pre-emergence herbicide and is effective against a number of annual broad leaved weeds and particularly grasses in cotton, groundnut and pea. Pendimethalin can also be used

as pre-plant in soybean, maize, onion and potato. The susceptible weeds are affected during germination or seedling emergence. It is formulated as emulsifiable concentrate and granules.

Chemical Name : [N-(1-ethylpropyl)-3, 4-dimethyl-2,6-dinitrobenzenamine]

Trade Name : Stomp 30 EC

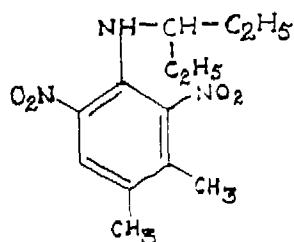
Structural formula :

Empirical formula : $C_{13}H_{19}N_3O_4$

Molecular weight : 281.31

Melting point : 56-57°C

Solubility : In water at 20°C, 0.3 mg/l. Readily soluble in alcohol, acetone, benzene, toluene, chloroform, methylene chloride. Average solubility in ether, carbon tetrachloride, xylene and slightly soluble in petroleum ether or petrol

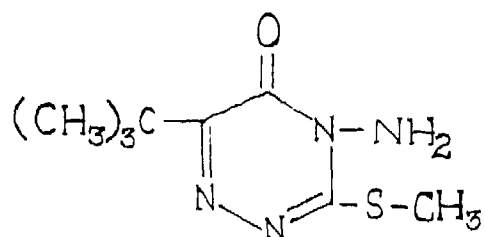


3.4.2. Metribuzin : It is a broad spectrum herbicide especially notable for its powerful action against both grass and broad leaved weeds when used pre-weed emergence in crops like soybean, potato, sugarcane, tomato, alfalfa etc. It acts only through the roots, as a soil applied herbicide.

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

Trade Name : Sencor 70% WP

Structural formula :



Empirical formula : $C_8H_{14}N_4O_5$

Molecular weight : 214.29

Melting point : 120-125°C

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

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

Chemical Name : [N-N-dimethyl-N-1-(3-(isopropyl) Phenyl urea]

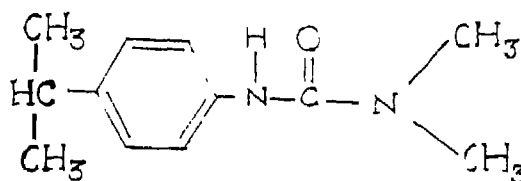
Trade Name : Arelon 75 WP

Nocilon 50 WP

Ronak 50 WP

Graminon 50 WP

Structural formula :



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

Molecular weight : 206.29

Melting point : 151-153°C

Solubility : In water at 20°C, 70 ml/l, readily soluble in organic solvents

3.5 FIELD OPERATIONS

The details of the various field operation followed during *kharif* and *rabi* season in both the years of experimentation are given in chronological order in Table 3.

Table 3. Schedule of field operations during the crop season

Operations	Date	
	1995-96	1996-97
A. Soybean		
i) Field preparation	02.07.95	10.07.96
ii) Layout of the experiment	08.07.95	15.07.96
iii) Fertilizer application	08.07.95	16.07.96
iv) Sowing of the crop	10.07.95	17.07.96
v) Pre-emergence herbicide spray	11.07.95	18.07.96
vi) Gap filling	20.07.95	26.07.96
vii) Thinning	21.07.95	26.07.96
viii) Hand weeding - First	30.07.95	06.08.96
- Second	19.08.95	26.08.96
ix) Insecticide spraying	25.08.95	28.08.96
x) Irrigation - one	29.10.95	05.10.96
xi) Harvesting	07.11.95	12.11.96
B. Wheat		
i) Field preparation	15.11.95	17.11.96
ii) Layout of the experiment	18.11.95	20.11.96
iii) Fertilizer	20.11.95	22.11.96
iv) Sowing of the crop	20.11.95	22.11.96
v) Pre-emergence herbicide spray	21.11.95	23.11.96
vi) Gap filling and thinning	02.12.95	03.12.96
vii) Hand weeding	21.12.95	23.12.96
viii) Irrigation - First	11.12.95	12.12.96
Second	10.01.96	11.1.97
Third	08.02.96	07.02.97
Fourth	05.03.96	09.03.97
Fifth	03.04.96	03.04.97
ix) Top dressing of fertilizer-First	15.12.95	16.12.96
-Second	14.01.96	15.01.97
x) Harvesting	24.04.96	25.04.97

3.5.1. Land preparation : The experimental field was ploughed, cross disced and levelled well just to achieve a good tilth in both *kharif* and *rabi* seasons. After harvesting of soybean, the fields were prepared for sowing of wheat without disturbing the original layout.

3.5.2 Fertilizer application : In soybean the recommended doses of 30 kg ha⁻¹ N, 80 kg ha⁻¹ P₂O₅, 60 kg ha⁻¹ K₂O and in wheat 120 kg ha⁻¹ N, 60 kg ha⁻¹ P₂O₅, and 40 kg ha⁻¹ K₂O were applied separately. The whole quantity of N, P and K was applied as a basal dressing in soybean, while in wheat entire amount of phosphorus, potassium and 50% of the recommended nitrogen was applied as basal dressing and remaining half of the nitrogen was top dressed into two equal split doses at 25 and 55 days after sowing which coincide with CRI and maximum tillering stages. The N, P and K were given in the form of urea, single super phosphate and muriate of potash respectively.

3.5.3. Sowing of seeds : Inoculated seeds (with *Rhizobium japonicum*) of soybean 80 kg ha⁻¹ were sown with the help of bullock drawn *Desi* plough (single row drill) at a row spacing of 30 cm (Pora method). Whereas, sowing of wheat was done with a tractor-drawn seed drill calibrated for the recommended seed rate of 100 kg ha⁻¹ adjusted for the spacing of 23 cm between rows.

3.5.4. Herbicide spraying : Pendimethalin and metribuzin as per treatments were applied as pre-emergence one day after sowing of soybean with the help of knapsack sprayer fitted with flat fan nozzle. Similarly isoproturon was sprayed as pre-emergence to wheat crop as per treatments using spray volume of 800 liters/ha.

3.5.5. Irrigation : Besides rainfall, water was supplied through irrigation system to meet the normal growth.

3.5.6. Gap filling and thinning : Gap filling in both soybean and wheat was done 8 days after of crop emergence wherever necessary.

3.5.7. Manual weeding : A complete weed removal was attempted only in hand weeding treatment at 20 and 40 days after sowing in soybean while weeds were removed in wheat once by hand weeding 30 DAS (days after sowing).

3.5.8. Plant protection measures : A mild infestation of leaf roller was noticed in soybean 35 days after sowing (DAS) which was controlled by spraying insecticide Endosulfan (Thiodon) 35 EC 0.35 litre/ha. No insecticide was applied in wheat.

3.5.9. Harvesting and threshing : Both the crops were harvested at their physiological maturity with the help of sickle and left in the field for 3 days for sun drying and then bundles were made treatment wise. Both the crops were threshed with the help of power drawn thresher.

3.6. OBSERVATION RECORDED

3.6.1. Observation on weeds

3.6.1.1. Emergence pattern of weeds : For recording observation, two spots of size 0.25 m² were marked with the help of bamboo stick at the opposite corners of each plot leaving the border rows. The weed species that emerged were counted at the interval of 15 days upto 60 DAS.

3.6.1.2. Weed population: An area of 0.25 m² was selected randomly by throwing a metallic quadrat of size 0.5 m x 0.5 m. The data thus

obtained were transformed as wide variation existed among the treatments and expressed in numbers per square meter.

3.6.1.3. Weed dry matter : Weeds collected from 0.25 m² area were first sun dried and then kept in an electric oven at 70°C for 48 hours and dry weight was recorded when samples attained a constant weight and expressed as g m⁻².

3.6.1.4. Importance value index (I.V.I.) : To calculate the I.V.I. values of major weeds methods described by Ashby (1948) and Mishra (1973) were used as per details given below

I.V.I. = Relative dominance + Relative density + Relative frequency

$$\text{Relative dominance(R.Dom.)} = \frac{\text{Total basal area of a species}}{\text{Total basal area of all species}} \times 100$$

$$\text{Relative density (R.D.)} = \frac{\text{Total number of plants of a species}}{\text{Total number of plants of all species}} \times 100$$

$$\text{Relative frequency (R.F.)} = \frac{\text{No. Of occurrence of one species}}{\text{No. Of occurrence of all species}} \times 100$$

3.6.2 Observation on crops

3.6.2.1 Soybean

3.6.2.1.1. Plant population : Plant population/m row length at 15 days and at harvest were recorded from two different rows (leaving border rows) in each plot to study the phytotoxic effect of herbicide on crop.

3.6.2.1.2. Plant height : Height of the ten plants selected randomly from each plot was measured from base level to the tip of the largest branch. The average of ten randomly selected plants was calculated and expressed as height of the plant in centimeter (cm).

3.6.2.1.3. Number of nodules per plant : Five plants were dug out carefully 60 DAS and then roots were washed gently and thoroughly with water .The effective nodules were counted and expressed as number of nodules per plant.

3.6.2.1.4. Dry matter production : Five plants which were dug out carefully from each plot were dried under the sun after removing the root biomass and kept overnight in an electric oven at 70°C for complete drying and their weight was recorded when samples attained a constant weight and expressed as g/plant.

3.6.2.1.5. Number of pods/plant : The total pods of ten randomly sampled plants were counted at harvest and the average was expressed as number of pods per plant.

3.6.2.1.6. Number of grains/pod : Twenty five pods were randomly chosen from each plot at harvest and their grains were counted. Average number of grains per pod was worked out later on.

3.6.2.1.7. 1000-grain weight (Test weight) : Grains were drawn randomly from the total produce of each plot and 1000 grains were counted with seed counter, weighed and expressed as 1000-grain weight in grams(g).

3.6.2.1.8. Biological yield : The weight of total produce harvested from each net plot was recorded after sun drying for 4 days and expressed as biological yield (q/ha).

3.6.2.1.9. Grain yield : The weight of grains obtained from each net plot was recorded and expressed as grain yield (q/ha).

3.6.2.1.10 Harvest index : The economic produce (grain yield) was divided by the biological yield (grain + straw) and the relationship was expressed as harvest index.

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

3.6.2.2 WHEAT

3.6.2.2.1 Plant population : Plant population per running meter was recorded from two different rows in each plot 15 DAS.

3.6.2.2.2 Plant height : The plant height from the basal level to the tip of the younger leaf was measured in centimeter. The average of 5 randomly sampled plant was calculated and expressed as plant height in centimeters(cm) whereas, at harvest plant height was measured from the base level to the lower portion of the spike.

3.6.2.2.3 Number of tillers/m row length : The total number of tillers/ m row length were recorded from two different rows in each plot leaving border rows.

3.6.2.2.4 Dry matter production : Five plants were dug out carefully from each plot, dried under the sun after removing the root biomass from basal level and kept overnight in an electric oven at 70°C for 24 hours and their weight was recorded when samples attained the constant weight and averaged to obtain dry weight per plant and expressed as g/plant.

3.6.2.2.5 Length of spike : The length of ten spike collected randomly from each plot was measured and the average was expressed as length of spike in centimeter (cm).

3.6.2.2.6 Number of spikelets/spike : Ten spikes collected from each plant were used to record the average spikelets per spike.

3.6.2.2.7 1000-grain weight : Grains were drawn randomly from the total produce of each net plot and 1000 grains were counted mechanically with seed counter and weighed and expressed in gram(1000-grain weight).

3.6.2.2.8 Biological yield : At harvest, the total produce (biological yield) from the net plot area was considered for determining dry weight which was recorded after sun drying for 4 days and expressed as biological yield (q/ha).

3.6.2.2.9 Grain yield : The weight of grains obtained from each net plot was recorded and expressed as grain yield (q/ha).

3.6.2.2.10 Harvest index : It was expressed as the ratio of grain yield to total biological yield.

$$H I = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.7 CHEMICAL ANALYSIS

3.7.1 NPK content and uptake by weeds and crops : The samples of weeds and crop straw and grain were dried in an electric oven at 70°C for 24 hours after sun drying for 5 days. The samples were grinded in a Willey mill and passed through 0.5 mm mesh sieve. A sample weighing 0.5 g each was used for determination of N, P and K content.

3.7.1.1 Nitrogen content : Nitrogen content (%) in plant samples was determined by Kjeldahl method as described by Jackson, 1967.

T-6275

3.7.1.2 Phosphorus content : Phosphorus content (%) in plant samples was determined by Vanado molybdophosphoric yellow colour method. The intensity of yellow colour developed was measured at 470 nm wave length using spectrophotometer (Jackson, 1967).

3.7.1.3 Potassium content : K content in plant samples (crops and weeds) was determined by using flame photometer as per method given by Jackson, 1967.

3.7.1.4 N, P and K uptake : N, P and K uptake by weeds, crop straw and grain were calculated by multiplying dry matter with corresponding values of their content and were expressed as kg/ha.

3.7.1.5 Protein Content and protein yield: The percentage of crude protein in grain was determined by multiplying the nitrogen content by a standard factor 6.25 as advocated by AOAC, 1966. Protein yield was worked out by multiplying grain yield and protein content

3.7.1.6 Nutrient status in soil after soybean harvest : Soil samples from 15 cm depth were collected from every plot after harvest of soybean. The soil samples were thoroughly mixed and air dried, then crushed gently in pestle and mortar and passed through a 2 mm sieve. Representative samples weighing 10, 2.5 and 5g were drawn for estimation of available N, P and K respectively.

3.7.1.7 Available nitrogen : Available N in soil was estimated by alkaline permanganate method (Subbiah and Ashija, 1956) and expressed as available N (kg/ha) in soil.

3.7.1.8 Available phosphorus : Available P in soil was estimated by Olsen's method (Olsen *et al.*, 1954) and expressed as kg/ha.

3.7.1.9 Available potassium : Available K in soil was estimated by flame photometer method as described by Jackson, 1967.

3.7.1.10 Oil content and oil yield : The oil percentage in grains was measured by using Nuclear Magnetic Resonance Instrument . Oil yield was calculated by multiplying the grain yield with oil content for each treatment.

3.7.2 HERBICIDE RESIDUE ESTIMATION IN SOIL

Soil samples from 15 cm depth were collected with the help of post hole auger from herbicide treated and untreated plots in each replication at 0, 15, 30, 45 and 120 days (harvest) after pendimethalin and metribuzin application. The samples were mixed thoroughly, dried in shade and passed through 2 mm sieve. One kilogram soil from each treatment was drawn by quartering technique and stored at - 10°C in deep freezer for the bioassay studies.

3.7.2.1 Bioassay studies : Plastic pots of size 10 cm x 9.5 cm were filled with 500 g soil and then 75 ml of water was added to each pot to bring the soil level to field capacity. Afterward, the moisture level of the soil was maintained at field capacity with top watering of soil as and when required. Eight seeds each of wheat and oats were sown at a depth of 2 cm in two sets of pots arranged in a randomized block design with four replication. Herbicide response was evaluated 30 days after sowing by harvesting the shoot portion and recording dry matter weight of the affected and unaffected plants.

3.7.2.2 Residue analysis by Gas Liquid chromatography (GLC).

3.7.2.2.1 Analysis of pendimethaline residues in soil : Twenty gram soil was weighed and transfered to 250 ml conical flask. To this 1 ml

of 0.1 N HCl was added and soil was mixed thoroughly with glass rod. After half-an-hour 100 ml of hexane was added to the flask and extracted thrice by shaking on a mechanical shaker for 30 minutes. The supernatant liquid was filtered through filter paper using ordinary funnel. Filtrate was concentrated to about 5 ml using kuderna-Danish Evaporator.

The residues were analysed by gas liquid chromatography on a Hewlett Packard gas chromatograph fitted with ^{63}Ni electron capture detector and a OV-17 megabore column. The column, injector and detector temperatures were maintained at 200, 225 and 250°C respectively. The flow of nitrogen gas was 30 ml/min.

The half-lives of the herbicides were calculated from the logarithmic plots of concentration of herbicides versus time (days) with the help of the following equation

$$T_{1/2} = 0.693/K$$

Where $T_{1/2}$ = The half-life of the herbicide

K = The rate constant.

3.7.2.2.2 Analysis of pendimethalin in soybean grain : Twenty five grams of finely grinded grain samples were weighed and transferred to filter paper thimbles and extracted for 4 hours with 200 ml of acetone (mixed with 1 ml of 0.1 N HCl) in soxhlet apparatus.

The extracts were concentrated to about 10 ml using Kuderna-Danish Evaporator. The concentrates were transferred to 500 ml separatory funnel and diluted to total volume of 80 ml with distilled water. Thereafter, the contents were extracted thrice with minimum volume (50 ml) of hexane. The hexane portions were discarded. 20 ml of saturated salt solution were

added to the separatory funnel and extracted thrice with 50 ml of dichloromethane. The dichloromethane extracts (lower layers) were pooled and filtered through a layer of anhydrous sodium sulphate. The extract was concentrated to dryness using Kuderna-Danish Evaporator.

The residues were dissolved in hexane : acetone (9:1 v/v) mixture and analysed by gas chromatography as mentioned in previous section 3.7.2.2.1.

3.7.2.2.3 Analysis of metribuzin residues in soil : Fifty gram of soil sample was weighed and transferred to 250 ml conical flask. To this 5 ml of distilled water was added and soil was mixed well with glass rod. After half-an-hour 100 ml mixture of acetonitrile and water (50:10, v/v) was added to the flask and extracted thrice by shaking on a mechanical shaker for thirty minutes. The supernatant liquids were filtered through whatman filter paper No. 1. Filtrates were concentrated to 10 ml using Kuderna-Danish Evaporator.

The 10 ml concentrates were transferred to a 250 ml separatory funnel and contents were extracted thrice with a 100 ml volume of dichloromethane. The fractions of dichloromethane were collected and passed through a layer of anhydrous sodium sulphate. The filtrate was concentrated to dryness using Kuderna-Danish Evaporator.

The residues were then dissolved in hexane : acetone (4:1) mixture and analysed by gas liquid chromatography on ECD. The temperatures of column, injector and detector were maintained at 180, 225 and 250°C respectively. The half-life of herbicide was calculated as per method given in previous page.

3.7.2.2.4 Analysis of metribuzin in soybean grain : 25 gram of finely powdered grain sample was weighed and transferred to the filter paper thimble in a soxhlet apparatus and extracted with 200 ml acetonitrile for 4 hours.

The extracts was filtered through the filter paper, the filtrate was collected and concentrated in KDE to about 10 ml. The concentrates were transferred to 250 ml separatory funnel and diluted to total volume of 80 ml with distilled water. After wards, the contents were extracted twice with minimum volume (15 ml) of hexane, discard the hexane fraction (upper layer). Twenty ml of saturated sodium chloride solution was added to separatory funnel and extracted thrice with 50 ml of dichlormethane. Then dichloromethane extracts were pooled and passed through a anhydrous sodium sulphate. The filtrate was concentrated to dryness using Kuderna-Danish Evaporator.

The residue was dissolved in benzene (5 ml) and transferred to a glass column packed with silica gel (5 g) over laid with anhydrous Sodium sulphate (1 cm) and pre-eluted with benzene (50 ml). Further elution was done with mixture of benzene and acetonitrile (99 : 1). First fraction of 20 ml was discarded and remaining 50 ml was collected and solvent evaporated. The residue was dissolved in hexane : acetone mixture (9 : 1) for analysis by GLC with conditions discribed in previous section 3.7.2.2.3 for metribuzin.

3.8 ECONOMICS OF PRODUCTION

The cost of production incurred on each treatment was worked out considering the prevailing market price of input and the produce (grain

and stover). The details are given in Appendix III. The net income per hectare was calculated by subtracting the cost of production from the gross returns per hectare.

-Gross return (Rs./ha)	=Cost of grain + cost of stover
-Net return (Rs./ha)	=Gross return - total cost of production
-Net return per rupee invested	=Net return/total cost of production
-Cost : Benefit ratio	=Gross return/Total cost of production

3.9 STATISTICAL ANALYSIS

The experimental data pertaining to each character were subjected to statistical analysis by using the techniques of variance and their significance was tested by "F" test (Cochran and Cox, 1967). The data recorded on weed population and dry weight of weeds were subjected to square root transformation to normalize their distribution. Standard error of means (SEm $\pm$) and critical different (C.D.) at 5% level of significance were worked out for each character studied to evaluate differences between treatment means. Two years' yield data were pooled and subjected to statistical analysis by followed appropriate statistical technique.

EXPERIMENTAL RESULTS

4.1 SOYBEAN

4.1.1 Weeds in Soybean

The intensity of broad leaved and grassy weeds at the critical growth stage (30 DAS) in unweeded plot was 61, and 39 per cent respectively, signifying preponderance of broad leaved weeds in soybean. Pre-dominant dicots weed species that infested the field were *Trianthema portulacastrum* (41.17%), *Digera arvensis* (13.08%) and *Phyllanthus niruri* (5.22%) and among monocots *Digitaria sanguinalis* (19.53), *Echinochloa colonum* (12.64%) and *Dactyloctenium aegyptium* (3.01%) were common. Perennial weed *Cyperus rotundus* was also present but its intensity (2.90%) was much lower. The other weed species that occurred in small numbers were *Convolvulus arvensis* and *Commelina benghalensis* (Appendix II).

4.1.2 Emergence pattern of weeds

Data presented in Table 4, 5, 6, 7 and 8; Fig. 5 illustrate the emergence of pre-dominant weeds *Trianthema portulacastrum*, *Digera arvensis*, *Digitaria sanguinalis*, *Echinochloa colonum*, and *Cyperus rotundus* under different treatments in 1995-96.

Variation in weed control treatments caused significant variation in emergence of *T. portulacastrum* at 15, 30 and 45 stages. At 15 and 30 day stages, pendimethalin (1.0 and 1.5 kg/ha) and metribuzin (0.50 and 0.75 kg/ha) treatments significantly lowered the emergence of *T. portulacastrum* as compared to weedy check and hand weeding. The

Table 4. Emergence pattern of *Trianthema portulacastrum* in soybean 15,30,45 and 60 DAS as affected by direct effect of pendimethalin and metribuzin in 1995-96

	Emergence (no. of plants /m ²)			
	15 DAS	30 DAS	45 DAS	60 DAS
T ₁ Pendimethalin 1.0 kg/ha	5.04 (25.0)	1.75 (2.0)	1.14 (1.0)	1.82 (1.0)
T ₂ Pendimethalin 1.50 kg/ha	3.29 (10.5)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)
T ₃ Metribuzin 0.50 kg/ha	3.30 (10.5)	1.18 (1.0)	0.71 (0.0)	1.84 (1.0)
T ₄ Metribuzin 0.75 kg/ha	1.98 (3.5)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)
T ₅ Hand weeding (20 & 40 DAS)	17.51 (308.0)	11.68 (137.5)	2.09 (4.0)	0.71 (0.0)
T ₆ Weedy Check	18.30 (334.5)	13.02 (130.0)	0.71 (0.0)	0.71 (0.0)
SEm ±	0.38	0.45	0.14	0.36
CD at 5%	1.14	1.35	0.42	NS

Figures in parenthesis indicate the original values.

Table 5. Emergence pattern of *Digera arvensis* in soybean 15,30,45 and 60 DAS as affected by direct effect of pendimethalin and metribuzin in 1995-96

	Emergence (no. of plants /m ²)			
	15 DAS	30 DAS	45 DAS	60 DAS
T ₁ Pendimethalin 1.0 kg/ha	4.32 (18.5)	3.86 (14.5)	1.98 (3.)	1.34 (1.5)
T ₂ Pendimethalin 1.50 kg/ha	3.51 (12.0)	3.22 (10.0)	1.56 (2.0)	1.40 (1.5)
T ₃ Metribuzin 0.50 kg/ha	2.44 (5.2)	1.14 (1.0)	0.71 (0.0)	1.22 (1.0)
T ₄ Metribuzin 0.75 kg/ha	1.98 (3.5)	1.18 (1.0)	0.71 (0.0)	0.71 (0.0)
T ₅ Hand weeding (20 & 40 DAS)	9.62 (92.2)	6.75 (40.5)	1.84 (3.0)	2.02 (4.0)
T ₆ Weedy Check	9.88 (97.5)	6.74 (45.0)	1.55 (2.0)	1.82 (3.0)
SEm ±	0.21	0.42	0.14	0.22
CD at 5%	0.65	1.28	0.43	0.67

Figures in parenthesis indicate the original values.

Table 6. Emergence pattern of *Digitaria sanguinalis* in soybean 15,30,45 and 60 DAS as affected by direct effect of pendimethalin and metribuzin in 1995-96

	Emergence (no. of plants /m ²)			
	15 DAS	30 DAS	45 DAS	60 DAS
T ₁ Pendimethalin 1.0 kg/ha	5.51 (30.0)	5.69 (32.0)	3.30 (10.5)	1.22 (1.0)
T ₂ Pendimethalin 1.50 kg/ha	5.13 (26.0)	5.41 (29.0)	2.70 (7.0)	1.22 (1.0)
T ₃ Metribuzin 0.50 kg/ha	5.01 (25.0)	5.82 (25.5)	3.23 (10.0)	0.71 (0.0)
T ₄ Metribuzin 0.75 kg/ha	5.03 (25.5)	4.61 (21.0)	3.08 (9.0)	0.71 (0.0)
T ₅ Hand weeding (20 & 40 DAS)	12.32 (151.5)	14.33 (205.0)	3.13 (12.0)	1.86 (2.0)
T ₆ Weedy Check	12.78 (163.0)	14.55 (211.5)	2.71 (7.0)	0.71 (0.0)
SEm ±	0.28	0.27	0.20	0.35
CD at 5%	0.84	0.81	NS	NS

Figures in parenthesis indicate the original values.

Table 7. Emergence pattern of *Cyperus rotundus* in soybean 15,30,45 and 60 DAS as affected by pendimethalin and metribuzin in 1995-96

	Emergence (no. of plants /m ²)			
	15 DAS	30 DAS	45 DAS	60 DAS
T ₁ Pendimethalin 1.0 kg/ha	4.34 (18.5)	4.28 (18.0)	4.99 (24.5)	4.61 (21.0)
T ₂ Pendimethalin 1.50 kg/ha	4.34 (18.5)	4.93 (24.0)	4.83 (23.0)	4.46 (20.0)
T ₃ Metribuzin 0.50 kg/ha	3.87 (15.0)	3.87 (15.0)	4.51 (20.0)	4.35 (19.0)
T ₄ Metribuzin 0.75 kg/ha	3.51 (12.0)	3.65 (13.0)	4.72 (22.0)	4.30 (18.5)
T ₅ Hand weeding (20 & 40 DAS)	3.74 (14.0)	4.51 (20.0)	4.93 (24.0)	4.63 (21.5)
T ₆ Weedy Check	4.04 (16.32)	3.93 (15.0)	4.49 (20.0)	4.52 (20.5)
SEm ±	0.32	0.27	0.24	0.26
CD at 5%	NS	0.81	NS	NS

Figures in parenthesis indicate the original values.

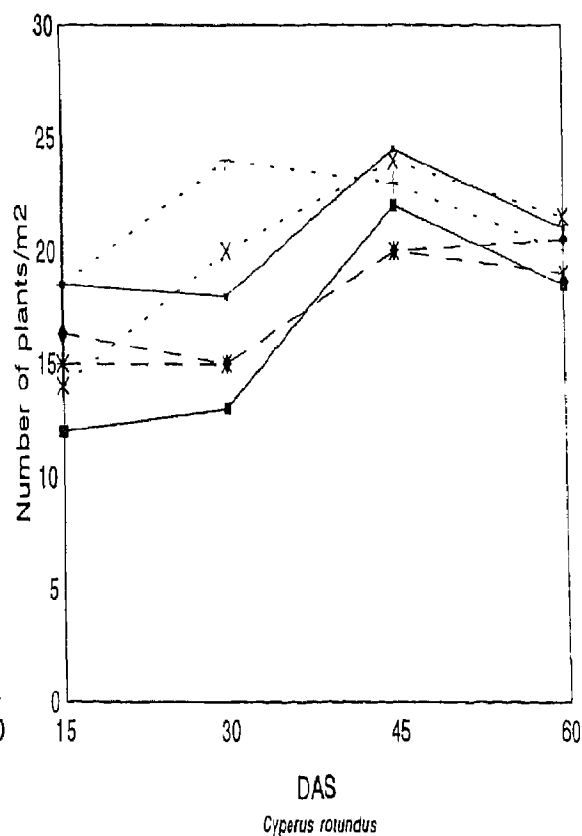
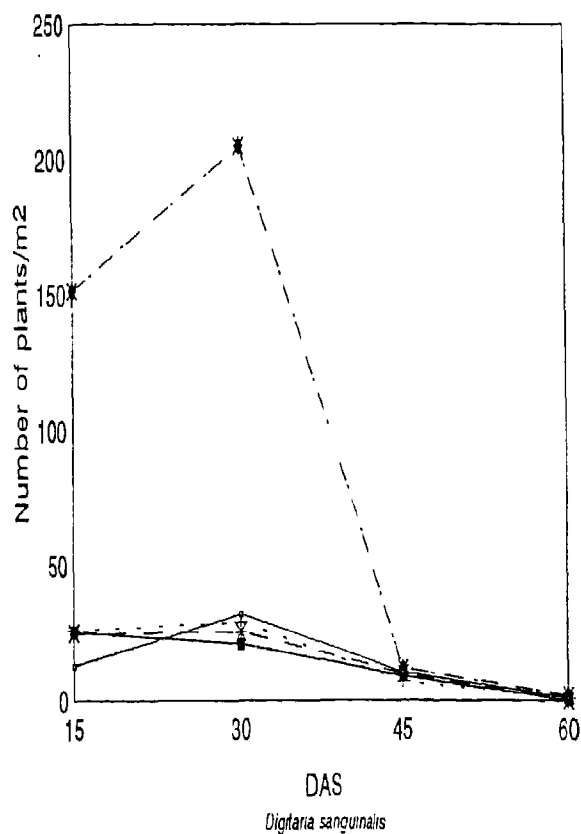
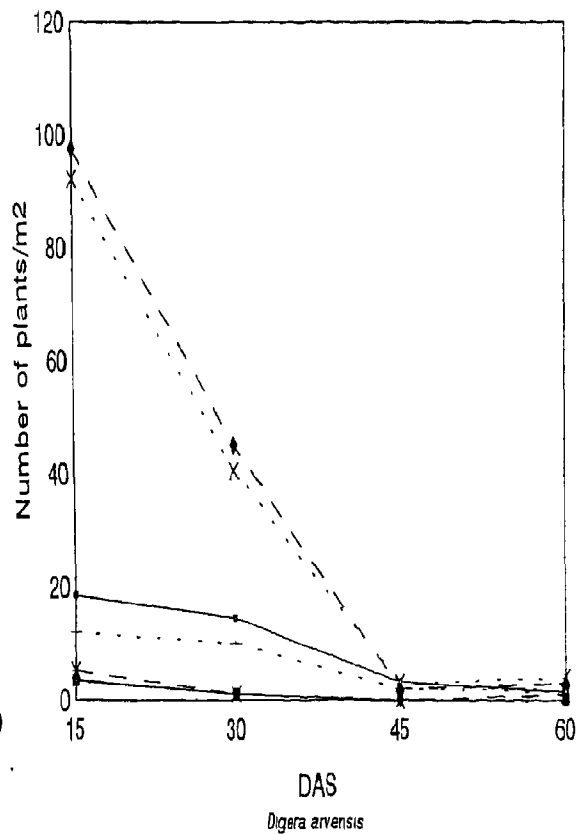
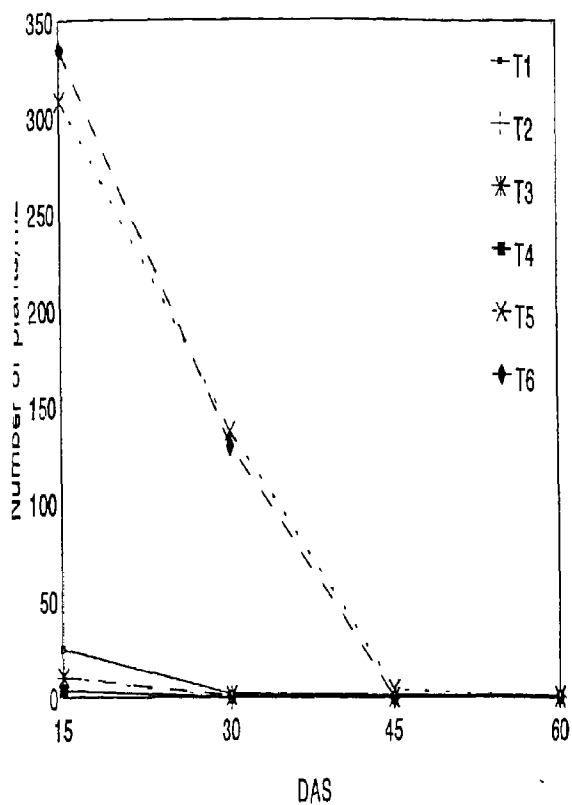


Fig.5. Emergence pattern of weeds in soybean as affected by direct effect of herbicides

Table 8. Emergence pattern of *Echinochloa colonum* in soybean 15,30,45 and 60 DAS as affected by direct effect of pendimethalin and metribuzin in 1995-96

	Emergence (No. of Plants /m ²)			
	15 DAS	30 DAS	45 DAS	60 DAS
T ₁ Pendimethalin 1.0 kg/ha	4.17 (17.0)	4.28 (18.0)	2.30 (5.0)	1.18 (1.0)
T ₂ Pendimethalin 1.50 kg/ha	3.51 (12.0)	3.66 (13.0)	1.83 (3.0)	1.56 (0.0)
T ₃ Metribuzin 0.50 kg/ha	2.53 (6.0)	2.46 (6.0)	1.83 (3.0)	1.56 (2.0)
T ₄ Metribuzin 0.75 kg/ha	2.59 (6.5)	2.72 (7.5)	1.56 (2.0)	0.71 (0.0)
T ₅ Hand weeding (20 & 40 DAS)	9.02 (81.0)	8.93 (79.5)	6.35 (40.0)	1.50 (2.0)
T ₆ Weedy Check	9.25 (85.5)	9.67 (93.0)	7.10 (50.0)	1.82 (3.0)
SEm ±	0.21	0.31	0.23	0.38
CD at 5%	0.63	0.94	0.69	NS

Figures in parenthesis indicate the original values.

effect of almost all herbicide treatments was alike. At 45-day stage, the emergence under pendimethalin at 1.5 kg/ha, metribuzin at 0.50 and 0.75 kg/ha and weedy check was identical but significantly lower than hand weeding and pendimethalin at 1.0 kg/ha.

Weed control treatments had marked effect on the emergence of *D. arvensis* at 15, 30, 45 and 60-day stages. At 15 and 30-day stage, metribuzin application both at 0.5 and 0.75 kg/ha lowered the emergence of *D. arvensis* as compared to weedy check and hand weeding significantly. Emergence in pendimethalin at 1.0 and 1.5 kg/ha was almost similar but slightly higher than in metribuzin. Even at 45-day stage effect of

metribuzin (0.5 and 0.75 kg/ha) was well marked. Pendimethalin (1.0 and 1.5 kg/ha) and hand weeding failed to check the emergence. At 60-day stage, emergence under metribuzin at 0.75 kg/ha was significantly lower as compared to pendimethalin (1.0 and 1.5 kg/ha) and hand weeding but at 0.50 kg/ha it was similar to pendimethalin.

At 15 and 30 day stages emergence of *D. sanguinalis* in pendimethalin (1.0 and 1.5 kg/ha) and metribuzin (0.5 and 0.75 kg/ha) was significantly lower than hand weeding and weedy check.

Cyperus rotundus emergence at 30-day stage under metribuzin and weedy check was markedly lower than pendimethalin and hand weeding.

Emergence of *Echinochloa colonum* at 15, 30 and 45-day stages under metribuzin and pendimethalin (1.0 and 1.5 kg/ha) was identical but significantly lower than hand weeding.

4.1.3 Specieswise weed population

Data on specieswise weed population 30, 60 DAS and at harvest (110 DAS) are presented in Table 9, 10, 11, 12, 13 and 14. The relative density, relative frequency, relative dominance and important value index of some major weeds are presented in Appendix II.

4.1.3.1 *Digitaria sanguinalis* : In both the years (1995-96 and 1996-97) 30 DAS, the population of *D. sanguinalis* was affected markedly by weed control treatments. Metribuzin (0.5 kg/ha and 0.75 kg/ha) proved superior to pendimethalin (1.0 and 1.5 kg/ha) and hand weeding in arresting the population. No significant difference existed between pendimethalin (1.0 kg/ha) and hand weeding but both lowered the population over weedy check. In both the years, 60 DAS and at the

Table 9. Weed population (no. of plants/m²) in soybean 30 DAS as affected by direct effect of pendimethalin and metribuzin in 1995-96

	<i>Digitaria sanguinalis</i>	<i>Trianthema portulacastrum</i>	Monocots	Dicots	Total Weeds
T ₁ Pendimethalin 1.0 kg/ha	3.66 (13.0)	0.71 (0.0)	7.98 (63.5)	2.33 (5.0)	8.30 (68.5)
T ₂ Pendimethalin 1.50 kg/ha	2.98 (8.0)	0.71 (0.0)	7.03 (49.0)	1.83 (3.0)	7.24 (52.0)
T ₃ Metribuzin 0.50 kg/ha	1.58 (2.0)	0.71 (0.0)	6.71 (37.0)	1.84 (3.0)	6.32 (40.0)
T ₄ Metribuzin 0.75 kg/ha	1.56 (2.0)	0.71 (0.0)	5.94 (35.0)	1.13 (1.0)	6.03 (36.0)
T ₅ Hand weeding (20 & 40 DAS)	3.21 (10.0)	6.74 (4.70)	5.23 (27.0)	6.48 (41.5)	8.30 (68.5)
T ₆ Weedy check	11.62 (134.5)	17.08 (291.0)	16.22 (262.7)	20.68 (427.3)	26.28 (690.0)
SEm ±	0.17	0.08	0.20	0.22	0.20
CD at 5%	0.51	0.26	0.61	0.67	0.62

Figures in parenthesis indicate the original values.

Table 10. Weed population (no. of plants/m²) in soybean 30 DAS as affected by direct effect of pendimethalin and metribuzin in 1996-97

	<i>Digitaria sanguinalis</i>	<i>Trianthema portulacastrum</i>	Monocots	Dicots	Total Weeds
T ₁ Pendimethalin 1.0 kg/ha	3.36 (11.0)	3.10 (10.0)	7.47 (55.5)	2.61 (6.5)	7.90 (62.0)
T ₂ Pendimethalin 1.50 kg/ha	3.23 (10.0)	0.71 (0.0)	5.95 (35.0)	2.54 (6.0)	6.40 (41.0)
T ₃ Metribuzin 0.50 kg/ha	1.56 (2.0)	0.71 (0.0)	5.15 (27.0)	1.70 (2.5)	5.46 (29.5)
T ₄ Metribuzin 0.75 kg/ha	0.71 (0.0)	0.71 (0.0)	4.62 (21.0)	1.72 (2.5)	4.89 (23.5)
T ₅ Hand weeding (20&40 DAS)	2.87 (8.0)	6.10 (37.0)	5.51 (30.0)	5.42 (29.0)	7.69 (59.0)
T ₆ Weedy check	11.43 (130.2)	15.86 (251.2)	16.52 (249.3)	19.45 (378.0)	25.05 (627.3)
SEm ±	0.20	0.18	0.43	0.21	0.29
CD at 5%	0.60	0.57	1.31	0.65	0.88

Figures in parenthesis indicate the original values.

Table 11. Weed population (no. of plants/m²) in soybean 60 DAS as affected by direct effect of pendimethalin and metribuzin in 1995-96

	Digitaria sanguinalis	Trianthema portulacastrum	Monocots	Dicots	Total Weeds
T ₁ Pendimethalin 1.0 kg/ha	3.87 (10.5)	1.70 (2.5)	6.81 (46.0)	3.60 (12.5)	7.68 (58.5)
T ₂ Pendimethalin 1.50 kg/ha	2.97 (9.0)	1.58 (2.0)	6.48 (41.5)	2.82 (8.0)	7.06 (49.5)
T ₃ Metribuzin 0.50 kg/ha	2.73 (7.0)	1.22 (1.0)	5.55 (30.5)	1.87 (3.0)	5.82 (33.5)
T ₄ Metribuzin 0.75 kg/ha	2.73 (6.5)	0.71 (0.0)	5.26 (27.5)	1.70 (2.5)	5.52 (30.0)
T ₅ Hand weeding (20&40 DAS)	1.18 (1.0)	3.23 (10.0)	4.05 (16.0)	5.31 (28.0)	6.66 (44.0)
T ₆ Weedy check	8.64 (74.5)	2.81 (7.5)	11.36 (128.5)	7.40 (54.5)	13.54 (183.0)
SEm ±	0.23	0.14	0.21	0.20	0.18
CD at 5%	0.70	0.41	0.63	0.62	0.54

Figures in parenthesis indicate the original values.

Table 12. Weed population (no. of plants/m²) in soybean 60 DAS as affected by direct effect of pendimethalin and metribuzin in 1996-97

	Digitaria sanguinalis	Trianthema portulacastrum	Monocots	Dicots	Total Weeds
T ₁ Pendimethalin 1.0 kg/ha	2.96 (8.5)	1.18 (1.0)	5.96 (35.5)	2.44 (5.5)	6.94 (41.0)
T ₂ Pendimethalin 1.50 kg/ha	2.98 (8.5)	0.71 (0.0)	5.56 (30.5)	1.13 (1.0)	5.65 (31.5)
T ₃ Metribuzin 0.50 kg/ha	2.34 (5.0)	0.71 (0.0)	4.63 (21.0)	1.56 (2.0)	4.83 (23.0)
T ₄ Metribuzin 0.75 kg/ha	2.22 (4.5)	0.71 (0.0)	4.63 (21.0)	0.71 (0.0)	4.59 (21.0)
T ₅ Hand weeding (20&40 DAS)	1.98 (3.5)	3.23 (10.0)	3.99 (15.5)	3.80 (14.0)	5.47 (29.5)
T ₆ Weedy check	7.77 (60.0)	2.64 (6.5)	11.83 (139.5)	7.96 (63.0)	14.24 (202.5)
SEm ±	0.18	0.09	0.13	0.18	0.21
CD at 5%	0.54	0.28	0.38	0.53	0.63

Figures in parenthesis indicate the original values.

Table 13. Weed population (no. of plants/m²) in soybean 110 DAS as affected by direct effect of pendimethalin and metribuzin in 1995-96

	<i>Digitaria sanguinalis</i>	<i>Trianthema portulacastrum</i>	Monocots	Dicots	Total Weeds
T ₁ Pendimethalin 1.0 kg/ha	3.15 (9.5)	1.56 (2.0)	6.40 (40.5)	3.92 (15.0)	7.29 (55.5)
T ₂ Pendimethalin 1.50 kg/ha	3.06 (9.0)	0.71 (0.0)	5.60 (31.0)	3.44 (11.5)	6.54 (42.5)
T ₃ Metribuzin 0.50 kg/ha	2.53 (6.0)	0.71 (0.0)	4.99 (24.5)	1.85 (3.0)	5.28 (27.5)
T ₄ Metribuzin 0.75 kg/ha	2.53 (6.0)	0.71 (0.0)	4.62 (21.0)	1.86 (3.0)	4.94 (24.0)
T ₅ Hand weeding (20&40 DAS)	1.72 (2.5)	3.23 (10.0)	5.65 (31.5)	4.68 (21.5)	7.31 (53.0)
T ₆ Weedy check	5.17 (26.5)	1.82 (3.0)	7.34 (53.5)	5.95 (35.0)	9.42 (88.5)
SEm ±	0.19	0.13	0.17	0.15	0.20
CD at 5%	0.56	0.38	0.53	0.45	0.60

Figures in the parenthesis indicate the original values.

Table 14. Weedy population (no. of plants/m²) in soybean 110 DAS as affected by direct effect of pendimethalin and metribuzin in 1996-97

	<i>Digitaria sanguinalis</i>	<i>Trianthema portulacastrum</i>	Monocots	Dicots	Total Weeds
T ₁ Pendimethalin 1.0 kg/ha	3.14 (9.5)	1.54 (2.0)	5.61 (31.6)	3.73 (13.5)	6.69 (44.5)
T ₂ Pendimethalin 1.50 kg/ha	2.88 (8.0)	1.18 (1.0)	5.33 (28.0)	3.04 (9.0)	6.12 (37.0)
T ₃ Metribuzin 0.50 kg/ha	2.11 (4.0)	0.71 (0.0)	3.93 (15.5)	2.23 (4.5)	4.45 (19.5)
T ₄ Metribuzin 0.75 kg/ha	2.21 (4.5)	0.71 (0.0)	3.60 (12.5)	1.70 (2.5)	3.87 (14.5)
T ₅ Hand weeding (20&40 DAS)	1.40 (1.5)	2.90 (8.0)	4.35 (19.0)	3.85 (14.5)	5.77 (33.0)
T ₆ Weedy check	4.67 (19.5)	2.34 (5.0)	6.44 (41.0)	5.42 (29.0)	8.39 (70.0)
SEm ±	0.17	0.13	0.13	0.16	0.17
CD at 5%	0.51	0.40	0.40	0.47	0.51

Figures in parenthesis are the original values.

harvest (110 DAS) pendimethalin and metribuzin were similar in their effect but proved statistically inferior to hand weeding.

4.1.3.2 *Trianthema portulacastrum* : In both the years 30 DAS herbicide treatments lowered the *T. portulacastrum* population significantly as compared to weed check and hand weeding. 60 DAS, under pendimethalin at 1.0 and 1.5 kg/ha and metribuzin at 0.5 and 0.75 kg/ha population was significantly lower as compared to weedy check. In 1995-96, at harvest, effect of pendimethalin at 1.5 kg/ha and metribuzin both at 0.5 and 0.75 kg/ha was conspicuous and they proved statistically superior to hand weeding, weedy check and pendimethalin at 1.0 kg/ha. No significant difference existed between latter two treatments. The similar was the effect of weed control treatments in 1996-97.

4.1.3.3 Monocots weeds : In the year 1995-96 30 DAS, hand weeding proved significantly superior to pendimethalin (1.0 and 1.5 kg/ha) and metribuzin at 0.5 and 0.75 kg/ha in reducing the population of monocots weeds, whereas, in 1996-97 it failed to arrest the population and proved inferior to metribuzin at 0.75 kg/ha. At 60-day stage in both the years, pendimethalin and metribuzin at both doses were found inferior to hand weeding but significantly superior to weedy check. In both the years, at harvest, metribuzin (0.5 and 0.75 kg/ha) caused maximum decrease and proved significantly superior to all other treatments in decreasing the monocots population.

4.1.3.4. Dicot weeds : In both the years 30 DAS, population of dicots in pendimethalin (1.0 and 1.5 kg/ha) and metribuzin (0.5 and 0.75 kg/ha) was identical but significantly lower than hand weeding and weedy

check. Difference between latter two treatments was significant. In both the years, 60 DAS, all the weed control treatments resulted in significantly lower population as compared to weedy check. In 1995-96, at 110 day stage metribuzin at both doses caused identical decrease and proved statistically superior to all other treatments in arresting the population whereas, in 1996-97 effect of metribuzin at 0.75 kg/ha was well pronounced and it proved significantly superior to pendimethalin (1.0 and 1.5 kg/ha), hand weeding and weedy check. Population under pendimethalin at 1.0 kg/ha and hand weeding was almost similar.

4.1.3.5 Total weed population : In both the years 30 and 110 DAS, the total weed population was significantly lower in weed control treatments as compared to weedy check. Effect of metribuzin (0.50 and 0.75 kg/ha) was well pronounced and it proved significantly superior to pendimethalin (1.0 and 1.5 kg/ha), hand weeding and weedy check in curtailing total weed population. Pendimethalin at 1.0 kg/ha and hand weeding caused similar reduction but were significantly inferior to pendimethalin at 1.5 kg/ha. At 60day stage, in both the years, metribuzin at both doses (0.50 and 0.75 kg/ha) proved its superiority over hand weeding and pendimethalin both at 1.0 and 1.5 kg/ha. Hand weeding and pendimethalin at 1.5 kg/ha resulted in significantly higher decrease than pendimethalin at 1.0 kg/ha.

4.1.4 Dry matter accumulation by weeds

Data on dry matter accumulation by various weeds 30 and 60 DAS and at harvest (110 DAS) as affected by different weed control treatments are presented in Table 15 and 16 and depicted in the Fig. 6.

Table 15. Dry matter accumulation by weeds (g/m²) in soybean 30,60 and 110 DAS as affected by direct effect of pendimethalin and metribuzin in 1995-96

Treatments	Weed dry matter accumulation		
	30 DAS	60 DAS	110 DAS
T ₁ Pendimethalin 1.0 kg/ha	4.63 (21.0)	6.62 (43.4)	8.00 (56.7)
T ₂ Pendimethalin 1.5 kg/ha	3.87 (14.5)	5.47 (29.5)	6.54 (37.5)
T ₃ Metribuzin 0.5 kg/ha	1.92 (3.2)	2.86 (7.7)	3.70 (13.2)
T ₄ Metribuzin 0.75 Kg/ha	1.58 (2.0)	2.54 (6.0)	3.63 (12.7)
T ₅ Hand weeding (20&40 DAS)	2.94 (8.2)	4.30 (18.0)	5.33 (28.0)
T ₆ Weedy check	9.35 (87.0)	12.27 (150.2)	13.37 (178.2)
SEm ±	0.09	0.09	0.24
CD at 5%	0.28	0.28	0.73

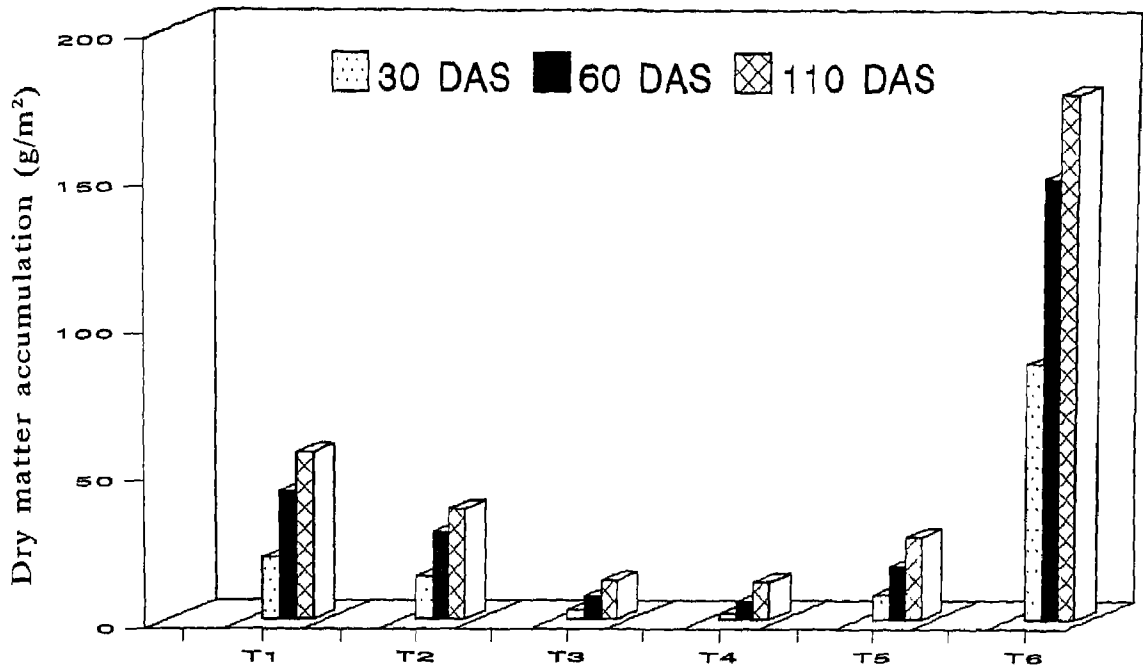
Figures in the paranthesis indicate the original values.

Table 16. Dry matter accumulation by weeds (g/m²) in soybean 30,60 and 110 DAS as affected by direct effect of pendimethalin and metribuzin in 1996-97

Treatments	Weed dry matter accumulation		
	30 DAS	60 DAS	110 DAS
T ₁ Pendimethalin 1.0 kg/ha	4.08 (16.2)	5.56 (30.7)	6.34 (40.0)
T ₂ Pendimethalin 1.5 kg/ha	3.95 (15.2)	5.09 (27.5)	5.96 (35.1)
T ₃ Metribuzin 0.5 kg/ha	1.97 (3.4)	2.83 (7.5)	3.41 (11.2)
T ₄ Metribuzin 0.75 kg/ha	1.41 (1.7)	2.62 (6.4)	3.33 (10.7)
T ₅ Hand weeding (20&40 DAS)	2.64 (6.5)	5.62 (35.2)	4.85 (23.0)
T ₆ Weedy check	8.71 (75.4)	11.44 (130.7)	12.65 (159.5)
SEm ±	0.11	0.70	0.16
CD at 5%	0.33	2.11	0.50

Figures in parenthesis indicate the original values.

1995-96



1996-97

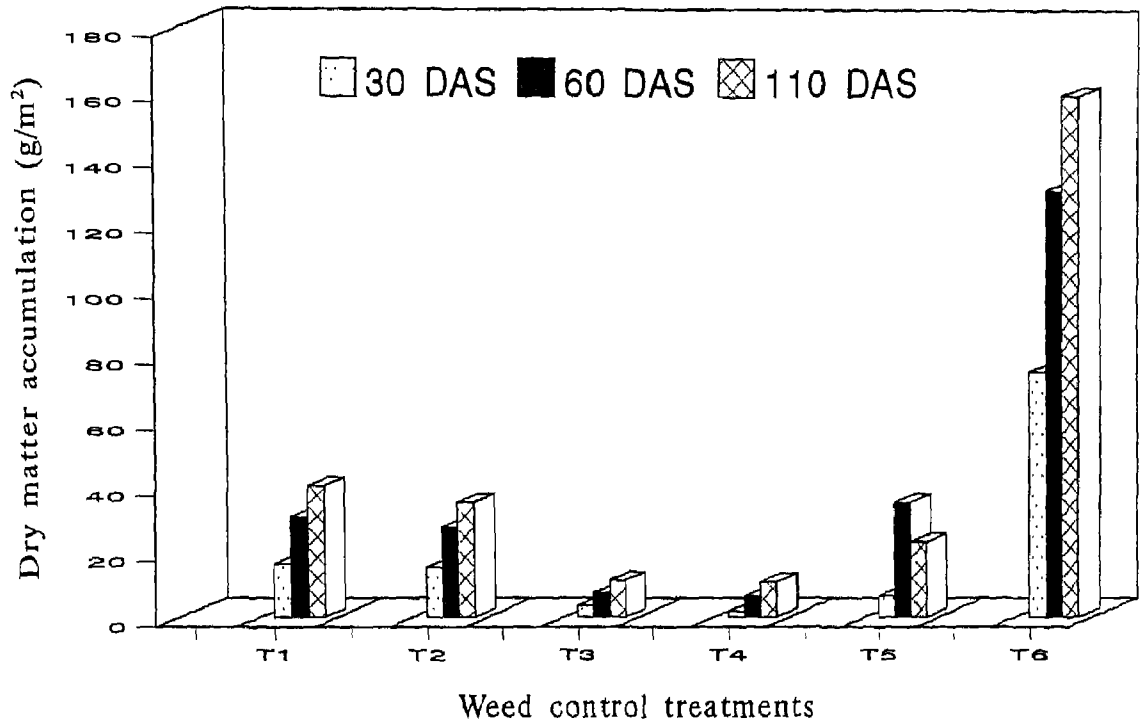


Fig. 6. Dry matter accumulation by weeds in soybean as affected by direct effect of pendimethalin and metribuzin

In both the years at 30-day stage metribuzin (at 0.5 and 0.75 kg/ha) and hand weeding caused higher reduction in weed biomass production and proved significantly superior to pendimethalin both at 1.0 and 1.5 kg/ha. Effect of latter two treatments was more or less similar. In 1995-96, 60 DAS, metribuzin both at 0.50 and 1.5 kg/ha resulted in maximum decrease and proved significantly superior to hand weeding and pendimethalin (1.0 and 1.5 kg/ha) and weeding check. But differences among latter three treatments were significant. In the year 1996-97, pendimethalin at 1.0 and 1.5 kg/ha and hand weeding caused identical decrease but significantly lower than metribuzin both at 0.50 and 0.75 kg/ha. In both the years the effect of weed control treatment 60 DAS and at harvest was almost alike.

4.1.5 Nitrogen, phosphorus and potassium content in weeds

Data pertaining to nitrogen, phosphorus and potassium content in weeds at harvest (110 DAS) are summarized in Table 17.

Table 17. Nitrogen, phosphorus and potassium content (%) in weeds at harvest (110 DAS) in soybean as affected by direct effect of pendimethalin and metribuzin.

Treatments	1995-96			1996-97		
	N	P	K	N	P	K
T ₁ Pendimethalin 1.0 kg/ha	1.23	0.14	1.01	1.24	0.15	0.99
T ₂ Pendimethalin 1.50 kg/ha	1.18	0.12	0.88	1.22	0.14	0.91
T ₃ Metribuzin 0.50 kg/ha	1.14	0.10	0.79	1.12	0.12	0.78
T ₄ Metribuzin 0.75 kg/ha	1.14	0.10	0.75	1.10	0.10	0.75
T ₅ Hand weeding (20&40 DAS)	1.18	0.13	1.07	1.18	0.13	1.01
T ₆ Weedy Check	1.37	0.21	1.41	1.28	0.18	1.24
SEm	0.26	0.21	0.27	0.15	0.20	0.25
CD at 5%	NS	NS	NS	NS	NS	NS

In both the years at harvest (110 DAS), N, P and K contents in weeds were not affected due to weed control treatments statistically.

4.1.6 Nitrogen, phosphorus and potassium depletion by weeds

Data on nitrogen, phosphorus and potassium depletion by weeds at harvest (110 DAS) are summerized in Table 18 and depicted in Fig. 7.

Table 18. Nitrogen, phosphorus and potassium depletion (kg/ha) by weeds in soybean as affected by direct effect of pendimethalin and metribuzin

Treatments	1995-96			1996-97		
	N	P	K	N	P	K
T ₁ Pendimethalin 1.0 kg/ha	2.73 (6.97)	1.14 (0.79)	2.49 (5.72)	2.33 (4.96)	1.04 (0.60)	2.11 (3.96)
T ₂ Pendimethalin 1.50 kg/ha	2.27 (4.69)	0.97 (0.45)	1.95 (3.30)	2.18 (4.28)	0.99 (0.49)	1.92 (3.19)
T ₃ Metribuzin 0.50 kg/ha	1.41 (1.50)	0.79 (0.13)	1.24 (1.04)	1.32 (1.25)	0.79 (0.13)	1.17 (0.87)
T ₄ Metribuzin 0.75 kg/ha	1.38 (1.41)	0.79 (0.12)	1.20 (0.95)	1.29 (1.17)	0.77 (0.10)	1.14 (0.80)
T ₅ Hand weeding (20&40 DAS)	1.94 (3.30)	0.93 (0.36)	1.86 (2.99)	1.74 (2.53)	0.89 (0.30)	1.68 (2.32)
T ₆ Weedy Check	4.99 (24.41)	2.06 (3.74)	5.06 (25.13)	4.57 (20.41)	1.83 (2.87)	4.50 (19.78)
SEm ±	0.20	0.10	0.17	0.15	0.12	0.15
CD at 5%	0.61	0.30	0.52	0.45	0.36	0.46

4.1.6.1 Nitrogen depletion : In both the years metribuzin (at 0.50 and 0.75 kg/ha), pendimethalin (at 1.0 and 1.5 kg/ha) and hand weeding brought down the N depletion significantly as compared to weedy check.

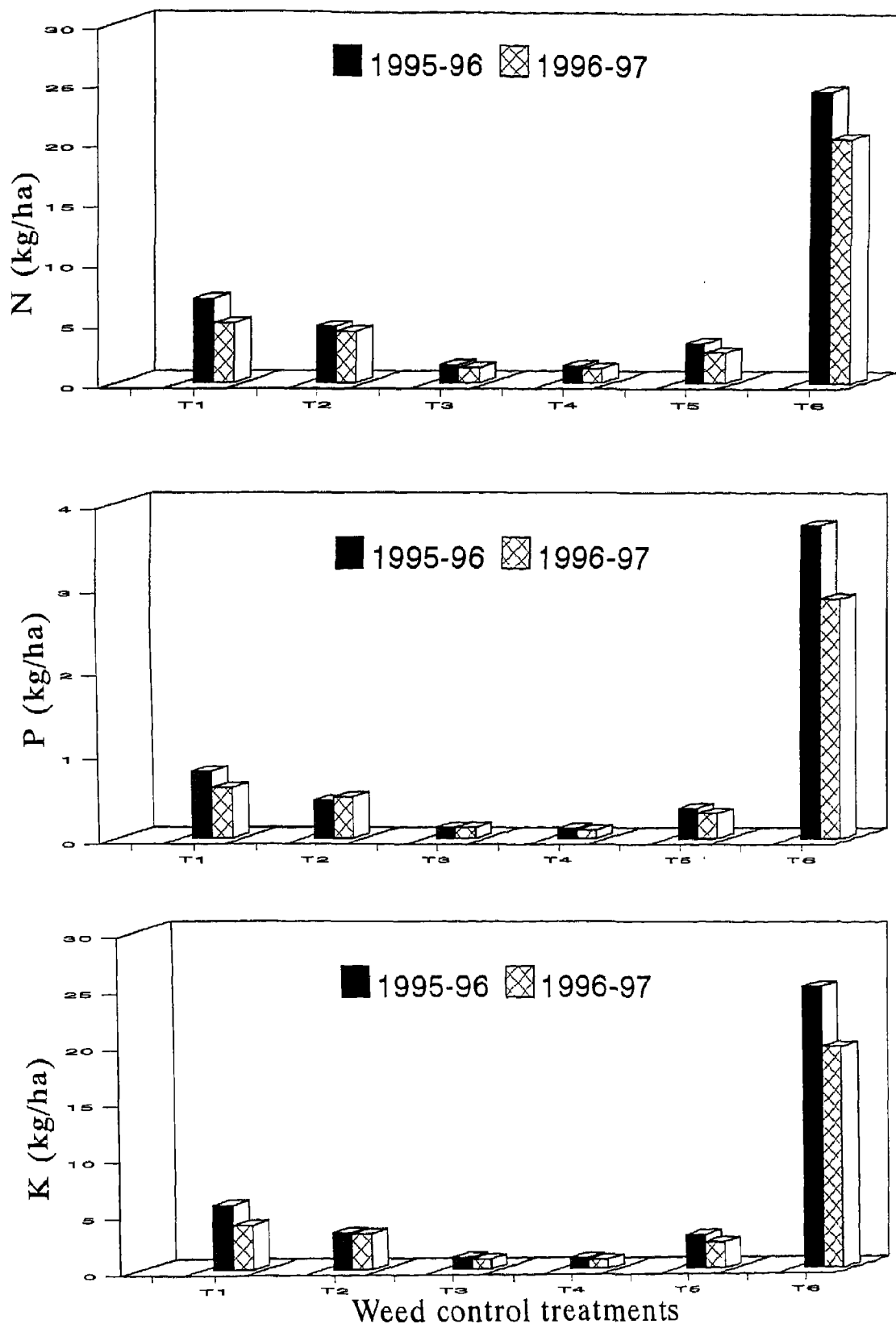


Fig. 7. N, P and K depletion by weeds in soybean as affected by direct effect of pendimethalin and metribuzin

No significant differences existed between two doses of metribuzin and pendimethalin. Metribuzin at both doses (0.50 and 0.75 kg/ha) arrested N depletion significantly higher as compared to pendimethalin at 1.0 kg/ha and 1.5 kg/ha. No significant differences existed among two doses of metribuzin and hand weeding. N depletion under metribuzin 0.50 and 0.75 kg/ha, pendimethalin at 1.0 and 1.5 kg/ha, handweeding and weedy check was to the tune of 1.50, 1.41, 6.97, 4.69, 3.30 and 24.41 kg/ha in 1995-96 and 1.25, 1.17, 4.96, 4.26, 2.53 and 20.41 in 1996-97, respectively.

4.1.6.2 Phosphorus depletion : Metribuzin, pendimethalin and hand weeding caused significant reduction in P depletion by weeds as compared to weedy check in both the years. Metribuzin at 0.50 and 0.75 kg/ha proved statistically superior to pendimethalin at 1.0 kg/ha in arresting P depletion. No significant differences existed among metribuzin doses, hand weeding and pendimethalin at 1.5 kg/ha in 1995-96 but in 1996-97 all weed control treatments were similar in their effect in arresting P depletion. Depletion of P under treatments metribuzin at 0.50 and 0.75 kg/ha, pendimethalin at 1.0 and 1.5 kg/ha, hand weeding and weedy check was 0.13, 0.12, 0.79, 0.45, 0.36 and 3.74 kg/ha in 1995-96 and 0.13, 0.10, 0.60, 0.49, 0.30 and 2.87 in 1996-97, respectively.

4.1.6.3 Potassium depletion : In both the years, metribuzin (0.50 and 0.75 kg/ha), pendimethalin (1.0 and 1.5 kg/ha) and hand weeding arrested K depletion and proved significantly superior to weedy check. No significant difference existed between two doses of metribuzin but were significantly superior to hand weeding and pendimethalin at 1.0 and 1.5

kg/ha. Latter two treatments were similar in their effect. Depletion of K under treatments metribuzin at 0.50 and 0.75 kg/ha, pendimethalin at 1.0 and 1.5 kg/ha, hand weeding and weedy check was to the tune of 1.04, 0.95, 5.72, 3.30, 2.99 and 25.13 kg/ha in 1995-96 and 0.87, 0.80, 3.96, 3.19, 2.32 and 19.78 kg/ha in 1996-97, respectively.

4.2 STUDIES ON SOYBEAN

4.2.1 Growth and development

Data pertaining to plant population, plant height, number of trifoliolate leaves and dry matter production by soybean at different growth stages are presented in Tables 19, 20, 21 and 22.

4.2.1.1 Plant population : Plant population was not influenced significantly due to different weed control treatments at any stage in both the years (Table 19).

Table 19. Soybean plant population (no. of plants/m) 30 DAS and at harvest as affected by direct effect of pendimethalin and metribuzin

Treatments	1995-96		1996-97	
	30 DAS	At harvest	30 DAS	At harvest
T ₁ Pendimethalin 1.0 kg/ha	15.23	15.00	16.42	16.13
T ₂ Pendimethalin 1.50 kg/ha	15.50	15.10	16.10	16.00
T ₃ Metribuzin 0.50 kg/ha	15.40	15.17	16.50	16.42
T ₄ Metribuzin 0.75 kg/ha	14.83	14.80	15.90	15.90
T ₅ Hand weeding (20&40 DAS)	15.10	15.00	16.67	16.60
T ₆ Weedy check	15.17	14.93	16.53	16.10
SEm ±	0.33	0.27	0.29	0.30
CD at 5%	NS	NS	NS	NS

Variation in weed control treatments had no significant effect on plant height at 30 and 60 day stages in any years but at harvest in metribuzin at 0.50 kg/ha, pendimethalin both at 1.0 and 1.5 kg/ha and hand weeding brought about similar increase in height and proved superior to metribuzin at 0.75 kg/ha and weedy check (Table 20).

Table 20. Plant height (cm) of soybean 30,60 DAS and at harvest as affected by direct effect of pendimethalin and metribuzin

Treatments	1995-96			1996-97		
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
T ₁ pendimethalin 1.0 kg/ha	31.37	70.62	83.47	35.12	76.10	91.25
T ₂ Pendimethalin 1.50 kg/ha	30.12	66.62	81.60	34.00	75.12	90.00
T ₃ metribuzin 0.50 kg/ha	32.12	64.72	84.12	36.20	73.00	92.47
T ₄ Metribuzin 0.75 kg/ha	32.00	62.77	77.25	35.97	70.86	83.00
T ₅ Hand weeding (20&40 DAS)	33.32	68.47	81.47	36.87	73.60	88.97
T ₆ Weedy Check	33.50	69.75	75.32	37.00	77.33	80.12
SEm ±	1.23	3.11	1.90	0.85	1.39	1.42
CD at 5%	NS	NS	5.73	NS	NS	4.29

4.2.1.2 Number of trifoliate leaves : Weed control treatments had no marked effect on number of trifoliate leaves at any stage in 1995-96 but their effect was conspicuous in 1996-97 at both 30 and 60 day stages. At 30 day stage hand weeding resulted in maximum increase and proved significantly superior to metribuzin at 0.75 kg and weedy check but at 60 day stage it proved superior to all herbicide treatments. No significant difference existed among pendimethalin both at 1.0 and 1.5 kg/ha and metribuzin at 0.5 kg/ha (Table 21).

Table 21. Number of trifoliate leaves (nos./plant) in soybean as affected by direct effect of pendimethalin and metribuzin

Treatments	1995-96		1996-97	
	30 DAS	60 DAS	30 DAS	60 DAS
T ₁ Pendimethalin 1.0 kg/ha	7.25	16.25	7.45	16.29
T ₂ Pendimethalin 1.50 kg/ha	6.75	17.00	7.40	16.50
T ₃ Metribuzin 0.50 kg/ha	7.25	16.62	7.47	16.80
T ₄ Metribuzin 0.75 kg/ha	6.37	16.50	6.95	15.70
T ₅ Hand weeding (20&40 DAS)	7.62	17.75	7.65	17.70
T ₆ Weedy check	5.37	13.50	5.25	14.25
SEm $\pm$	0.39	0.82	0.11	0.29
CD at 5%	NS	NS	0.34	0.88

4.2.1.3 Dry matter production : Effect of weed control treatments on dry matter production was conspicuous in both the years at 30 and 60 day stages. At 30 day stage, metribuzin at 0.5 kg/ha and pendimethalin at 1.5 kg/ha caused maximum increase in dry matter production and proved statistically superior to hand weeding and pendimethalin at 1.0 kg/ha. Significantly lowest dry matter production was recorded under weedy check. At 60 day stage the highest dry matter production was noted with application of metribuzin at 0.50 kg/ha and it proved superior to all the treatments in 1995-96 but was at par with hand weeding in 1996-97 (Table 22).

4.2.2 Nodulation Studies

Weed control treatments had no significant effect on nodule numbers (no. of nodules/plant) and nodule dry weight (g) of soybean in any year (Table 23).

Table 22. Dry matter production (g/plant) by soybean as affected by direct effect of pendimethalin and metribuzin

Treatments	1995-96		1996-97	
	30 DAS	60 DAS	30 DAS	60 DAS
T ₁ Pendimethalin 1.0 kg/ha	3.17	6.32	3.6	6.25
T ₂ Pendimethalin 1.50 kg/ha	4.15	6.90	4.1	7.00
T ₃ Metribuzin 0.50 kg/ha	4.00	7.15	4.2	7.37
T ₄ metribuzin 0.75 kg/ha	2.75	6.00	3.0	6.20
T ₅ Hand weeding (20&40 DAS)	3.55	6.52	3.8	7.23
T ₆ Weedy Check	2.47	4.24	2.3	4.6
SEm ±	0.14	0.07	0.09	0.08
CD at 5%	0.43	0.21	0.29	0.26

Table 23. Nodules numbers (no. of nodules/plant) and nodules dry weight (g) of soybean 60 DAS as affected by direct effect of pendimethalin and metribuzin

Treatments	1995-96		1996-97	
	No. of nodules	Nodules Dry weight	No. of Nodules	Nodules Dry weight
T ₁ Pendimethalin 1.0 kg/ha	47.0	0.95	43.8	0.89
T ₂ Pendimethalin 1.50 kg/ha	49.0	0.97	43.7	0.88
T ₃ Metribuzin 0.50 kg/ha	50.8	1.01	45.1	0.90
T ₄ Metribuzin 0.75 kg/ha	47.5	0.96	43.8	0.90
T ₅ Hand weeding (20&40 DAS)	48.2	0.97	44.5	0.88
T ₆ Weedy check	45.3	0.90	43.0	0.85
SEm ±	4.46	0.04	2.89	0.05
CD at 5%	NS	NS	NS	NS

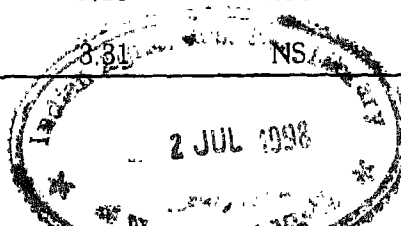
4.2.3 Yield attributing characters

Data on number of branches/plants, number of pods/plant, number of grains/pod and 1000 grain weight recorded under different treatments are presented in Table 24 and 25.

Effect of weed control treatments on number of branches/plant was conspicuous in both the years. All the weed control treatments resulted in increase in number of branches/plant as compared to weedy check but maximum increase was registered with hand weeding which proved significant superior to metribuzin at 0.5 kg/ha and pendimethalin at both doses. Difference between hand weeding and metribuzin at 0.75 kg/ha was not significant.

Table 24. Branches per plant (no. of branches/plant), pods per plant (no. of pods/plant), grains per pod (no. of grains/pod) and 1000-grain weight (g) of soybean as affected by direct effect of pendimethalin and metribuzin in 1995-96

	No. of branches/ plant	No. of pods/ plant	No. of grains/ pod	1000- grain weight
T ₁ Pendimethalin 1.0 kg/ha	4.9	19.1	2.00	90.2
T ₂ Pendimethalin 1.50 kg/ha	5.2	20.0	2.00	93.5
T ₃ Metribuzin 0.50 kg/ha	5.3	22.4	2.10	92.9
T ₄ Metribuzin 0.75 kg/ha	6.1	20.7	2.10	97.6
T ₅ Hand weeding (20 & 40 DAS)	6.8	21.9	2.10	101.5
T ₆ Weedy check	3.2	13.3	2.00	89.1
SEm $\pm$	0.32	1.10	0.15	4.02
CD at 5%	0.96	3.31	NS	NS



All the weed control treatments effected increase in the number of pods/plant over weedy check in both the years. Hand weeding resulted in maximum increase but was statistically at par with metribuzin and pendimethalin each at both doses. No significant difference existed between latter two treatments.

Number of grains/pod was not affected due to variation in weed control treatments in any year.

In both the years, weed control treatments had no effect on 1000-grain weight.

Table 25 Branches per plant (no. of branches/plant), pods per plant (no. of pods/ plant), grains per pod (no. of grains/pod) and 1000-grain weight (g) of soybean as affected by direct effect of pendimethalin and metribuzin in 1996-97

	No. of branches/ plant	No. of pods/ plant	No. of grains/ pod	1000- grain weight
T ₁ Pendimethalin 1.0 kg/ha	5.4	24.3	2.10	93.7
T ₂ Pendimethalin 1.50 kg/ha	5.8	25.8	2.10	95.9
T ₃ Metribuzin 0.50 kg/ha	5.9	27.0	2.20	95.9
T ₄ Metribuzin 0.75 kg/ha	6.7	25.1	2.10	99.3
T ₅ Hand Weeding (20&40 DAS)	7.4	26.1	2.2	102.6
T ₆ Weedy check	3.6	16.0	2.0	90.4
SEm ±	0.45	1.38	0.45	3.97
CD at 5%	1.37	4.16	NS	NS

4.2.4 yield

Data pertaining to grain yield, stover yield and harvest index recorded under various treatments are given in Table 26 and depicted in Fig. 8.

4.2.4.1 Grain yield : Weed control treatments resulted in significant increase in grain yield and their effect was almost similar in both the years. Hand weeding caused maximum increase in grain yield and proved significantly superior to pendimethalin (1.0 and 1.5 kg/ha) and weedy check but at par to metribuzin (0.5 and 0.75 kg/ha) in 1995-96 whereas in 1996-97 it was at par with pendimethalin at

Table 26. Grain yield (q/ha) stover yield (q/ha) and harvest index (%) of soybean as influenced by direct effect of pendimethalin and metribuzin

Treatments	Grain yield			Stover yield		Harvest index	
	1995-96	1996-97	Pooled	1995-96	1996-97	1996-96	1996-97
T ₁ Pendimethalin 1.0 kg/ha	15.45	22.85	19.15	21.65	34.93	41.64	39.74
T ₂ Pendimethalin 1.50 kg/ha	16.80	24.90	20.85	22.70	37.48	42.52	39.92
T ₃ Metribuzin 0.50 kg/ha	19.60	27.25	23.42	26.41	40.57	42.57	40.19
T ₄ metribuzin 0.75 kg/ha	18.70	24.50	21.60	25.66	35.95	42.06	40.52
T ₅ Hand weeding 20 & 40 DAS	21.00	28.15	24.57	27.83	40.86	43.02	40.78
T ₆ Weedy checked	10.56	13.79	12.17	15.99	22.33	39.77	38.09
SEm ±	0.83	1.49	0.91	1.06	2.25	1.20	1.16
CD at 5%	2.51	4.48	2.76	3.20	6.80	NS	NS

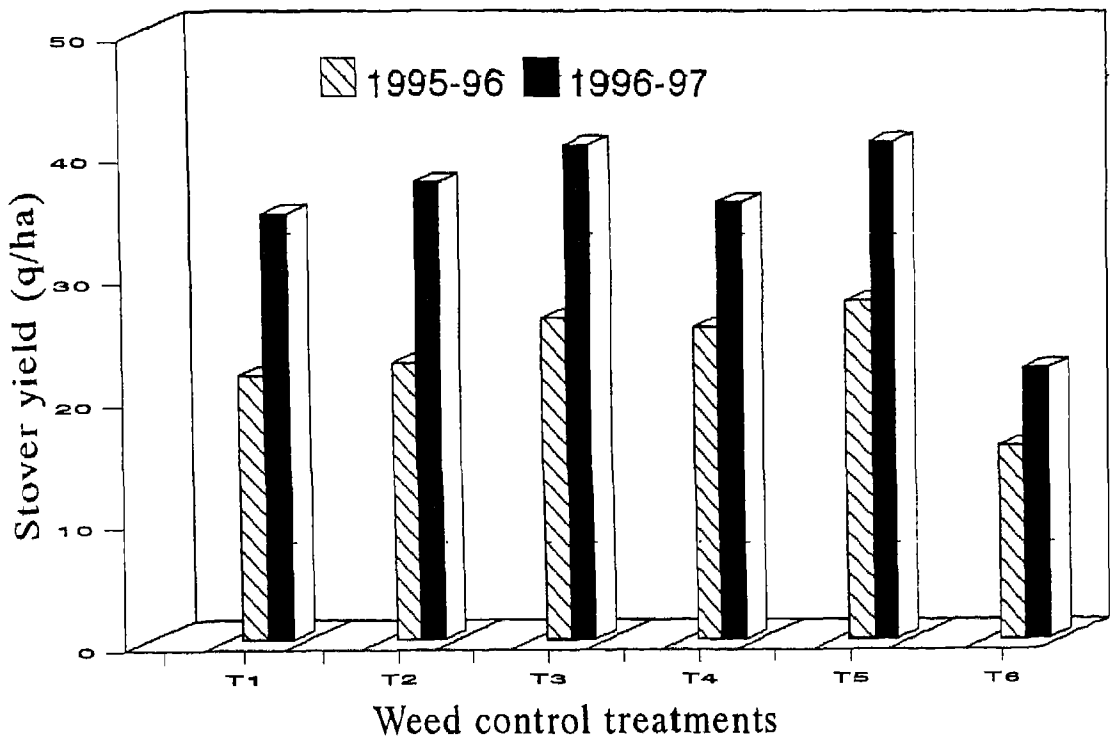
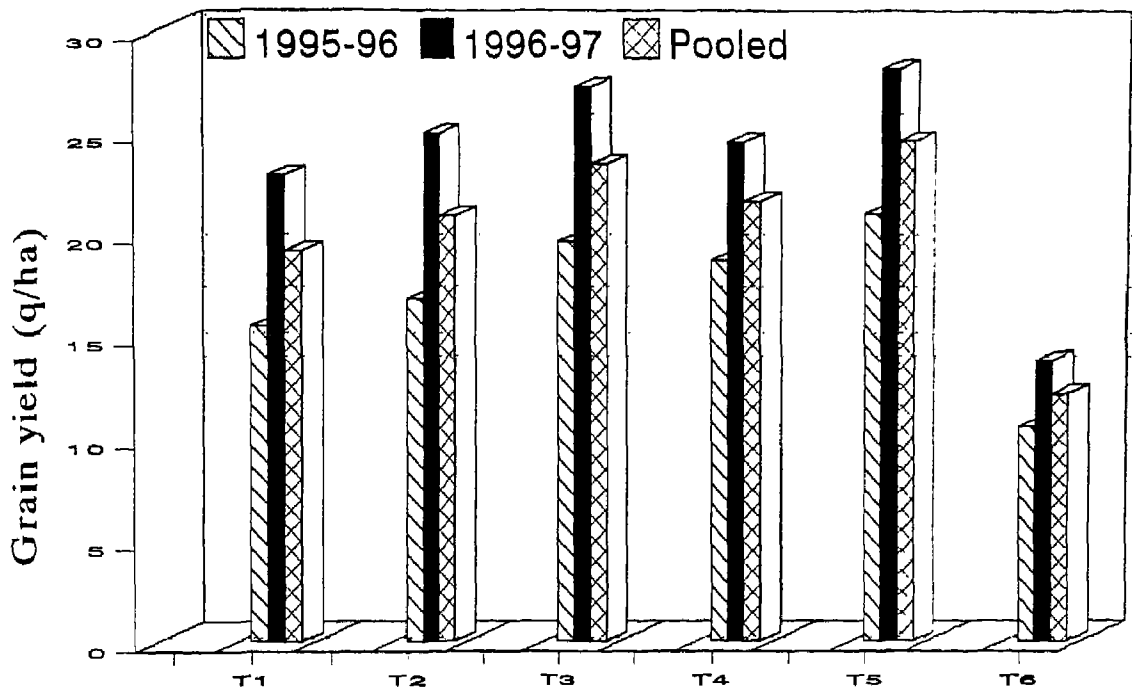


Fig. 8. Grain and stover yield of soybean as influenced by direct effect of pendimethalin and metribuzin

1.5 kg/ha also. Pendimethalin (1.0 and 1.5 kg/ha) was identical in their effect. Its application resulted in increase over weedy check but increase was not conspicuous. The increase in grain yield over weedy check was to the tune of 98.8, 85.6, 77.0, 46.3 and 59.0 per cent in 1995-96 whereas in 1996-97, it was 104.1, 97.6, 77.6, 65.6 and 80.5 per cent in hand weeding, metribuzin at 0.50 and 0.75 kg/ha and pendimethalin at 1.0 and 1.5 kg/ha respectively.

4.2.4.2 Pooled grain yield : Data pertaining to pooled grain yield are presented in Table 25 and depicted in Fig 8.

It is obvious from the data that variation in weed control treatments had a significant effect on pooled grain yield. Hand weeding resulted in highest yield (24.57 q/ha) closely followed by metribuzin at 0.5 (23.42 q/ha) and 0.75 kg/ha (21.60 q/ha); and pendimethalin at 1.0 (20.85 q/ha) and 1.5 kg/ha (19.15 q/ha). The lowest yield 12.17 q/ha was recorded in weedy check. Hand weeding proved significantly superior to all the treatments except metribuzin at 0.50 kg/ha. Differences among other treatments were non significant. All the weed control treatments proved superior to weedy check.

4.2.4.3 Stover yield : Variation in weed control treatments had pronounced effect on the stover yield of soybean. In 1995-96, hand weeding produced significantly higher stover yield as compared to pendimethalin at both doses and weedy check but was statistically similar to that of metribuzin at 0.50 and 0.75 kg/ha, whereas in 1996-97, it produced significantly higher only to that of weedy check. Application of both metribuzin (0.50 and 0.75 kg/ha) and pendimethalin (1.0 and 1.5 kg/ha) resulted in significantly higher stover yield as compared to

weedy check. Difference between doses of metribuzin at 0.50 and 0.75 kg/ha and pendimethalin at 1.0 and 1.5 kg/ha were non significant.

4.2.4.4 Harvest Index : Harvest index was not affected significantly due to variation in weed control treatments in any year (Table 26).

4.2.5 N, P and K content in soybean

In both the years, NPK content in soybean grain and stover were not affected due to weed control treatments (Table 27 and 28).

4.2.6 Nitrogen, phosphorus and potassium uptake by Soybean : Data pertaining to NPK uptake by soybean at harvest are presented in Tables 29, 30, 31 and depicted in Fig 9a and 9b.

4.2.6.1. Uptake by grain

(a) **Nitrogen :** Hand weeding facilitated higher uptake and proved significantly superior to pendimethalin at 1.0 and 1.5 kg/ha and weedy check in 1995-96 but in 1996-97 hand weeding and pendimethalin at 1.50 kg/ha resulted in similar uptake. Application of metribuzin (0.50 and 0.75 kg/ha) and pendimethalin (1.0 and 1.5 kg/ha) caused significant increase in N uptake and proved statistically superior to weedy check in both the years but they were inferior to hand weeding. There was non significant difference between doses of metribuzin (0.50 and 0.75 kg/ha) and pendimethalin (1.0 and 1.5 kg/ha).

(b) **Phosphorus :** All the weed control treatments registered significantly higher P uptake than weedy check in both the years. Hand weeding resulted in highest uptake and proved significantly superior to pendimethalin at 1.0 kg/ha and weedy check but was statistically at par with metribuzin at 0.50 and 0.75 kg/ha and pendimethalin at 1.5 kg/ha. Metribuzin

Table 27. Nitrogen, phosphorus and potassium content (%) in soybean at harvest as affected by direct effect of pendimethalin and metribuzin in 1995-96

Treatments	Grain			Stover		
	N	P	K	N	P	K
T ₁ Pendimethalin 1.0 kg/ha	6.61	0.98	1.62	0.73	0.19	0.90
T ₂ Pendimethalin 1.5 kg/ha	6.66	1.00	1.65	0.74	0.21	0.92
T ₃ Metribuzin 0.5 kg/ha	6.56	0.93	1.63	0.71	0.18	0.88
T ₄ Metribuzin 0.75 kg/ha	6.55	0.92	1.61	0.72	0.17	0.86
T ₅ Hand weeding (20&40 DAS)	6.52	0.92	1.60	0.70	0.20	0.88
T ₆ Weedy Check	6.35	0.90	1.54	0.69	0.15	0.81
SEm ±	0.27	0.10	0.04	0.02	0.01	0.05
CD at 5%	NS	NS	NS	NS	NS	NS

Table 28 Nitrogen, phosphorus and potassium content (%) of soybean at harvest as affected by direct effect of pendimethalin and metribuzin in 1996-97

Treatments	Grain			Stover		
	N	P	K	N	P	K
T ₁ Pendimathalin 1.0 kg/ha	6.11	0.80	1.50	0.68	0.17	0.80
T ₂ Pendimethalin 1.50 kg/ha	6.15	0.80	1.52	0.69	0.18	0.82
T ₃ Metribuzin 0.5 kg/ha	6.07	0.78	1.51	0.66	0.17	0.79
T ₄ Metribuzin 0.75 kg/ha	6.07	0.76	1.50	0.66	0.15	0.72
T ₅ Hand weeding (20&40 DAS)	6.05	0.78	1.49	0.68	0.18	0.81
T ₆ Weedy check	5.95	0.71	1.38	0.65	0.15	0.70
SEm ±	0.49	0.04	0.17	0.03	0.02	0.04
CD at 5%	NS	NS	NS	NS	NS	NS

Table 29. Nitrogen, phosphorus and potassium uptake (kg/ha) by soybean grain as affected by direct effect of pendimethalin and metribuzin

Treatments	1995-96			1996-97		
	N	P	K	N	P	K
T ₁ Pendimethalin 1.0 kg/ha	101.98	15.11	24.94	139.28	17.99	34.76
T ₂ Pendimethalin 1.50 kg/ha	111.65	16.60	27.71	154.93	19.80	36.96
T ₃ metribuzin 0.50 kg/ha	118.78	18.24	31.89	166.29	21.23	51.06
T ₄ Metribuzin 0.75 kg/ha	122.64	17.29	29.92	148.99	18.69	36.44
T ₅ Hand weeding (20&40 DAS)	136.79	19.36	33.63	170.37	21.94	41.80
T ₆ Weedy check	67.33	9.48	24.61	82.01	9.73	19.11
SEm ±	7.18	1.08	3.60	7.52	1.20	6.14
CD at 5%	21.65	3.27	NS	22.60	3.64	NS

Table 30. Nitrogen, phosphorus and potassium uptake (kg/ha) by soybean stover as affected by direct effect of pendimethalin and metribuzin

Treatments	1995-96			1996-97		
	N	P	K	N	P	K
T ₁ Pendimethalin 1.0 kg/ha	15.83	4.12	19.48	23.82	5.93	27.92
T ₂ Pendimethalin 1.50 kg/ha	16.80	4.75	20.86	25.14	6.88	30.58
T ₃ Metribuzin 0.50 kg/ha	18.76	4.75	23.28	26.75	6.89	32.06
T ₄ Metribuzin 0.75 kg/ha	18.41	4.35	22.08	23.90	5.31	25.97
T ₅ Hand weeding (20&40 DAS)	19.50	5.78	24.84	27.81	7.87	33.06
T ₆ Weedy check	11.04	2.37	12.99	14.28	3.37	15.70
SEm ±	1.07	0.38	1.04	2.31	0.84	2.53
CD at 5%	3.25	1.62	3.13	NS	2.54	7.64

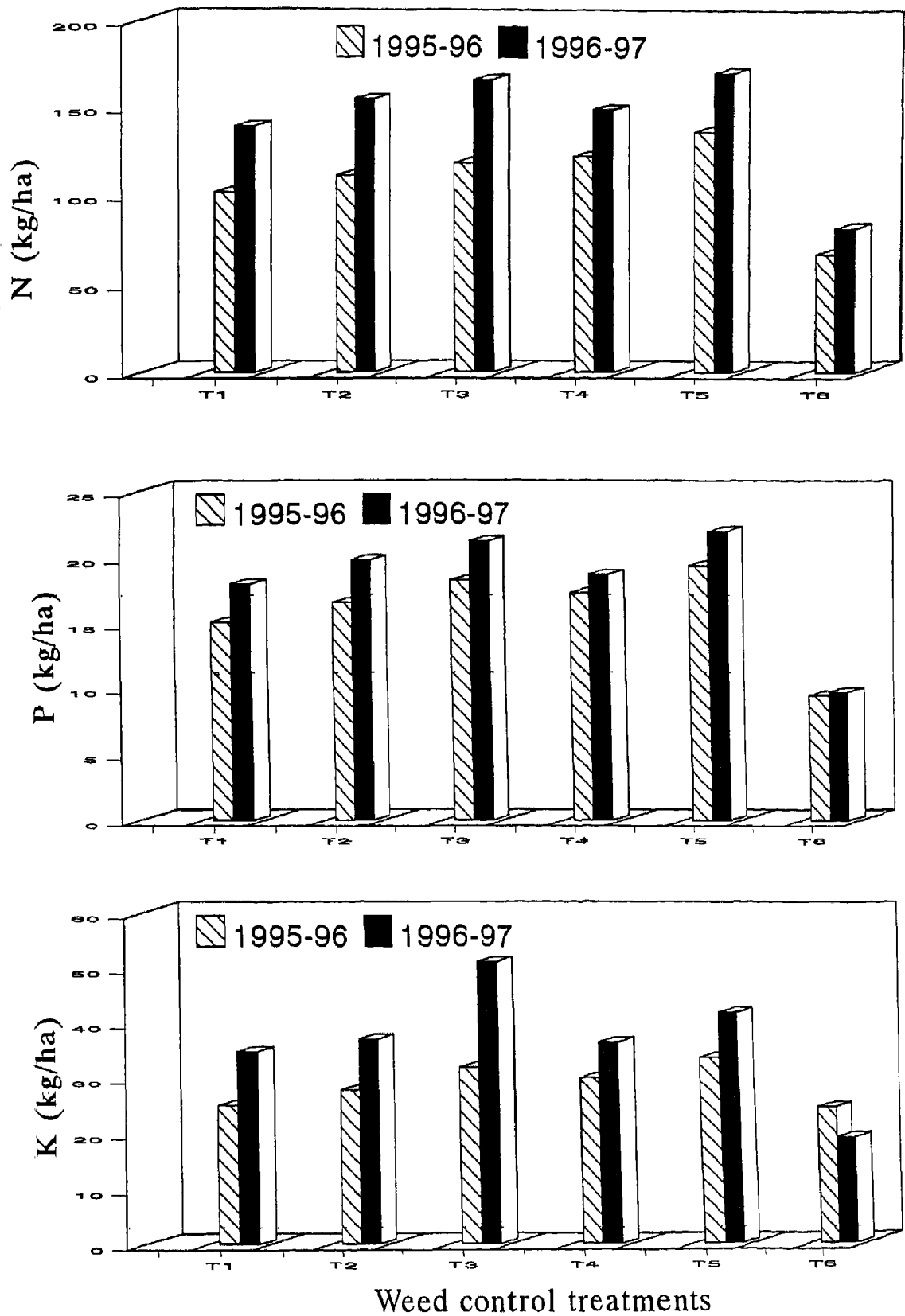


Fig. 9a. N, P and K uptake by soybean grain as affected by direct effect of pendimethalin and metribuzin

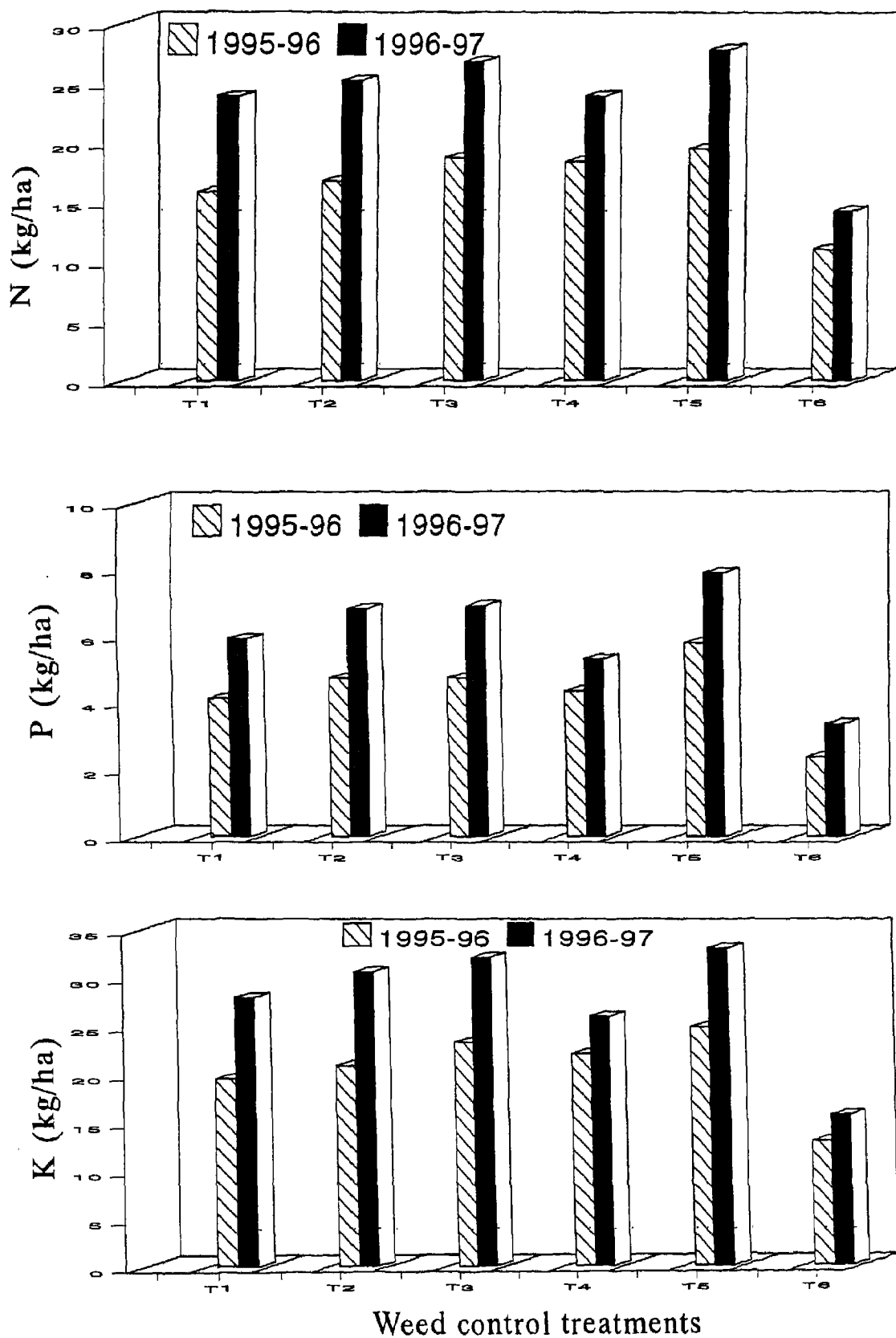


Fig. 9b. N, P and K uptake by soybean stover as affected by direct effect of pendimethalin and metribuzin

at 0.5 and 0.75 kg/ha and pendimethalin at 1.0 and 1.5 kg/ha resulted in 92.4, 82.3, 59.3 and 75.1 per cent higher P uptake over weedy check in 1995-96; and 118.1, 92.0, 84.8 and 103.4 per cent in 1996-97.

(c) **Potassium** : K uptake in grain was not affected due to weed control treatments in any year (Table 29).

4.2.6.2 Uptake by stover

(a) **Nitrogen** : All the weed control treatments resulted in significant increase in N uptake over weedy check in 1995-96 but had no marked effect in 1996-97. Hand weeding effected maximum increase and proved statistically superior to pendimethalin at 1.0 kg/ha and weedy check but was statistically at par with metribuzin at 0.50 and 0.75 kg/ha and pendimethalin at 1.5 kg/ha. All the herbicidal treatment caused identical increase over weedy check in 1996-97.

(b) **Phosphorus** : All the weed control treatments significantly affected increase in P uptake by soybean stover over weedy check except metribuzin at 0.75 kg/ha in 1996-97. Hand weedy registered maximum increase and proved significantly superior to pendimethalin at 1.0 kg and weedy check but was at par with metribuzin at 0.50 and 0.75 kg/ha and pendimetalin at 1.5 kg/ha in 1995-96. Whereas in 1996-97 it was found superior to metribuzin at 0.75 kg/ha and weedy check. In 1995-96, the effect of herbicide treatments was not evident.

(c) **Potassium** : Variation in weed control treatments had significant effect on K uptake. Of the weed control treatments, hand weeding caused maximum increase in K uptake but was statistically at par with other treatments in 1996-97 and with metribuzin in 1995-96.

Table 31. Total nitrogen, phosphorus and potassium uptake (kg/ha) by soybean (Grain + stover) as affected by direct effect of pendimethalin and metribuzin

Treatments	1995-96			1996-97		
	N	P	K	N	P	K
T ₁ Pendimethalin 1.0 kg/ha	117.81	19.24	44.42	163.10	23.92	62.68
T ₂ Pendimethalin 1.50 kg/ha	128.45	21.35	48.57	181.07	26.88	67.54
T ₃ Metribuzin 0.50 kg/ha	137.54	23.00	55.17	193.04	28.12	83.11
T ₄ Metribuzin 0.75 kg/ha	141.06	21.64	52.00	172.90	24.01	62.41
T ₅ Hand Weeding (20&40 DAS)	156.29	24.93	58.47	198.18	29.81	74.88
T ₆ Weedy check	78.37	11.85	37.60	96.29	13.11	34.82
SEm ±	7.88	1.33	3.71	8.75	1.62	7.63
CD at 5%	23.76	4.01	11.18	26.52	4.88	23.01

4.2.6.3 Total nitrogen, phosphorus and potassium uptake by Soybean:

Variation in weed control treatments effected marked increase in total NPK uptake in both the years. Of the weed control treatments, hand weeding resulted in maximum N uptake and proved significantly superior to pendimethalin both at 1.0 and 1.50 kg/ha and weedy check in 1995-96 but only to pendimethalin at 1.0 kg/ha and weedy check in 1996-97. Herbicides at both doses caused identical increase in total N uptake over weedy check. Uptake of P under hand weeding was higher in both the years but was statistically similar to metribuzin at 0.50 kg and pendimethalin at 1.50 kg/ha in 1996-97 whereas in 1995-96, only hand weeding, metribuzin at 0.5 and 0.75 kg/ha and pendimethalin at 1.5 kg/ha caused increase.

All the weed control treatments caused significant increase in total K uptake over weedy check but hand weeding resulted in higher increase in 1995-96 and metribuzin at 0.5 kg/ha in 1996-97. In both the years difference between metribuzin (0.5 and 0.75 kg/ha) and pendimethalin at 1.5 kg/ha was not significant. Pendimethalin at 1.0 kg proved inferior to these treatments.

4.2.7 Grain quality

Data on protein content, protein yield, oil content and oil yield of soybean as affected by weed control treatments in 1995-96 and 1996-97 are presented in Table 32 and 33.

4.2.7.1 Protein Content : Weed control treatments had no effect on protein content in any year of experimentation.

4.2.7.2 Protein yield : Protein yield varied due to variation in weed control treatments. Hand weed and metribuzin at 0.5 kg/ha caused higher increase and proved significantly superior to pendimethalin at 1.0 kg/ha and weedy check in 1995-96 but to weedy check only in 1996-97. In 1996-97 all the weed control treatments caused similar increase in protein yield and were superior to weedy check.

4.2.7.3. Oil Content : Oil content of soybean was not affected due to variation in weed control treatments in any year (Table 33).

4.2.7.4 Oil yield : Oil yield varied identically due to various weed control treatments. Hand weeding caused maximum increase as compared to all other treatments. In both the years, metribuzin at 0.50 kg/ha brought out marked increase and proved significantly superior to pendimethalin at 1.0 kg/ha and weedy check but was at par with

Table 32. Protein content (%) and protein yield (q/ha) of soybean as affected by direct effect of pendimethalin and metribuzin

Treatments	Protein content		Protein yield	
	1995-96	1996-97	1995-96	1996-97
T ₁ Pendimethalin 1.0 kg/ha	41.32	38.19	6.37	8.70
T ₂ Pendimethalin 1.50 kg/ha	41.62	38.44	6.97	9.72
T ₃ Metribuzin 0.50 kg/ha	41.00	37.94	8.02	10.39
T ₄ Metribuzin 0.75 kg/ha	40.94	37.94	7.66	9.31
T ₅ Hand weeding (20&40 DAS)	40.75	37.81	8.54	10.64
T ₆ Weedy check	39.69	37.19	4.21	5.12
SEm ±	1.70	3.10	0.40	1.07
CD at 5%	NS	NS	1.20	3.23

Table 33. Oil content (%) and oil yield (q/ha) of soybean as affected by direct effect of pendimethalin and metribuzin

Treatments	Oil content		Oil yield	
	1995-96	1996-97	1995-96	1996-97
T ₁ Pendimethalin 1.0 kg/ha	21.02	20.50	3.25	4.66
T ₂ Pendimethalin 1.5 kg/ha	21.00	20.40	3.52	5.09
T ₃ Metribuzin 0.50 kg/ha	20.67	20.50	4.07	5.59
T ₄ Metribuzin 0.75 kg/ha	20.80	20.30	3.90	4.98
T ₅ Hand weeding (20&40 DAS)	20.90	20.50	4.40	5.77
T ₆ Weedy check	20.90	20.40	2.20	2.83
SEm ±	0.90	0.70	0.24	0.34
CD at 5%	NS	NS	0.73	1.02

pendimethalin at 1.5 kg/ha and metirbuzin at 0.75 kg/ha in 1995-96. Whereas in 1996-97 all treatments were alike in their effect and effected significant increase over weedy check.

4.2.8 Nutrient status in soil after soybean harvest

Data on available nitrogen, phosphorus and potassium content in soil after soybean harvest are presented in Table 34.

Table 34. Available nitrogen, phosphorus and potassium status (kg/ha) in soil after soybean harvest as affected by direct effect of pendimethalin and metribuzin

Treatments	1995-96			1996-97		
	N	P	K	N	P	K
T ₁ Pendimethalin 1.0 kg/ha	185.81	20.45	248.98	210.25	22.65	255.96
T ₂ Pendimethalin 1.50 kg/ha	199.25	20.95	251.52	209.79	23.10	262.80
T ₃ metribuzin 0.50 kg/ha	210.75	21.15	263.89	221.66	23.28	270.92
T ₄ metribuzin 0.75 kg/ha	215.45	20.89	266.15	230.02	23.30	270.90
T ₅ Hand Weeding (20&40 DAS)	195.35	21.05	248.45	215.50	22.90	261.68
T ₆ Weedy check	171.99	16.68	220.50	180.50	18.75	224.88
SEm±	3.86	0.89	2.25	5.61	0.67	3.49
CD at 5%	11.63	2.68	6.78	16.91	2.03	10.53

4.2.8.1 Available N : In 1995-96, available N in soil was significantly higher in metribuzin applied plots (0.5 and 0.75 kg/ha) as compared to all other treatments. In hand weeding and pendimethalin at 1.5 kg/ha content was similar but higher than pendimethalin at 1.0 kg/ha.

4.2.8.2 Available P : Under weed control treatments P content was significantly higher than weedy check in both the years. In 1995-96, content was slightly higher in metribuzin at 0.50 kg/ha and hand weeding than weedy check but similar to the rest of the treatments. In 1996-97, P content was higher under metribuzin at 0.50 and 0.75 kg/ha but almost similar under all other weed control treatments except weedy check which registered lowest content in soil.

4.2.8.3 Available K : In both the years, in metribuzin at 0.50 and 0.75 kg/ha, K content was remarkably higher and it was even higher than hand weeding, pendimethalin (1.0 and 1.5 kg/ha) and weedy check in 1995-96 but in 1996-97 it proved statistically superior to pendimethalin and weedy check.

4.2.9 Detection of pendimethalin and metribuzin residues

4.2.9.1 Bioassay studies : Data on dry matter accumulation of oat and wheat grown in soil collected at different intervals after pendimethalin and metribuzin application are presented in Tables 35 and 36 and depicted in Fig 10.

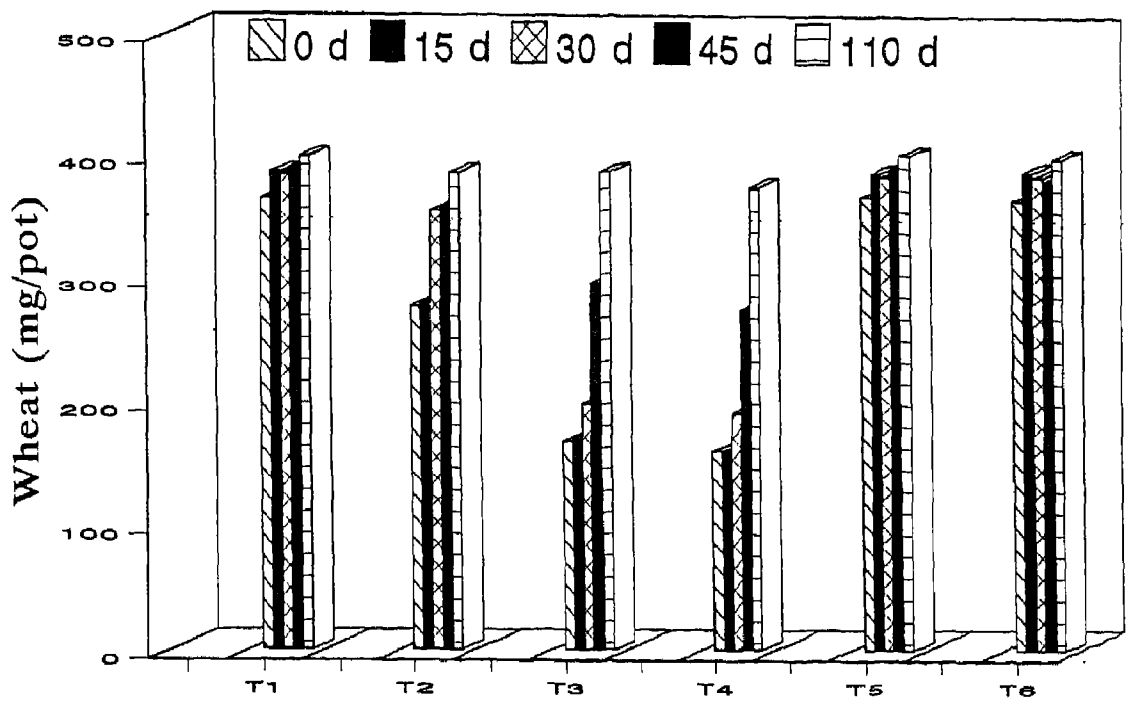
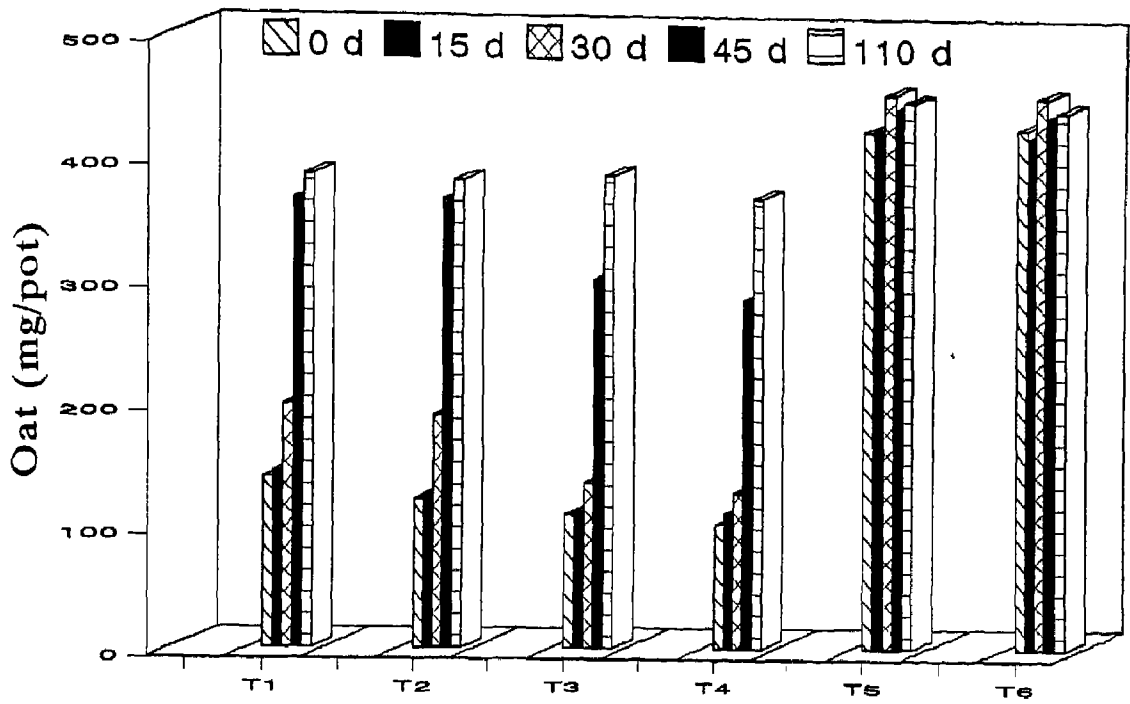
(a) Bioassay with oats : Oats plants produced markedly higher dry matter in untreated (hand weeding and weedy check) soil as compared to metribuzin (0.50 and 0.75 kg/ha) and pendimethalin (1.0 and 1.5 kg/ha) treated soil. Both the herbicide treatments adversely effected the dry matter accumulation by oats upto 30 days after application but effect of metribuzin (0.50 and 0.75 kg/ha) was well pronounced upto 45 days after application. In all the soils collected at different intervals (0, 15, 30, 45 and 110 days), the lowest dry matter production by oat plants was in soil treated at 0.75 kg/ha of metribuzin implying its persistence

Table 35. Dry matter accumulation by oat (mg/pot) grown in soil collected from soybean (experiment) treated with pendimethalin and metribuzin

Treatments	Soil collected at days after application				
	0	15	30	45	110
T ₁ Pendimethalin 1.0 kg/ha	139.44	144.25	198.65	365.88	385.78
T ₂ Pendimethalin 1.50 kg/ha	121.40	125.35	189.82	365.95	381.35
T ₃ metribuzin 0.50 kg/ha	109.35	112.15	135.35	301.65	385.66
T ₄ metribuzin 0.75 kg/ha	101.85	110.85	127.45	285.32	367.95
T ₅ Hand weeding (20&40 DAS)	423.20	425.78	454.00	441.75	446.78
T ₆ Weedy check	425.95	419.22	451.75	435.80	440.25
SEm ±	3.13	2.44	2.54	2.52	2.50
CD at 5%	9.45	7.35	7.65	7.61	7.54

Table 36. Dry matter accumulation by wheat (mg/pot) grown in soil collected from soybean (experiment) treated with pendimethalin and metribuzin.

Treatments	Soil collected at days after application				
	0	15	30	45	110
T ₁ Pendimethalin 1.0 kg/ha	365.15	387.50	385.25	383.70	400.15
T ₂ Pendimethalin 1.50 kg/ha	277.80	280.07	356.35	360.38	387.38
T ₃ metribuzin 0.50 kg/ha	169.03	170.12	199.25	297.20	388.72
T ₄ metribuzin 0.75 kg/ha	161.00	160.98	192.75	276.05	376.65
T ₅ Hand weeding (20&40 DAS)	369.57	388.20	385.04	392.67	403.00
T ₆ Weedy check	366.84	390.10	385.90	382.22	400.78
SEm ±	4.22	4.66	5.29	5.34	4.83
CD at 5%	12.72	14.06	15.94	16.10	14.58



Weed control treatments

Fig. 10. Dry matter accumulation by oat and wheat grown in soil collected from soybean (experiment) treated with pendimethalin and metribuzin

upto harvest of soybean crop. In general, there was gradual decrease in dry matter production by oats with increment in metribuzin and pendimethalin doses and their adverse effect was mitigated with the lapse of time.

(b) Bioassay with wheat : Both the herbicides metribuzin (0.50 and 0.75 kg/ha) and pendimethalin (1.5 kg/ha) adversely effected the dry matter production of wheat upto 30 days of application. Dry matter accumulation in hand weeding and weedy check was identical. 45 days after application, the dry matter production in pendimethalin at 1.5 kg/ha treated soil was identical and significantly higher than metribuzin at 0.50 and 0.75 kg/ha treated soil but significantly lower than untreated (hand weeding and weedy check) soil. In soil collected 110 days after application dry matter production was statistically similar in untreated (hand weeding and weedy check and treated pendimethalin both at 1.0 and 1.5 kg/ha and metribuzin at 0.50 kg/ha but significantly higher to metribuzin applied at 0.75 kg/ha. In general, with increase in pendimethalin and metribuzin doses there was gradual decline in dry matter production and detrimental effect of these treatments was mitigated with advancement in time.

4.2.9.2 Chemical extraction : The average recoveries of both pendimethalin and metribuzin from fortified soil samples at 0.5 and 1.0 ppm levels were 81 and 80% and for grain 80 and 82%, respectively.

(a) Soil : The residues levels and per cent dissipation of pendimethalin and metribuzin in soil are given in Tables 37 and 38. Linear correlation, coefficient, rate constant, regression equation and half-life values are given

Table 37. Pendimethalin and metribuzin residues ($\mu\text{g/g}$) in soil at different intervals (applied in kharif 1995)

Herbicide	dose (a.i. kg ha ⁻¹)	Residues (µg g ⁻¹)*				
		Days after spraying				
		0	15	30	45	110 (harvest)
Pendimethalin						
	1.0	0.99	0.64 (35.35)	0.45 (54.54)	0.27 (72.73)	ND
	1.5	1.08	0.71 (34.25)	0.48 (54.45)	0.29 (73.14)	ND
Metribuzin						
	0.5	0.63	0.46 (26.98)	0.38 (39.68)	0.30 (52.38)	ND
	0.75	0.71	0.51 (28.17)	0.43 (39.43)	0.35 (50.75)	ND

* Figures of composite soil samples
 Figures in parenthesis indicate per cent dissipation
 ND - Not detectable

Table 38. Pendimethalin and metribuzin residues ($\mu\text{g/g}$) in soil at different intervals (applied in kharif 1996)

Herbicide	Dose (a.i. kg ha ⁻¹)	Residues (µg g ⁻¹)*				
		Days after spraying				
		0	15	30	45	110 (harvest)
Pendimethalin						
	1.0	1.16	0.72 (37.93)	0.51 (56.03)	0.34 (70.68)	ND
	1.5	1.20	0.77 (35.83)	0.49 (59.16)	0.36 (70.00)	ND
Metribuzin						
	0.5	0.66	0.49 (25.76)	0.43 (34.85)	0.32 (51.51)	ND
	0.75	0.68	0.50 (26.47)	0.46 (32.35)	0.35 (48.53)	ND

* Figures of composite soil samples
 Figures in parenthesis indicate per cent dissipation
 ND - Not detectable

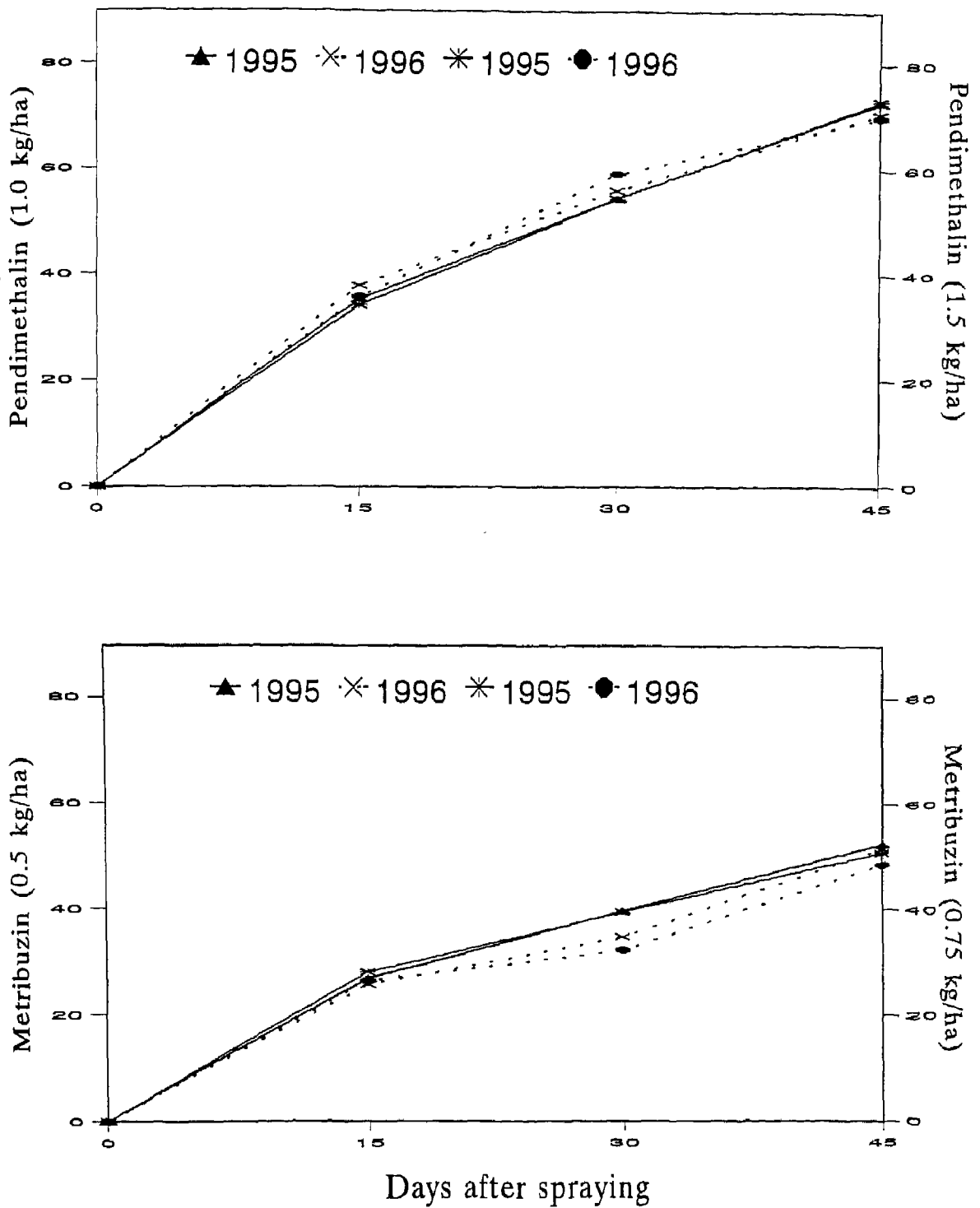


Fig. 11. Per cent dissipation of pendimethalin and metribuzin in soil at different intervals

in Tables 39 and 40. The dissipation of both herbicides in soil is depicted in Fig. 11.

In 1995-96, in the initial soil sample collected just after application of herbicides residues of pendimethalin were 0.99 and 1.08 $\mu\text{g/g}$ at 1.0 and 1.5 kg/ha and 0.63 and 0.71 $\mu\text{g/g}$ of metribuzin at 0.5 and 0.75 kg/ha of application respectively. There was rapid dissipation of both herbicides during first 15 days. The residues level after 15 days came down to 0.64 and 0.71 $\mu\text{g/g}$ at 1.0 and 1.5 kg/ha of pendimethalin and 0.46 and 0.51 $\mu\text{g/g}$ at 0.5 and 0.75 kg/ha of metribuzin, respectively. Per cent dissipation of pendimethalin at 1.0 and 1.5 and metribuzin at 0.5 and 0.75 was about 33.35 to 34.25 and 26.98 to 28.17 per cent in first 15 days, 54.54 to 55.45 and 39.43 to 39.68 per cent in 30 days and 72.73 to 73.14 and 50.75 to 52.38 per cent in 45 days, respectively. Both pendimethalin and metribuzin at different rates degraded to non-detectable limit by 110 days.

In 1996-97, the initial deposit of pendimethalin in soil was 1.16 and 1.20 $\mu\text{g/g}$ at 1.0 and 1.5 kg/ha and 0.66 and 0.68 $\mu\text{g/g}$ of metribuzin at 0.5 and 0.75 kg/ha, respectively. In second year also there was rapid loss of both herbicides during 15 days of their application. Residues level scale down to 0.72 and 0.77 $\mu\text{g/g}$; and 0.49 and 0.50 $\mu\text{g/g}$ in 15 days at 1.0 and 1.5 kg/ha of pendimethalin and 0.5 and 0.75 kg/ha of metribuzin, respectively. Dissipation of pendimethalin at 1.0 and 1.5 kg/ha and metribuzin at 0.5 and 0.75 kg/ha was 35.83 to 37.93 and 25.76 to 26.47 per cent in first 15 days, 56.03 to 59.16 and 32.33 to 34.85 per cent in 30 days and 70.00 to 70.68 and 48.53 to 51.51 per cent in 45 days, respectively. By 110 days, herbicide residues at different rates were below detected limit.

Table 39. Correlation coefficient, rate constant regression, equation and half-life of herbicides (applied in kharif 1995)

Herbicide	Dose (a.i. kg ha ⁻¹)	Correlation coefficient 'r'	Rate constant 'k'	Regression equation	Half-life (days)
Pendimethalin					
	1.0	-0.997	0.0286	$Y=0.996-0.0123x$	24.2
	1.5	-0.998	0.0291	$Y=1.037-0.0125x$	23.8
Metribuzin					
	0.5	-0.993	0.0161	$Y=0.786-0.0069x$	43.1
	0.75	-0.991	0.0156	$Y=0.834-0.0067x$	44.4

Table 40. Correlation coefficient, rate constant regression equation and half-life of herbicides (applied in kharif 1996)

Herbicide	Dose (a.i. kg ha ⁻¹)	Correlation coefficient 'r'	Rate constant 'k'	Regression equation	Half-life (days)
Pendimethalin					
	1.0	-0.998	0.027	$Y=1.051-0.0116x$	25.6
	1.5	-0.996	0.027	$Y=1.069-0.0117x$	25.4
Metribuzin					
	0.5	-0.991	0.016	$Y=0.813-0.0068x$	43.7
	0.75	-0.966	0.014	$Y=0.819-0.0061x$	48.7

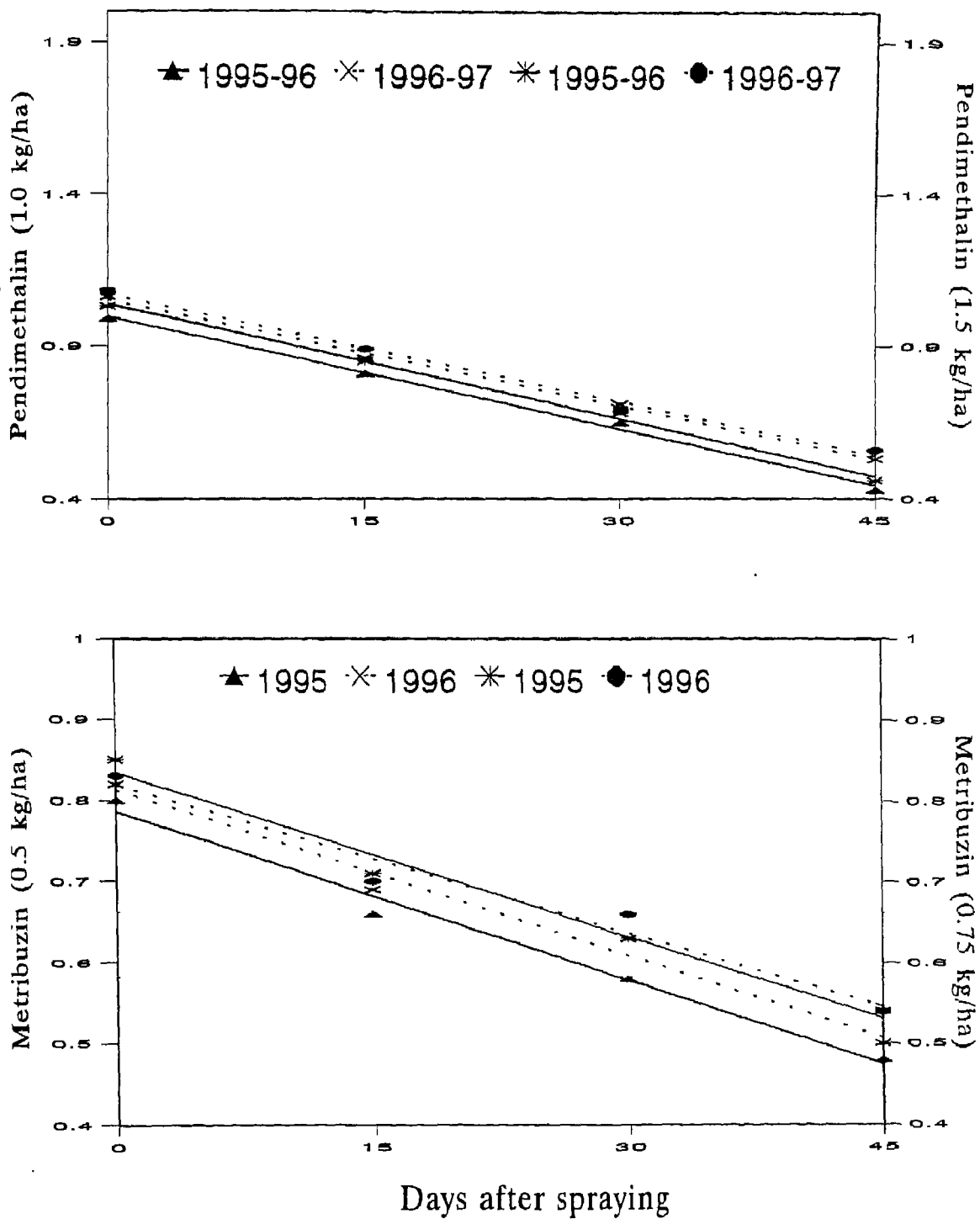


Fig. 12. Log [Residues ($\mu\text{g/g}$) $\times$ 10] residues of pendimethalin and metribuzin in soil at different intervals

The semi logarithmic plots of the data (Fig. 12) revealed that the rate of dissipation of pendimethalin and metribuzin did not follow first order rate kinetics at any rate of application in both the years. The half-life values for pendimethalin ranged between 23.8 to 24.2 days in 1995-96 and 25.4 to 25.6 days in 1996-97. Whereas, half-life values for metribuzin was some what higher and ranged between 43.1 to 44.4 days in the first year and 43.7 to 48.7 days in the second year.

(b) **Grain** : Data on the residue of pendimethalin and metribuzin are presented in Table 41.

Table 41. Herbicides residues ($\mu\text{g/g}$) in soybean grain

Herbicide	Dose (a.i. kg/ha)	Residues ($\mu\text{g g}^{-1}$)*	
		1995	1996
Pendimethalin			
	1.0	ND	ND
	1.5	ND	ND
Metribuzin			
	0.5	ND	ND
	0.75	ND	ND

* Figures of composite soil samples
ND - Not detectable

In both the years, pendimethalin (1.0 and 1.5 kg/ha) and metribuzin (0.5 and 0.75 kg/ha) residues in soybean grain were beyond detectable limits.

4.3 STUDIES ON WEEDS IN WHEAT

4.3.1 Weeds in wheat

In the year 1995-96 the intensity of broad leaved and grassy weeds at 45-day stage was 75.2 and 24.8 per cent respectively, signifying that broad leaved were more dominant in wheat. Predominant dicot weeds that invade the field were *Chenopodium album* (41.3 %), *Melilotus indica* (20/1 %), *Spergula arvensis* (4.61 %), *Fumaria parviflora* (4.3 %); and monocots *Avena ludoviciana* (20.2 %) and *Phalaris minor* (4.9 %). Besides, *Anagalis arvensis* (2.4 %), *Convolvulus arvensis* (1.9 %) and *Cyperus rotundus* (1.5 %) also occurred in small numbers (Appendix II).

4.3.2 Weed population

Weed population 45 DAS and at harvest recorded in wheat are presented in Tables 42, 43 and 44.

4.3.2.1 Effect of treatments on weed population in wheat : Treatments applied in soybean had marked effect on weeds of succeeding wheat crop in both the years. Monocot population 45 DAS in both the years and total weed population at harvest in first year (1995-96) were not affected statistically. In 1996-97, preceding metribuzin at 0.50 and 0.75 kg/ha proved superior in arresting dicot and total weed population as compared to hand weeding, pendimethalin (1.0 and 1.5 kg/ha) and weedy check. However, during first year the residual effect of preceding metribuzin at 0.5 kg/ha on weeds population was not well pronounced and population under it was similar to hand weeding (Table 42 and 43).

In both the years, 45 DAS and at harvest, the direct effect of weed control treatments was conspicuous on both monocot and dicot weeds

Table 42. Monocot and dicot population (no. of plants/m²) in wheat 45 DAS as affected by residual effect of pendimethalin and metribuzin and direct effect of isoproturon

Treatments	1995-96		1996-97	
	Monocot	Dicot	Monocot	Dicot
Residual effect				
T ₁ Pendimethalin 1.0 kg/ha	4.77 (25.3)	8.63 (78.26)	5.48 (38.43)	9.14 (88.19)
T ₂ Pendimethalin 1.50 kg/ha	4.57 (22.9)	8.64 (78.70)	5.91 (37.26)	9.31 (91.73)
T ₃ Metribuzin 0.50 kg/ha	4.44 (22.43)	8.65 (79.33)	5.88 (36.80)	6.90 (50.06)
T ₄ Metribuzin 0.75 kg/ha	4.20 (20.46)	8.23 (73.18)	5.75 (35.83)	7.04 (50.6)
T ₅ Hand weeding (20&40 DAS)	4.51 (23.0)	8.50 (77.50)	5.64 (34.15)	8.20 (75.46)
T ₆ Weedy check	4.40 (22.4)	8.75 (81.50)	5.84 (37.06)	8.49 (82.83)
SEm±	0.20	0.10	0.20	0.12
CD at 5%	NS	0.32	NS	0.36
Direct effect				
W ₁ Isoproturon 0.75 /ha	2.58 (6.30)	6.99 (48.41)	4.28 (17.95)	6.34 (40.59)
W ₂ Hand weeding 30 DAS	4.05 (16.0)	6.96 (48.10)	5.00 (24.60)	6.82 (46.56)
W ₃ Weedy check	6.81 (45.8)	11.75 (137.72)	8.22 (67.22)	11.39 (132.28)
SEm±	0.05	0.06	0.05	0.06
CD at 5%	0.16	0.18	0.13	0.16

Table 43. Total weed population (no. of plants/m²) in wheat 45 DAS and at harvest as affected by residual effect of pendimethalin and metribuzin and direct effect of isoproturon

Treatments	1995-96		1996-97	
	45 DAS	Harvest	45 DAS	Harvest
Residual effect				
T ₁ Pendimethalin 1.0 kg/ha	9.87 (103.56)	6.73 (48.43)	10.91 (78.26)	7.63 (62.1)
T ₂ Pendimethalin 1.50 kg/ha	9.77 (101.6)	6.66 (46.86)	11.01 (78.70)	7.33 (58.16)
T ₃ Metribuzin 0.50 kg/ha	9.72 (101.76)	6.72 (48.53)	9.05 (79.33)	6.19 (41.46)
T ₄ Metribuzin 0.75 kg/ha	9.24 (93.65)	6.41 (44.2)	9.09 (73.18)	5.77 (35.06)
T ₅ Hand weeding (20&40 DAS)	9.62 (100.5)	6.49 (45.7)	9.93 (77.50)	6.64 (50.53)
T ₆ Weedy check	9.81 (103.9)	6.75 (49.13)	10.28 (81.5)	7.20 (58.35)
SEm ±	0.09	0.15	0.16	0.24
CD at 5%	0.27	NS	0.50	0.74
Direct effect				
W ₁ Isoproturon 0.75 /ha	7.42 (54.73)	5.00 (24.61)	7.63 (48.41)	5.10 (25.87)
W ₂ Hand weeding 30 DAS	8.03 (64.16)	5.56 (30.53)	8.44 (48.10)	5.54 (30.58)
W ₃ Weedy check	13.56 (183.50)	9.31 (86.28)	14.07 (137.72)	9.74 (96.38)
SEm±	0.05	0.06	0.05	0.11
CDat 5%	0.13	0.18	0.15	0.32

Table 44. Total weeds (no. of plants/m²) in wheat at harvest as affected by interaction between residual effect of pendimethalin and metribuzin and direct effect of isoproturon in 1996-97

Residual effect	Direct effect		
	Isoproturan W ₁	Hand weeding W ₂	Weedy check W ₃
T ₁ Pendimethalin 1.0 kg/ha	6.00 (35.6)	6.37 (40.2)	10.53 (110.5)
T ₂ Pendimethalin 1.50 kg/ha	5.65 (31.5)	5.89 (34.3)	10.45 (108.7)
T ₃ Metribuzin 0.50 kg/ha	4.68 (21.5)	5.02 (24.8)	8.86 (78.1)
T ₄ Metribuzin 0.75 kg/ha	4.86 (23.2)	5.02 (24.8)	7.41 (57.2)
T ₅ Hand weeding (20&40 DAS)	4.51 (19.9)	5.13 (25.98)	10.30 (105.8)
T ₆ Weedy check	4.89 (23.5)	5.82 (33.5)	10.88 (118.0)
SEm ±	0.29		
CD at 5%	0.87		

(Table 42). Monocot population was significantly lower in isoproturon as compared to hand weeding and weedy check in first year (1995-97) but in second year no significant differences existed among weed control treatments. Isoproturon and hand weeding brought about similar reduction in the dicot population over weedy check in 1995-96, but former treatment resulted in marked reduction in 1996-97. Total weed population 45 DAS and at harvest was significantly lower in isoproturon as compared to weedy check. Hand weeding also caused decrease but its effect was not well pronounced.

Interaction between residual and direct effect of weed control treatments on total weeds population at harvest was significant in 1996-97 (Table 44). The residual effect of metribuzin (0.5 and 0.75 kg/ha) and isoproturon application in wheat or preceding hand weeding followed by hand weeding registered lower total weed population as compared to other combinations. Total weed population was lowest at harvest in preceding metribuzin treated plots signifying the persistence of herbicide in the soil.

4.3.3 Dry matter accumulation by weeds

Data on dry matter production by weeds under different treatments recorded 45 DAS and at harvest are presented in Tables 45 and 46 and depicted in Fig 13.

4.3.3.1 Effect of treatments on dry matter production by weeds :

Treatments applied in soybean had no effect on dry matter production by weed in succeeding wheat crop 45 DAS in both the years (Table 45). But at harvesting residual effect of metribuzin (0.50 and 0.75 kg/ha) and hand weeding caused higher decrease in dry matter production as compared to residual effect of pendimethalin (1.0 and 1.5 kg/ha). Metribuzin residues at 0.50 kg/ha caused identical decrease in both the year.

The direct effect of weed control treatments on dry matter accumulation was significant at both the stages in both the years. Isoproturon application and hand weeding significantly resulted in lower dry matter as compared to weedy check. The effect of former two treatments was well marked at harvest than that of 45 DAS.

Table 45. Drymatter accumulation by weeds (kg/ha) in wheat 45 DAS and at harvest as affected by residual effect of pendimethalin and metribuzin and direct effect of isoproturon

Treatments	Weed dry matter accumulation			
	1995-96		1996-97	
	45 DAS	Harvest	45 DAS	Harvest
Residual effect				
T ₁ Pendimethalin 1.0 kg/ha	12.67 (1666.6)	31.02 (1047.6)	14.62 (218.5)	34.08 (1382.6)
T ₂ Pendimethalin 1.50 kg/ha	12.59 (164.0)	31.42 (1070.0)	14.50 (219.3)	31.9 (1313.3)
T ₃ Metribuzin 0.50 kg/ha	12.77 (170.6)	27.77 (913.2)	13.61 (209.9)	27.57 (992.5)
T ₄ Metribuzin 0.75 kg/ha	12.06 (154.0)	28.91 (914.2)	11.99 (147.6)	29.66 (1071.3)
T ₅ Hand weeding (20&40 DAS)	12.74 (171.0)	29.03 (912.0)	12.78 (174.3)	30.04 (1157.3)
T ₆ Weedy check	13.22 (182.6)	30.65 (1023.1)	13.22 (188.3)	35.03 (1427.4)
SEm ±	0.46	0.86	1.16	0.78
CD at 5%	NS	2.61	NS	2.38
Direct effect				
W ₁ Isoproturon 0.75 /ha	10.30 (106.2)	21.43 (466.2)	11.55 (147.1)	19.36 (383.7)
W ₂ Hand weeding 30 DAS	11.30 (128.5)	25.11 (635.1)	11.86 (142.0)	22.54 (494.9)
W ₃ Weedy check	16.42 (269.9)	42.86 (1838.8)	16.95 (289.9)	52.75 (2793.6)
SEm±	0.18	0.28	0.49	0.34
CD at 5%	0.53	0.82	1.42	0.98

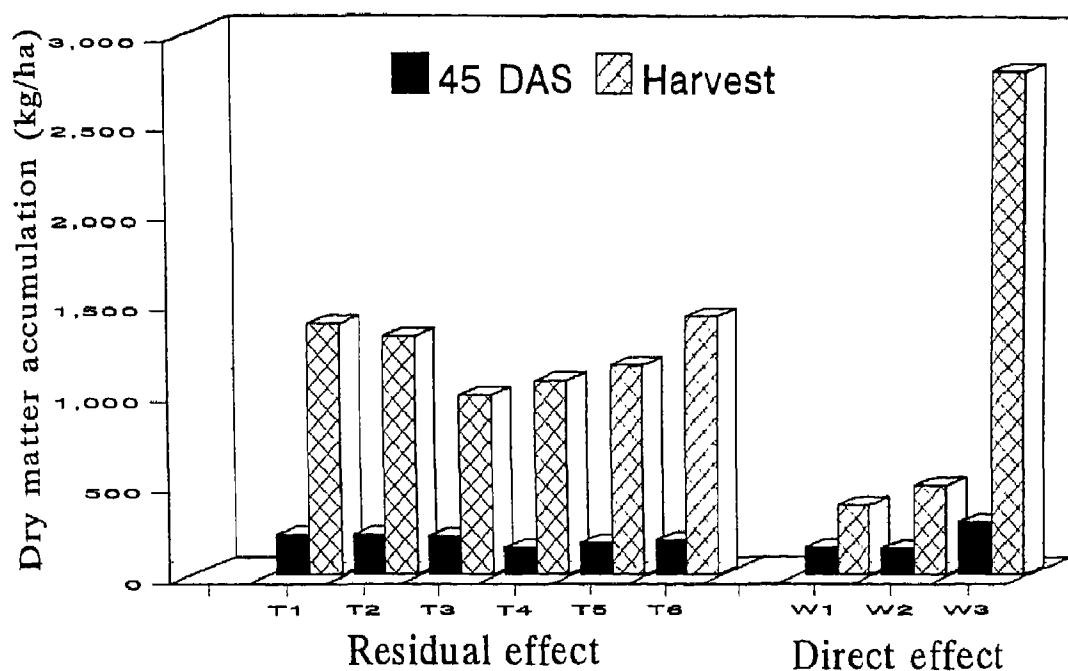
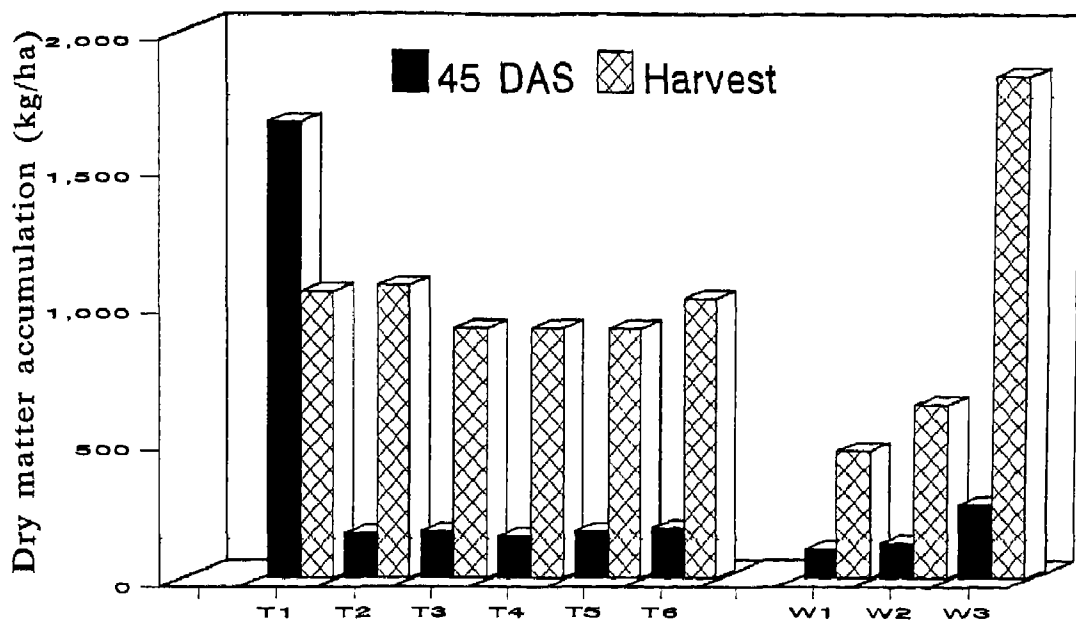


Fig. 13. Dry matter accumulation by weeds in wheat 45 DAS and at harvest as affected by residual effect of pendimethalin and metribuzin and direct effect of isoproturon

Table 46. Weed dry matter accumulation (kg/ha) in wheat at harvest as affected by interaction between residual effect of pendimethalin and metribuzin and direct effect of isoproturon in 1996-97.

Residual effect	Direct effect		
	Isoproturan W ₁	Handweeding W ₂	Weedy check W ₃
T ₁ Pendimethalin 1.0 kg/ha	22.43 (503.0)	24.789 (615.0)	55.04 (3030.0)
T ₂ Pendimethalin 1.50 kg/ha	17.24 (302.0)	22.42 (503.0)	55.99 (3135.0)
T ₃ Metribuzin 0.50 kg/ha	16.07 (259.0)	17.57 (312.5)	49.05 (2406.0)
T ₄ Metribuzin 0.75 kg/ha	18.25 (333.0)	21.58 (466.0)	49.14 (2415.0)
T ₅ Hand weeding (20&40 DAS)	17.97 (323.0)	19.85 (298.0)	52.30 (2751.0)
T ₆ Weedy check	24.11 (582.2)	25.98 (675.0)	54.99 (3025.0)
SEm ±	0.94		
CD at 5%	2.73		

Interaction between residual and direct effect was significant at harvest in 1996-97 (Table 46). Higher reduction in dry matter was noted under isoproturon and hand weeding in wheat with preceding metribuzin at 0.5 kg/ha. Residues of metribuzin at 0.5 and 0.75 kg/ha lowered weed dry matter production even in weedy check as compared to preceding pendimethalin (1.0 and 1.5 kg/ha), hand weeding and weedy check.

4.3.4 Effect of treatments on N, P and K content in weeds at harvest

Data on NPK content (%) in weeds at harvest as affected by weed control treatments applied to soybean and wheat are presented in Table 47.

4.3.4.1 N, P and K content in weeds : Treatment applied to soybean had no marked effect on the N, P and K content in weeds at harvest in any year (Table 47).

Table 47. Nitrogen, phosphorus and potassium content (%) in weeds in wheat at harvest as affected by residual effect of pendimethalin and metribuzin and direct effect of isoproturon

Treatments	1995-96			1996-97		
	N	P	K	N	P	K
Residual effect						
T ₁ Pendimethalin 1.0 kg/ha	1.16	0.25	1.47	1.26	0.33	1.54
T ₂ Pendimethalin 1.50 kg/ha	1.16	0.26	1.47	1.25	0.33	1.54
T ₃ Metribuzin 0.50 kg/ha	1.16	0.25	1.45	1.25	0.33	1.54
T ₄ Metribuzin 0.75 kg/ha	1.16	0.24	1.46	1.24	0.31	1.53
T ₅ Hand weeding (20&40 DAS)	1.17	0.25	1.47	1.23	0.33	1.54
T ₆ Weedy check	1.17	0.25	1.48	1.24	0.32	1.55
SEm ±	0.007	0.006	0.01	0.02	0.01	0.02
CD at 5%	NS	NS	NS	NS	NS	NS
Direct effect						
W ₁ Isoproturon 0.75 /ha	1.14	0.24	1.42	1.25	0.30	0.52
W ₂ Hand weeding 30 DAS	1.17	0.23	1.42	1.26	0.31	1.53
W ₃ Weedy check	1.19	0.28	1.56	1.37	0.38	1.57
SEm±	0.003	0.002	0.006	0.006	0.006	0.006
CD at 5%	0.007	0.006	0.02	0.02	0.02	0.02

In both the years, in weedy check N content recorded was highest (1.19 and 1.37 %) followed by hand weeding (1.17 and 1.26 %) and lowest was in isoproturon (1.14 and 1.25 %). P content was higher in weedy check (0.28 and 0.38 %) and lower both in isoproturon and hand weeding in both the years. K content was similar under isoproturon and hand weeding (1.42 %) in 1995-97 but the lowest under former treatment in 1996-97, whereas highest content (1.56 and 1.57 %) was recorded in weedy check in both the years.

.3.5 N, P and K depletion by weeds

Data on N, P and K depletion by weeds at harvest recorded under various treatments in wheat are presented in Table 48 and depicted in Fig. 14.

4.3.5.1 N, P and K depletion by weeds : Soybean applied treatments had no effect on N, P and K depletion by weeds in 1995-96 and on P in 1996-97 at harvest. But in 1996-97, preceding metribuzin at 0.5 and 0.75 kg/ha caused significant reduction in N and K depletion and proved superior to pendimethalin (1.0 and 1.5 kg/ha) and weedy check. Hand weeding in soybean resulted in lower N and K depletion by weeds however, its effect was not well pronounced. The highest depletion of N was in weedy check and it was 42.6, 33.3, 24.4 and 7.8 per cent higher than that of metribuzin (0.5, 0.75 kg/ha), hand weeding and pendimethalin at 1.5 kg/ha, whereas N depletion in pendimethalin at 1.0 kg/ha was almost similar to weedy check. The K depletion was also highest in weedy check (22.12 kg/ha) and it was 44.7, 34.9 and 24.13 per cent higher as compared to metribuzin at 0.5, 0.75 kg/ha and hand weeding respectively, but statistically similar to pendimethalin at 1.0 and 1.5 kg/ha.

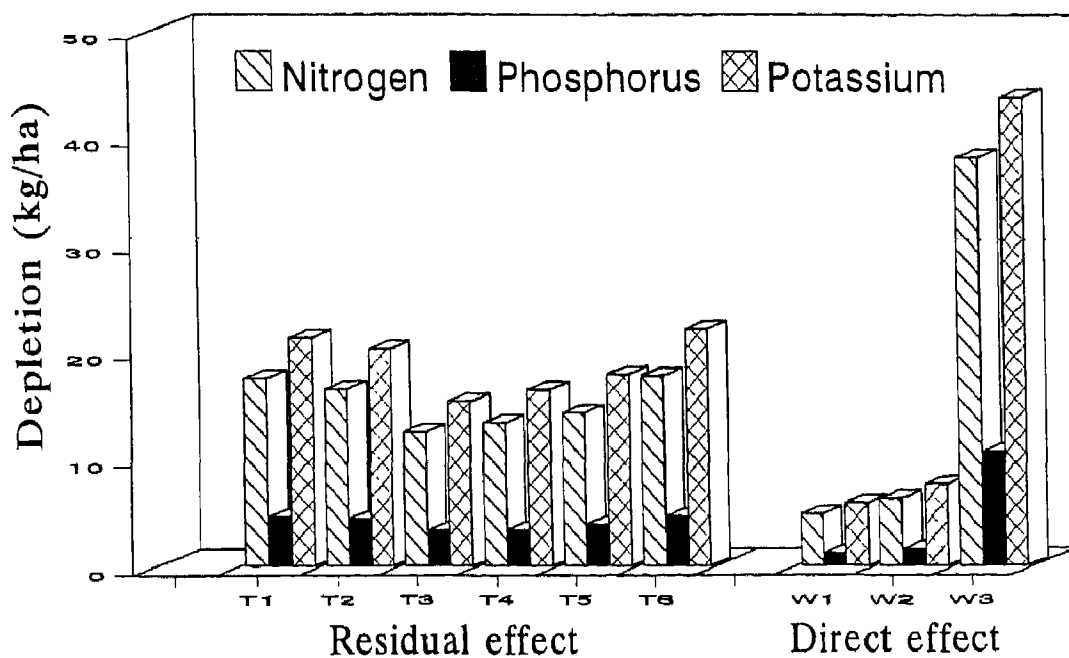
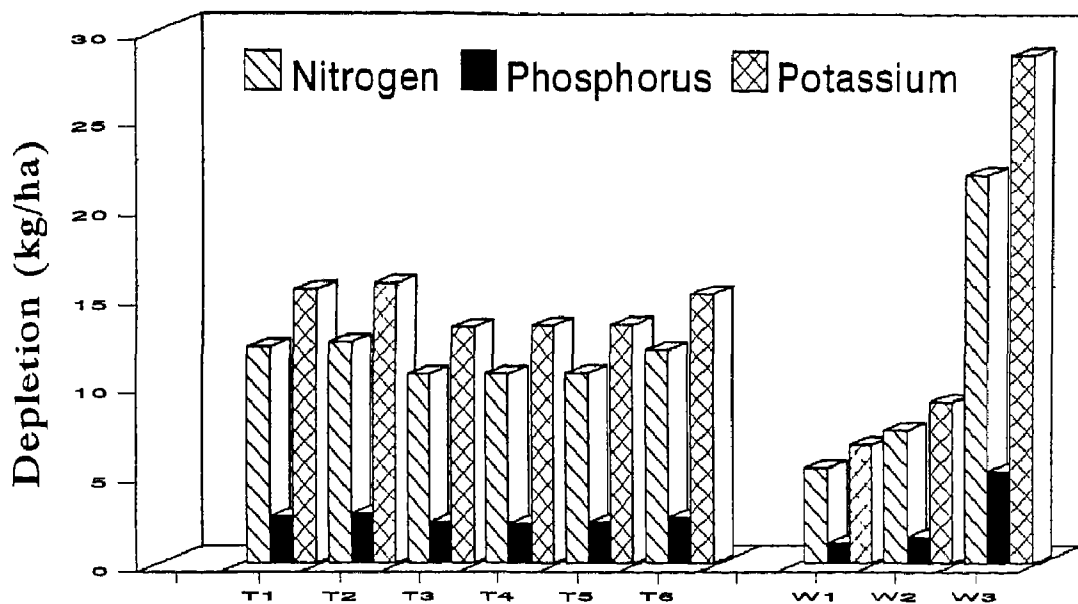


Fig. 14. N, P and K depletion by weeds in wheat at harvest as affected by residual effect of pendimethalin and metribuzin and direct effect of isoproturon

7.43 and 21.88 kg/ha in 1995-96 and 4.80, 6.23 and 38.27 kg/ha in 1996-97 in isoproturon, hand weed and weedy check, respectively.

4.3.5.1.2 P depletion : In isoproturon applied plots depletion was lowest and it proved statistically superior to hand weeding and weedy check in arresting P depletion in both the years. Depletion in hand weeding was significantly lower than weedy check. Depletion in isoproturon, hand weeding and weedy check was to the extent of 1.12, 1.46 and 5.15 kg/ha in 1995-96 and 1.15, 1.53 and 10.61 kg/ha in 1996-97, respectively.

4.3.5.1.3 K depletion : Direct effect of weed control treatments was conspicuous on K depletion. The lowest depletion was in isoproturon and it proved significantly superior to hand weeding and weedy check in arresting K depletion. Hand weeding brought about reduction in K depletion but did not reach the level of isoproturon but proved superior to weedy check. K depletion in isoproturon, hand weeding and weedy check was 6.62, 9.02 and 28.68 kg/ha in 1995-96 and 5.83, 7.57 and 43.85 kg/ha, respectively.

4.4 STUDIES ON WHEAT

4.4.1 Growth and development

The data pertaining to plant population, plant height and dry matter production are presented in Tables 49, 50 and 51.

Growth and development characters were not affected significantly by preceding treatments at any stage either in 1995-96 or in 1996-97.

The treatments applied to wheat did not cause significant variation in plant population in any years (Table 49).

The treatments applied to wheat had no marked effect on plant height 45 DAS and at harvest in any year (Table 50).

Table 49. Plant population (no. of plants/m) of wheat 15 DAS as affected by residual effect of pendimethalin and metribuzin and direct effect of isoproturon

Treatments	Plant Population	
	1995-96	1996-97
Residual effect		
T ₁ Pendimethalin 1.0 kg/ha	56.5	58.5
T ₂ Pendimethalin 1.50 kg/ha	56.5	58.2
T ₃ Metribuzin 0.50 kg/ha	56.8	58.4
T ₄ Metribuzin 0.75 kg/ha	56.6	57.8
T ₅ Hand weeding (20&40 DAS)	56.4	58.8
T ₆ Weedy check	56.2	58.2
SEm ±	0.85	0.90
CD at 5%	NS	NS
Direct effect		
W ₁ Isoproturon 0.75 /ha	56.8	58.1
W ₂ Hand weeding 30 DAS	56.5	58.5
W ₃ Weedy check	56.1	58.4
SEm±	0.42	0.47
CD at 5%	NS	NS

Table 50. Plant height (cm) of wheat 45 DAS and at harvest as affected by residual effect of pendimethalin and metribuzin and direct effect of isoproturon

Treatments	Plant height			
	45 DAS		Harvest	
	1995-96	1996-97	1995-96	1996-97
Residual effect				
T ₁ Pendimethalin 1.0 kg/ha	30.39	32.29	63.55	64.83
T ₂ Pendimethalin 1.50 kg/ha	30.612	32.19	65.27	64.5
T ₃ Metribuzin 0.50 kg/ha	31.33	32.44	63.96	66.16
T ₄ Metribuzin 0.75 kg/ha	30.06	32.37	64.81	65.32
T ₅ Hand weeding (20&40 DAS)	29.53	31.35	63.55	68.38
T ₆ Weedy check	30.03	32.42	65.66	64.85
SEm ±	1.29	1.51	1.59	2.42
CD at 5%	NS	NS	NS	NS
Direct effect				
W ₁ Isoproturon 0.75 /ha	29.82	32.64	63.18	65.65
W ₂ Hand weeding 30 DAS	30.34	32.18	64.23	64.80
W ₃ Weedy check	30.81	31.71	65.99	66.57
SEm±	0.39	0.50	0.51	0.80
CD at 5%	NS	NS	NS	NS

The dry matter accumulation was not affected significantly by direct effect of treatments 30 and 60 DAS in both the years (Table 51).

Table 51. Dry matter accumulation (g/plant) by wheat 30 and 60 DAS as affected by residual effect of pendimethalin and metribuzin and direct effect of isoproturon

Treatments	Dry matter accumulation			
	30 DAS		60 DAS	
	1995-96	1996-97	1995-96	1996-97
Residual effect				
T ₁ Pendimethalin 1.0 kg/ha	0.15	0.16	0.72	0.75
T ₂ Pendimethalin 1.50 kg/ha	0.15	0.16	0.72	0.73
T ₃ Metribuzin 0.50 kg/ha	0.16	0.17	0.73	0.74
T ₄ Metribuzin 0.75 kg/ha	0.16	0.17	0.72	0.72
T ₅ Hand weeding (20&40 DAS)	0.16	0.17	0.72	0.72
T ₆ Weedy check	0.16	0.16	0.72	0.73
SEm ±	0.007	0.006	0.01	0.02
CD at 5%	NS	NS	NS	NS
Direct effect				
W ₁ Isoproturon 0.75 /ha	0.15	0.16	0.73	0.74
W ₂ Hand weeding 30 DAS	0.15	0.16	0.73	0.74
W ₃ Weedy check	0.15	0.16	0.71	0.72
SEm±	0.003	0.003	0.006	0.01
CD at 5%	NS	NS	NS	NS

4.4.2 Yield attributes

Data pertaining to number of tiller/m row length, spike length, number of spikelets/spike and 1000-grain weight as influenced by treatment applied to soybean and wheat are presented in Table 52 and 53.

Table 52. Number of tillers/ m row length, spike length (cm), number of spikelets/spike and 1000 grain weight (g) of wheat as affected by residual effect of pendimethalin and metribuzin and direct effect of isoproturon in 1995-96

Treatments	No. of tillers	Spike length	No. of spikelets	1000-grain weight
Residual effect				
T ₁ Pendimethalin 1.0 kg/ha	99.21	10.13	18.00	37.35
T ₂ Pendimethalin 1.50 kg/ha	99.56	10.16	18.57	37.25
T ₃ Metribuzin 0.50 kg/ha	100.72	10.33	18.36	36.33
T ₄ Metribuzin 0.75 kg/ha	100.64	10.65	18.66	37.06
T ₅ Hand weeding (20&40 DAS)	100.40	10.29	18.30	37.33
T ₆ Weedy check	100.52	10.45	18.22	36.98
SEm ±	1.00	0.24	0.41	1.55
CD at 5%	NS	NS	NS	NS
Direct effect				
W ₁ Isoproturon 0.75 /ha	105.17	10.43	18.88	37.40
W ₂ Hand weeding 30 DAS	104.10	10.43	18.72	37.36
W ₃ Weedy check	91.26	10.16	17.44	36.39
SEm±	0.64	0.13	0.17	0.82
CD at 5%	1.84	NS	0.50	NS

Table 53. Number of tillers/m row length, spike length (cm), number of spikelets/spike and 1000 grain weight (g) of wheat as affected by residual effect of pendimethalin and metribuzin and direct effect of isoproturon in 1996-97

Treatments	No. of tillers	Spike length	No. of spikelets	1000-grain weight
Residual effect				
T ₁ Pendimethalin 1.0 kg/ha	96.94	10.10	18.06	36.26
T ₂ Pendimethalin 1.50 kg/ha	97.47	10.15	18.36	36.36
T ₃ Metribuzin 0.50 kg/ha	98.79	10.28	18.33	35.81
T ₄ Metribuzin 0.75 kg/ha	99.12	10.68	18.69	36.68
T ₅ Hand weeding (20&40 DAS)	96.00	10.35	18.09	36.67
T ₆ Weedy check	96.04	10.52	18.18	36.58
SEm ±	1.58	0.28	0.40	1.05
CD at 5%	NS	NS	NS	NS
Direct effect				
W ₁ Isoproturon 0.75 /ha	98.54	10.47	18.91	36.57
W ₂ Hand weeding 30 DAS	99.68	10.39	18.71	37.15
W ₃ Weedy check	93.96	10.18	17.24	35.46
SEm±	0.73	0.15	0.18	0.38
CD at 5%	2.09	NS	0.54	1.10

Number of tillers/m row length, spike length, number of spikelets/spike and 1000-grain weight were not affected markedly by preceding treatments at harvest in any year.

Treatments applied to wheat caused significant increase in number of tillers/m row length. Isoproturon and hand weeding produced similar increase in number of tillers/m row length and were statistically superior

to weedy check. No significant difference existed between former two treatments in any year.

The spike length was not affected significantly by treatments in both the years.

Isoproturon and hand weeding caused significant increase in number of spikelets/spike and were statistically superior to weedy check in which lowest number of spikelets/spike were recorded in both 1995-96 and 1996-97.

Thousand grain weight under isoproturon and hand weeded plots was significantly higher than weedy check in both the years. Hand weeding caused slightly higher increase than isoproturon, but its effect was not well pronounced.

4.4.3 Yield

Data on biological yield, grain yield, pooled grain yield and harvest index of wheat as influenced by preceding and direct effect of wheat applied treatments are presented in Table 54 and depicted in Fig. 15.

Treatments applied to soybean had no marked effect on above parameters either in 1995-96 or 1996-97.

Hand weeding effected significant increase in biological yield as compared to isoproturon and weedy check in 1995-96, but in 1996-97 former two treatment caused similar increase and proved significantly superior to weedy check.

In both the years, direct effect of treatments applied to wheat was significant on grain yield. The effect was not alike in both the years. The

Table 54. Biological yield (q/ha), grain yield (q/ha) and harvest index (%) of wheat as affected by residual effect of pendimethalin and metribuzin and direct effect of isoproturon

Treatments	Biological yield		Grain yield			Harvest index	
	1995-96	1996-97	1995-97	1996-97	Pooled	1995-96	1996-97
Residual effect							
T ₁ Pendimethalin 1.0 kg/ha	95.27	91.16	42.53	40.52	41.52	44.54	44.34
T ₂ Pendimethalin 1.50 kg/ha	95.95	91.94	42.85	40.86	41.86	44.55	44.33
T ₃ Metribuzin 0.50 kg/ha	96.91	92.84	43.31	41.33	42.42	44.59	44.42
T ₄ Metribuzin 0.75 kg/ha	97.20	93.44	43.49	41.64	42.57	44.65	44.47
T ₅ Hand weeding (20&40 DAS)	93.77	90.04	41.81	43.29	42.55	44.48	47.82
T ₆ Weedy check	92.71	89.56	41.39	39.72	40.56	44.53	44.21
SEm ±	2.25	1.75	1.06	2.69	1.52	0.09	2.50
CD at 5%	NS	NS	NS	NS	NS	NS	NS
Direct effect							
W ₁ Isoproturon 0.75 /ha	99.86	96.37	45.36	45.28	45.32	45.43	47.03
W ₂ Hand weeding 30 DAS	102.91	99.09	46.65	44.64	45.65	45.33	45.05
W ₃ Weedy check	83.14	79.03	35.67	33.77	34.72	42.91	42.72
SEm±	0.93	1.05	0.43	0.99	0.55	0.04	1.02
CD at 5%	2.66	3.03	1.22	2.83	1.59	0.10	2.93

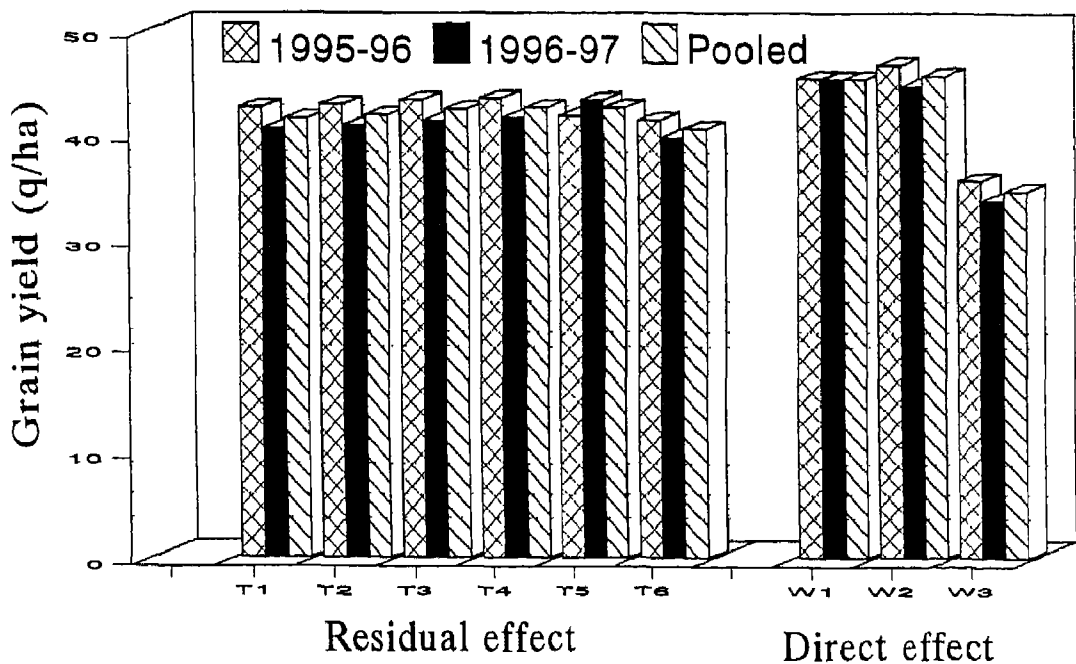
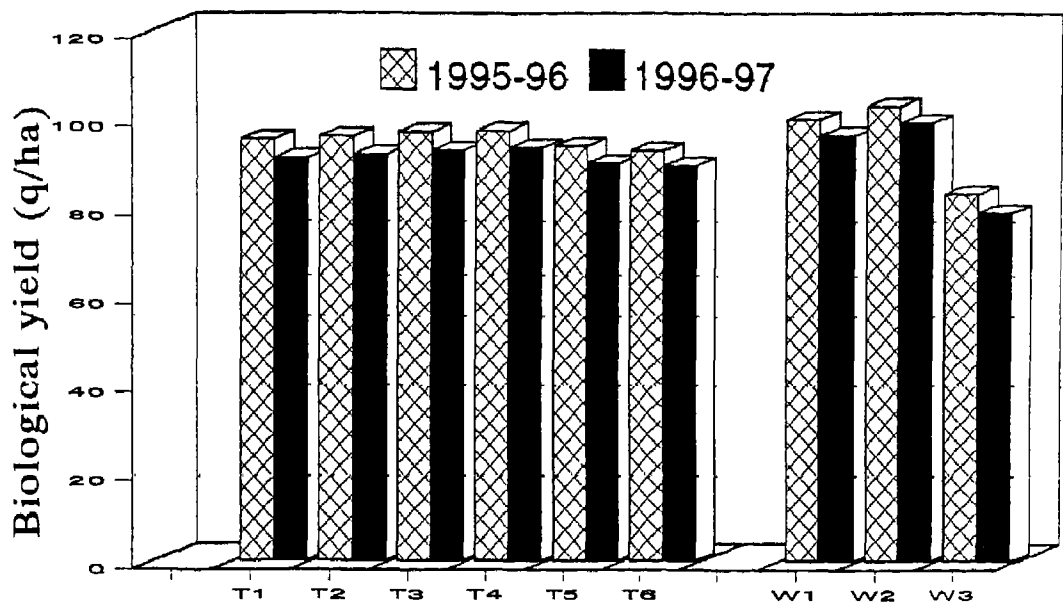


Fig. 15. Biological and grain yield of wheat as affected by residual effect of pendimethalin and metribuzin and direct effect of isoproturon

yield in hand weeding was significantly higher as compared to isoproturon and weedy check in 1995-96, whereas in 1996-97 former two treatments caused similar but significantly higher increase over weedy check. Pooled grain yield under these treatments was significantly higher than weedy check.

Isoproturon resulted in significant higher harvest index over hand weeding and weedy check in 1996-97, but in 1995-96 it was almost similar to hand weedy but proved statistically superior to weedy check.

4.4.4 N, P and K uptake by wheat

Data pertaining to N, P and K uptake by grain, stover and total NPK as affected by different treatments are presented in Tables 55 and 56 and depicted in Fig. 16.

4.4.4.1 Uptake by grain : N, P and K uptake by grain was not influenced due to preceding treatments (applied to soybean) in any year.

Hand weeding once in wheat registered significant increase in N, P and K uptake over isoproturon and weedy check during first year, but in second year both in hand weeding and isoproturon uptake was similar but statistically higher than weedy check in which N, P and K uptake was lowest.

5.4.4.2 Uptake by stover : The effect of preceding treatments was not conspicuous on N, P and K uptake in any year.

Direct effect of hand weeding and isoproturon was identical on N, P and K uptake in 1996-97 and on N and P uptake in 1995-96 but K uptake was significantly higher under hand weeding as compared to isoproturon. Uptake in weedy check was significantly lower than other two treatments in both the years.

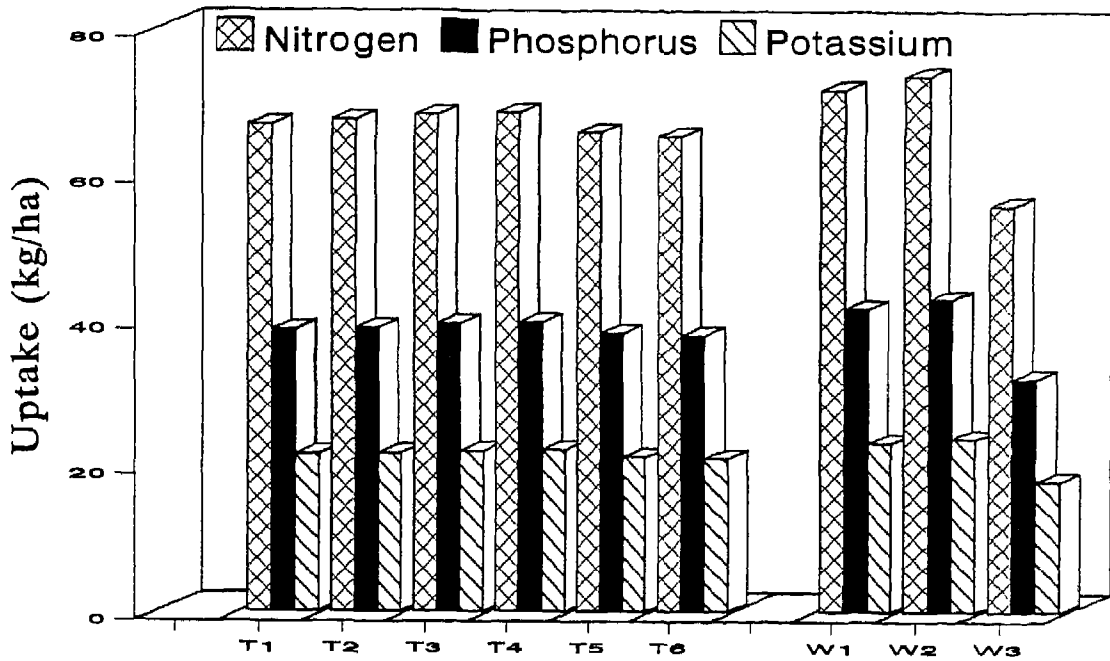
Table 55. Nitrogen, phosphorus and potassium uptake (kg/ha) by wheat as affected by residual effect of pendimethalin and metribuzin and direct effect of isotroturon in 1995-96

Treatments	Grain			Stover			Total		
	N	P	K	N	P	K	N	P	K
Residual effect									
T ₁ Pendimethalin 1.0 kg/ha	66.92	38.64	21.58	8.43	35.37	76.44	75.34	74.01	98.03
T ₂ Pendimethalin 1.50 kg/ha	67.56	38.89	21.69	8.58	35.61	76.99	76.15	74.50	98.68
T ₃ Metribuzin 0.50 kg/ha	68.25	39.45	21.99	8.79	36.01	77.86	77.03	75.46	99.85
T ₄ Metribuzin 0.75 kg/ha	68.52	39.67	22.19	8.79	36.14	78.13	77.30	75.81	100.32
T ₅ Hand weeding (20&40 DAS)	65.85	38.22	21.20	8.52	35.01	75.55	74.37	73.23	96.75
T ₆ Weedy check	65.27	37.92	20.99	8.40	34.52	74.61	73.68	72.44	95.60
SEm ±	1.78	1.24	1.01	0.49	0.95	1.46	1.88	1.90	2.21
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Direct effect									
W ₁ Isotroturon 0.75 /ha	71.68	41.56	23.16	8.90	36.61	79.10	80.59	78.17	102.27
W ₂ Hand weeding 30 DAS	73.62	42.83	23.75	9.15	37.86	81.72	82.77	80.69	105.47
W ₃ Weedy check	55.88	32.02	17.91	7.70	31.86	68.98	63.58	63.87	86.88
SEm±	0.65	0.48	0.36	0.24	0.59	0.74	0.68	0.97	1.01
CD at 5%	1.87	1.38	1.04	0.69	1.68	2.12	1.94	2.79	2.90

Table 56 Nitrogen, phosphorus and potassium uptake (kg/ha) by wheat as affected by residual effect of pendimethalin and metribuzin and direct effect of isoproturon in 1996-97

Treatments	Grain			Stover			Total		
	N	P	K	N	P	K	N	P	K
Residual effect									
T ₁ Pendimethalin 1.0 kg/ha	64.98	38.06	21.33	9.12	34.93	74.96	74.09	72.99	96.29
T ₂ Pendimethalin 1.50 kg/ha	65.79	38.29	21.51	9.29	35.26	75.68	75.09	73.56	97.19
T ₃ Metribuzin 0.50 kg/ha	66.38	38.84	21.79	9.49	35.63	76.34	75.88	74.17	98.14
T ₄ Metribuzin 0.75 kg/ha	66.85	39.31	21.95	9.53	35.83	76.84	76.38	75.14	98.79
T ₅ Hand weeding (20&40 DAS)	69.50	41.01	22.89	8.61	32.56	69.35	78.11	73.56	92.23
T ₆ Weedy check	63.83	37.57	20.94	9.17	34.57	73.91	72.9	72.14	94.85
SEm ±	4.33	2.78	1.60	0.64	1.61	3.50	4.02	2.30	2.52
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Direct effect									
W ₁ Isoproturon 0.75 /ha	72.92	42.85	24.00	9.39	35.40	75.72	82.31	78.25	99.43
W ₂ Hand weeding 30 DAS	71.84	42.26	23.65	9.95	37.74	80.69	81.79	79.99	104.35
W ₃ Weedy check	53.91	31.29	17.55	8.26	31.26	67.13	62.17	62.54	84.68
SEm±	1.58	1.03	0.56	0.33	0.96	1.76	1.46	0.94	1.50
CD at 5%	4.54	2.97	1.62	0.94	2.75	5.07	4.2	2.71	4.32

1995-96



1996-97

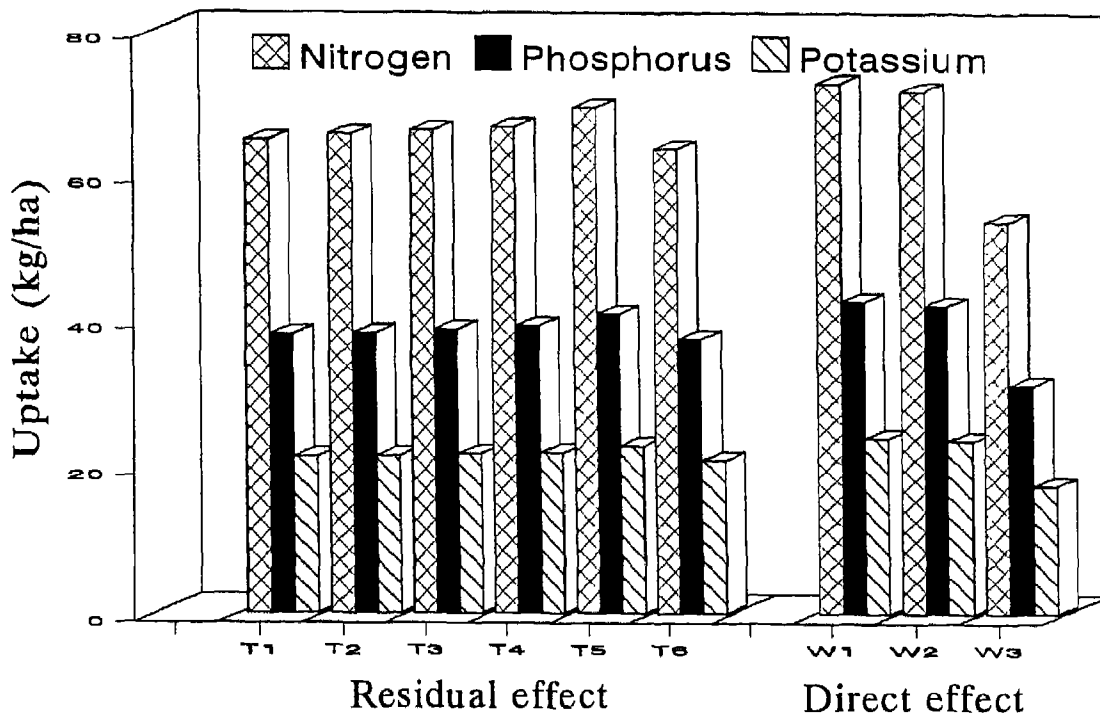


Fig. 16. N, P and K uptake (kg/ha) by wheat grain as affected by residual effect of pendimethalin and metribuzin and direct effect of isoproturon

5.4.4.3 Total N, P and K uptake : The effect of preceding treatments applied to soybean was not evident on total uptake in any year.

In 1995-96, N, P and K uptake was similar under all the weed control treatments but in 1996-97 hand weeding effected significant increase and proved statistically superior to other treatments (isoproturon and weedy check) in respect of K uptake while N and P uptake was statistically similar under hand weeding and isoproturon. The N, P and K uptakes in latter treatments were higher to weedy check in both the years.

5.5 TOTAL PRODUCTIVITY OF CROPPING SYSTEM

Data pertaining to total productivity in terms of soybean equivalent under various treatments are presented in Table 57.

5.5.1 Total productivity of soybean-wheat system

Effect of preceding treatments applied to soybean was conspicuous in both the years and in pooled total productivity. Hand weeding resulted in maximum increase and it proved statistically superior to preceding pendimethalin at 1.0 kg/ha and weedy check in 1995-96 but only to weedy check in 1996-97. Residual effect of metribuzin at 0.5 and 0.75 kg/ha and pendimethalin at 1.0 and 1.5 kg/ha effected increase but their effect was not well pronounced during first year (1995-96) while during second year residual effect of metribuzin 0.5 kg and hand weeding caused identical but higher increase as compared to residual effect of pendimethalin, however, weed control treatments were statistically alike but superior to weedy check. Impact of preceding treatments (applied to soybean) on pooled grain yield was identical. Residual effect of metribuzin at 0.5 kg/ha caused maximum increase followed by hand weeding and metribuzin at 0.75. All these

Table 57. Total productivity of cropping system in terms of soybean equivalent* (q/ha) as affected by residual effect of pendimethalin and metribuzin and direct effect of isoproturon

	Soybean - Wheat Cropping System		
	1995-96	1996-97	Pooled
Residual effect			
T ₁ Pendimethalin 1.0 kg/ha	42.18	48.16	45.17
T ₂ Pendimethalin 1.50 kg/ha	43.47	50.44	46.95
T ₃ Metribuzin 0.50 kg/ha	46.63	53.10	49.86
T ₄ Metribuzin 0.75 kg/ha	46.37	50.51	48.44
T ₅ Hand weeding (20&40 DAS)	47.12	53.11	48.81
T ₆ Weedy check	36.41	39.11	37.76
SEm ±	1.57	2.79	
CD at 5%	4.75	8.41	
Direct effect			
W ₁ Isoproturon 0.75 /ha	45.33	51.07	48.20
W ₂ Hand weeding 30 DAS	46.22	51.48	48.85
W ₃ Weedy check	39.53	44.66	42.09
SEm±	0.33	0.30	
CD at 5%	0.94	0.86	

* Soybean equivalent calculated considering the market prices of soybean Rs. 700/- and wheat Rs. 450/q.

treatments resulted in higher increase as compared to residual effect of pendimethalin at 1.0 and 1.5 kg/ha.

Hand weeding and isoproturon resulted in higher total productivity and were significantly superior to weedy check in both the years. Direct effect of weed control treatments on pooled productivity was well pronounced and was identical in both the years.

4.6 Economics of weed control

Economics of cropping sequence was calculated taking pooled yield (grain + stover) is presented in Table 58 and details of cost of cultivation for individual crops are given in Appendix III.

In soybean-wheat cropping sequence, the highest net return (Rs. 26467/ha), net return per rupee invested (Rs. 1.60) and benefit : cost ratio (2.6) were obtained with hand weeding in soybean and isoproturon in wheat (T_5W_1) and it excelled to all other treatment combinations. Next profitable combinations were preceding metribuzin at 0.50 kg/ha + isoproturon (T_3W_1), hand weeding in soybean + no weeding in wheat and hand weeding in both soybean and wheat. Net return under these three combinations was higher by 47.2, 45.4 and 49.8 per cent over no weeding (T_6W_3) in both the seasons.

Table 58 Economics of cultivation under different treatments in soybean-wheat sequence

Treatments	Cost of Cultivation excluding weeding cost (Rs/ha)		Cost of weeding including spraying (Rs/ha)	Total Cost Cultivation (Rs/ha)	Gross return (Rs/ha)		Total (Rs.)	Net Return (Rs/ha)	Net Return Rupees invested	Benefit : Cost Ratio
	Soybean	Wheat			Soybean (G + S)	Wheat (G + S)				
T ₁	W ₁	6356	7873	16551	14254	23211	37465	20914	1.26	2.26
	W ₂	6356	7873	16735	14254	23803	38057	21322	1.27	2.27
	W ₃	6356	7873	15905	14254	18348	32602	16697	1.04	2.04
T ₂	W ₁	6356	7873	17306	15498	23222	38720	21414	1.23	2.23
	W ₂	6356	7873	17590	15498	24012	39510	21920	1.24	2.24
	W ₃	6356	7873	16660	15498	18646	34144	17484	1.05	2.05
T ₃	W ₁	6356	7873	16148	17399	23459	40858	24710	1.53	2.53
	W ₂	6356	7873	16512	17399	24128	41527	25015	1.51	2.51
	W ₃	6356	7873	15682	17399	18994	36393	20711	1.32	2.32
T ₄	W ₁	6356	7873	16976	16044	23629	39673	22697	1.34	2.34
	W ₂	6356	7873	17160	16044	24160	40204	23044	1.34	2.34
	W ₃	6356	7873	16330	16044	19172	35216	18886	1.15	2.15
T ₅	W ₁	6356	7873	16535	18229	24773	43002	26467	1.60	2.60
	W ₂	6356	7873	16719	18229	23644	41873	25154	1.50	2.50
	W ₃	6356	7873	15889	18229	20067	40296	24407	1.53	2.53
T ₆	W ₁	6356	7873	14875	9094	23650	32744	17869	1.20	2.20
	W ₂	6356	7873	15059	9094	23641	32735	17676	1.17	2.17
	W ₃	6356	7873	14229	9094	21922	31016	16787	1.17	2.17
One hand weeding (20 man-days)				Rs. 830;	Herbicide spraying (4 man-days)		Rs. 166;			
Pendimethalin (30 EC)				Rs. 453	Metribuzin		Rs. 1800/kg;			
Isoproturon (50 WP)				Rs. 320/kg	Soybean grain		Rs. 700/q;			
Soybean stover				Rs. 30/q	Wheat grain		Rs. 450/q;			
Wheat stover				Rs. 60/q	G		Grain			
					S		Stover			

DISCUSSION

The investigations conducted for two consecutive years and reported herein were designed primarily to study the direct and residual effect of herbicides on soybean-wheat sequence. The experiment with soybean was carried out with pendimethalin (1.0 and 1.5 kg/ha), metribuzin (0.5 and 0.75 kg/ha), hand weeding twice (20 and 40 DAS) and weedy check in randomized block design with four replications. The residual effect of preceding treatment was studied in a split plot design with four replications on succeeding crop of wheat. In *rabi* each soybean plot was divided into three sub-plots to which three weed control treatments viz. isoproturan 0.75 kg/ha, hand weeding once (30 DAS) and unweeded check were allotted randomly. The experiment was conducted during *kharif* and *rabi* seasons of 1995-96 and 1996-97.

In this chapter an effort has been made to discuss the reasons which may be responsible for some of the important results outlined in the previous chapter. As the yield is the final criterion for the evaluation of the efficiency of different treatments, the discussion, therefore, is necessarily centered around the effect of treatments on various characters as they finally decide the yield.

The direct and residual effect of herbicides were assessed in terms of the effect of treatments on weed population, dry matter accumulation and major nutrients (nitrogen, phosphorus and potassium) depletion by weeds. Comparison of the effects of herbicides on crop growth, dry matter production, nutrient uptake and final grain yield with that of manual weeding provides a reliable measure of the selectivity and bioefficacy of

herbicides. The results obtained and outlined in the previous chapter are discussed in brief in the forthcoming pages to reach valid conclusions.

5.1 SOYBEAN

Weed species, weed population and dry matter accumulation

The predominant dicot weeds that infested the fields were *Trianthema portulacastrum* and *Digera arvensis*. This may be due to slightly higher soil pH (alkalinity) and higher redox potential during crop growing period. Pandey *et al.* (1996), Singh *et al.* (1995) and Chhokar *et al.* (1995) observed preponderance of these two weed species in soybean. Among monocots *Digitaria sanguinalis*, *Echinochloa colonum* and *Dactyloctenium aegyptium* were prevalent. Tiwari *et al.* (1994) and Muniyappa *et al.* (1986) reported the dominance of *Echinochloa colonum* and *Dactyloctenium aegyptium*, whereas predominance of *Digitaria sanguinalis* was observed by Singh *et al.* (1995) in soybean. Weeds prefer a particular range of soil pH has earlier been established by Bruchli (1936) and Ellenberg (1950).

Pre-emergence application of metribuzin at 0.5 and 0.75 kg/ha and pendimethalin at 1.0 and 1.5 kg/ha identically lowered emergence (Fig. 5) and population of *T. portulacastrum* as well as other weeds over weedy check. Pendimethalin was found ineffective against *D. arvensis* (Table 5). Lokras *et al.* (1985) and Agrawal *et al.* (1995) have earlier reported low population of almost all the associated weeds with pre emergence application of metribuzin. Pandey *et al.* (1996) found better control of weeds with pendimethalin and fluchloralin but partial control of *D. arvensis*. This may be due to its insensitivity to pendimethalin. Effect of hand weeding was well pronounced. Except 30 DAS, at all

other stages it drastically decreased the infestation of *D. sanguinalis* and other monocots and was superior to all other treatments statistically. This may be attributed to frequent removal of weeds. Tewari *et al.* (1992) and Chandrakar and Urkurkar (1993) registered higher grain yield with two hand weeding (30 and 50 DAS). The poor performance of hand weeding in first 30 DAS may be due to incessant emergence of weeds owing to heavy buildup seed bank in soil. It is important to note that non-of the weed control treatments affected the emergence and population of *Cyperus rotundus* at any stage.

In both the years, efficacy of pendimethalin was almost similar. It was inferior to hand weeding in arresting total weed population (Table 9, 10, 11, 12, 13 and 4) and dry matter accumulation (Fig 6) but metribuzin effected higher decrease compared to both the treatments. The former two treatments effected significantly higher decrease over weedy check. Lower efficacy of pendimethalin may be ascribed to preponderance of insensitive weed species *D. arvensis*. Because of lack of competition from *T. portulacastrum* and other dicot weeds, *D. arvensis* accumulated significantly higher total dry matter and this may be assigned to decrease in biological activity of the herbicide in soil after 25 days after application. Jayakumar *et al.* (1992) established that very low amount of pendimethalin persist in soil 10 days after application in alluvial soil and calculate half-life 26 days.

Nutrient depletion by weeds

The depletion of nutrients was markedly higher when weeds were allowed to grow unchecked (weedy check). On an average, the N, P and K depletion was to the extent of 22.4 kg N, 3.3 Kg P and

22.4 Kg K/ha, respectively. It has been earlier been reported that weeds divest the soybean crop on an average 35.9 to 41.6 kg N, 10.6 to 19.97 kg P and 56.1 to 66.7 kg K/ha besides 118, 45, 190 and 4765 g each of Zn, Cu, Mn and Fe/ha, respectively (Singh and Mani, 1977 and Pandey *et al.*, 1981). In both the years in weed control treatments nutrient depletion was conspicuous but substantially lower than weedy check. The efficacy of both metribuzin (0.5 and 0.75) and hand weeding was almost alike in both the year in arresting nutrient depletion. Under these treatments depletion was significantly lower than pendimethalin. The higher depletion under pendimethalin was due to its inability to arrest dry matter accumulation by weeds particularly *D. arvensis* because of rapid loss of herbicides in the soil profile. Decreased depletion of nutrient in metribuzin and hand weeded plots is due to lower weed dry matter accumulation owing to better weed control (Table 18). Similar decrease in nutrient depletion by weeds with metribuzin and hand weeding has been reported earlier by Jain *et al.* (1995) and Singh and Nepalia (1997). They also assigned similar reasons of lower depletion.

Growth and development of soybean

Soybean population was not affected due to variation in weed control treatments. In both the years, metribuzin at 0.75 kg/ha caused phytotoxicity but crop recovered 15 days after emergence. These observations are in agreement with the results of Rafael *et al.* (1976). They also observed adverse effect of metribuzin at higher dose (0.8 kg/ha).

Effect of weed control treatments on plant height was remarkable in the later growth stages in both the years. Metribuzin at 0.5 and pendimethalin at both doses and hand weeding facilitated higher increase

over metribuzin at 0.75 and weedy check. The higher increase in these treatments may be attributed to favourable conditions created for cell divisional and expansion and enhanced nutrients availability due to elimination of competition. The results is in agreement with the finding of Gardner *et al.* (1985). They postulated that non-availability of N limits cell division and expansion. Lower plant height in metribuzin at 0.75 kg/ha might be due to initial set back in plant growth and development processes. Similar was the observations of Rafael *et al.* (1976). Lower plant height in weedy check may be attributed to low availability of nutrients owing to severe crop weed competition and deleterious effect of allelo compounds on the growth.

Number of trifoliolate leaves in soybean was maximum under hand weeding in both the years. This is perhaps due to congenial micro environment created due to frequent disturbance in upper soil layer due to hand weeding that favoured enhanced nutrient and availability in the absence of intense crop-weed competition at critical growth stages.

Dry matter production by crop at both the stages 30 and 60 DAS was higher under metribuzin at 0.5 kg/ha, pendimethalin at 1.5 kg/ha and hand weeding as compared to weedy check and even higher than pendimethalin at 1.0 and metribuzin 0.75 kg/ha. This increase may be attributed to greater nutrient and water availability to crop plant and increase in number of trifoliolate leaves/plant. Increase in nutrient availability and trifoliolate leaves were also recorded earlier by Chin (1991). The lower dry matter production under metribuzin at 0.75 kg/ha and pendimethalin at 1.0 kg/ha, may be due to phytotoxic effect of former and crop-weed competition in latter due to presence of insensitive weed *D. arvensis*,

respectively. The finding is in accordance with the findings of Rafael *et al.*, 1976 and Pandey *et al.*, 1996.

Number of nodules and their dry weight was not affected due to weed control treatments 60 DAS in both the years. Similar was the observation of Deuber *et al.* (1981). They reported that pre-emergence applied pendimethalin under field condition had no affect on soybean nodule number and their dry weight.

Yield attributes

Weed control treatments brought about identical increase in number of branches/plant and number of pods/plant in both the years, but number of grains/pod and 1000-grain weight were not affected due to variation in weed control treatments (Table 24 and 25). In general hand weeding, metribuzin and pendimethalin caused higher increase in yield attributes and proved statistically superior to weedy check. Improvement in yield attributing characters occurs when weeds are controlled in the early growth stages particularly during critical growth period either manually or with herbicides, which scale down competition and create congenial micro environment for better establishment and growth of the crop. Weed control treatments effected increase in number of green trifoliate leaves that facilitated higher photosynthates production and translocation from source to sink, resulting in an overall improvement in yield attributing traits. Improvement in yield attributing characters due to effective weed management has also been reported by Jain *et al.* (1988), Jain and Tiwari (1992) and Singh *et al.* (1994). Lokras *et al.* (1988) observed increase in the branches/plant, pods/plant and 1000-grain weight with pendimethalin, metribuzin and hand weeding.

Total N, P and K uptake by soybean

In both the years, variation in weed control treatments effected marked increase in total N, P and K uptake. Hand weeding and herbicide treatments facilitated higher uptake than weedy check. Higher uptake in these former treatments may be due to decreased crop-weed competition, concurrent increase in nutrient availability, better crop establishment and growth and higher biomass production coupled with slightly higher nutrient content. This result is in agreement with the findings of Shekara and Nanjappa (1993), Chhokar *et al.* (1997), Chin (1991), Jain *et al.* (1995) and Singh and Nepalia (1997).

Grain Yield

Weed control treatments caused identical increase in grain yield in both the years. Hand weeding and metribuzin at 0.5 kg/ha effected almost identical but significantly higher increase than other treatments in both the years. Pendimethalin at 1.5 and 1.0 kg/ha and metribuzin at 0.75 kg/ha also augmented yield substantially and proved statistically superior to weedy check. In 1995-96, the increase in grain yield over weedy check was to the tune of 98.8, 85.6, 77.0, 46.3 and 59.0 per cent, whereas in 1996-97, it was 104.1, 97.6, 77.6, 65.6 and 75.0 kg/ha. Superiority of hand weeding and metribuzin may be ascribed to congenial micro environment created due to effective control of weeds during critical periods that favoured improvement in yield attributing traits viz. branches/plant, pods/plant and 1000-grain weight (Table 24 and 25), lower nutrient depletion by weeds (Table 18) and higher nutrient availability and uptake by crop (Table 29 and 30) ultimately higher crop yield. These results are in agreement with the findings of Shisodia *et al.* (1988), Pandey *et al.*

(1996), Chandrakar and Urkurkar (1993). Comparatively lower magnitude of increase in pendimethalin to that of handweeding and metribuzin may be attributed lower weed control efficiency and increased crop-weed competition due to its failure to control *D. arvensis* a major weed. Pandey *et al.* (1996) noted significant reduction in yield (84%) with 10, 13, 49, 9 and 8 plants/m² of *D. arvensis*, *T. portulacastrum*, *D. adscendens*, *D. aegyptium* and *C. rotundus*, respectively, and estimated a loss of about half kilogram of soybean grain per kilogram of weeds dry weight. Low yield under weedy check was due to higher weed densities and dry matter accumulation by weeds (Fig. 5), less nutrient availability to crop owing to higher nutrient depletion (Table 18 and 31) and all these unfavourable conditions affected adversely yield attributing traits viz. branches/plant, pods/plant and 1000 grain yield. Similar reduction in yield due to uncontrolled weed growth has also been reported by Young *et al.* (1982), Wiley *et al.* (1984), Rana and Angiras (1996), Bajpai (1994) and Kurmawanshi *et al.* (1995).

Protein yield

In both the years protein yield increased remarkably under weed control treatments. Hand weeding effected maximum increase and proved better than other treatments. This increase is because of reduced crop-weed competition, increased N content and its uptake by grain and higher grain yield. Chin (1991) found increase in total nitrogen and protein yield with hand weeding. On an average protein yield under metribuzin at 0.5 and 0.75 kg/ha and pendimethalin at 1.0 and 1.5 kg/ha was 97.3, 81.9, 61.5 and 78.9 per cent higher than weedy check. These results are in accordance with the findings of Singh *et al.* (1975) and Inder Dev

(1997). They found an improvement in protein content in soybean due to application of herbicides. Ries *et al.* (1968) noted higher content due to increased activity of nitrate reductase enzyme in simazine treated plants as the plant respired more rapidly and absorbed higher percentage of nitrate. The increased level of nitrate is reduced to ammonia due to activities of nitrate reductase enzyme and this ammonia is incorporated into amino acids and ultimately results in more proteins.

Oil yield

Oil yield varied identically due to various weed control treatments. On an average hand weeding, metribuzin (0.5 and 0.75 kg/ha) and pendimethalin at 1.0 and 1.5 kg/ha effected 102.2, 92.0, 76.5, 57.2 and 71.2 per cent increase over weedy check, respectively. Chin (1991) also observed identical increase in oil yield with the application of imazethapur + pendimethalin mixture in soybean.

Nutrient control in Soil after harvest of Soybean

In the soil available nitrogen, phosphorus and potassium were higher in weed control treatments after the harvest of soybean. In metribuzin at 0.5 and 0.75 kg/ha. available N and K content in soil after harvest of the crop was higher than the rest of the treatment. N, P and K content were higher by 16.5, 24.0 and 14.5 per cent in hand weeding, 12.4, 21.6 and 13.4 and 16.0, 24.3 and 15.5 per cent in pendimethalin at 1.0 and 1.5 kg/ha and 22.7, 25.4 and 20.1 and 26.4, 24.7 and 20.6 per cent in metribuzin (0.5 and 0.75 kg/ha) over weedy check. Ghenea (1964) postulated from his studies that triazines stimulated the growth of nitrifier thereby increased the availability of microbiologically fixed nitrogen

in soil. Improvement in phosphorus and potassium content in the soil with triazine application has also been reported by Talabaev and Azimbegov (1967).

Persistence of pendimethalin and metribuzin

From bioassay studies with oat and wheat, it is evident that both pendimethalin (1.5 kg/ha) and metribuzin (0.5 and 0.75 kg/ha) persisted in the soil upto the 110 days (Table 35). Reduction in dry matter in oat and wheat plants in soil collected 30 days after pendimethalin at 1.5 kg/ha and 45 days after metribuzin at 0.5 and 0.75 kg/ha. application, was recorded. Pendimethalin half-life is only 24 to 25 days whereas of metribuzin 44 to 49 days. This might be the possible reason of longer persistence of metribuzin. In general, with each increased dose of pendimethalin and metribuzin there was decrease in dry matter production and their detrimental effect mitigated with advancement in time. Lower dry matter accumulation by test plants in pendimethalin, metribuzin and atrazine treated soil has earlier been reported by Padmavati *et al.* (1994), Savage (1977), Hance and McKone (1976) and Saikia (1997).

It is evident from the chemical analysis of herbicide treatments that there was rapid dissipation of pendimethalin in soil upto 15 days of its application in both the years. Thereafter dissipation was gradual (Fig. 11 and 12). It was to the extent of 54 to 59 per cent both in 1.0 and 1.5 kg/ha application in 30 days. More than 60 per cent degradation during first 60 days after its application was observed by Singh *et al.*, (1994). At the time of crop harvest (110 days), residue level was below detectable limit in the soil. These results are in agreement with the findings of Berayon and Mercadod (1983). Contrary to this, Walker and Brown

(1982) found 25% of the original value of pendimethalin remain biologically active in soil even after 140 days of application at 1.2 and 4.0 kg/ha in soybean. Dissipation of metribuzin was rather gradual. Its dissipation was only between 51 to 52 per cent in the first year and 48 to 51 per cent in second year 45 days after its application. The findings is in contrast to the findings of Savage (1980), he found rapid loss of metribuzin during the first 5 to 7 days. At the time of crop harvested, metribuzin residue was found to be below detectable limit in the soil. Similar was the finding of David *et al.* (1986).

Pendimethalin and metribuzin did not follow first order kinetics. This finding is in contrast to the findings of Jensen *et al.* (1989) and David *et al.* (1986). The calculated half-life of pendimethalin and metribuzin ranged around 24 to 25 days and 44 to 49 days, respectively (Table 39, 40). Jayakumar *et al.* (1992) estimated 26 days half-life of pendimethalin in alluvial soil and of metribuzin 21 days after shallow incorporation in soil was found by Savage (1977).

In both the years, pendimethalin (1.0 and 1.5 kg/ha) and metribuzin (0.5 to 0.75 kg/ha) residues in soybean grain reached below detectable limit (Table 41). These findings suggest that pendimethalin at 1.0 and 1.5 kg/ha and metribuzin at 0.5 to 0.75 kg/ha can safely be used as pre-emergence control weed in soybean. Similar was the finding of Saikia (1997). He did not get the residue of atrazine in maize grain when applied at 1.0 and 1.5 kg/ha.

5.2 WHEAT

Weed population, dry matter accumulation and nutrient depletion

Residual effect of preceding treatments was well pronounced on weeds in succeeding wheat crop both at 45 DAS and at harvest. The dicot and total weed population in preceding treatments metribuzin (0.5 and 0.75 kg/ha) and hand weeded plots were lower at both 45 DAS and at harvest as compared to other treatments. The residue of metribuzin might have hanged up germination of several weeds and arrested the growth of weeds in the earlier stages of crop growth. While in hand weeded plots weed seeds germinated in greater number owing to conducive condition and were controlled subsequently. This may be the possible reason for lower weed population under these treatments. The finding is in agreement with the findings of Tiwari *et al.* (1996). They assigned similar reasons for lower weed population in wheat due to residual effect of herbicides applied to soybean.

The direct effect of weed control treatment was remarkable on both monocot and docot weeds population, and total weed population 45 DAS and at harvest in both the years. Isoproturon caused decrease in the population of both monocot and dicot and total weed population 45 DAS and at harvest. Tiwari *et al.* (1988) and Panwar *et al.*, (1988) also observed isoproturon effective against the monocots viz. *Phalaris minor*, *Avena ludoviciana* and dicot weeds particularly *Chenopodium album*.

Total weed population at harvest in wheat in 1996-97 was significantly affected due to interaction effect of residual and direct effect (Table 45). Residual effect of metribuzin (0.5 and 0.75 kg/ha) and direct

effect of isoproturon was conspicuous on weed population in wheat. The residue of metribuzin might have hanged up germination of several weeds and affected the growth mechanism in weeds in the early stages of crop and subsequent application of isoproturon might have impaired initial growth process in the most of the sensitive weeds thereby resulting in death of most of the weeds and lower total weed population. The next best combination was no weeding in soybean and isoproturon application in wheat. The lower total weed population in this combination may be attributed to more weed dry matter incorporation in the soil after the harvest of soybean. The green biomass in soil during the decomposition releases several organic acids that either hasten or retard the vital growth process in weeds thereby making these seedlings easy target to herbicides. This may be the reason of enhanced isoproturon activity and ultimately lower total weed population. Effect of residue of metribuzin at 0.75 kg/ha was visible. Similar residual effect of preceding oxadiazon and hand weeding treatments on germination of rabi weeds particularly *Anagallis arvensis* and *Chenopodium album* has earlier been reported by Tiwari *et al.* (1996).

Dry matter accumulation by weeds in wheat was affected markedly due to residual effect of preceding weed control treatments applied to soybean in both the years at harvest (Table 45). In preceding metribuzin (0.5 and 0.75 kg/ha) and hand weeded plots, the dry matter production was lower than that of other preceding treatments. The lower dry matter under these preceding treatments ascribed to poor growth of weeds due to impairment in growth and development process owing to absorption of metribuzin residue during emergence. Saikia (1997) also assigned similar reasons for lower dry matter production by weeds in mustard due to residual effect of preceding atrazine applied to maize.

Direct effect of weed control was identical. Isoproturon and hand weeding effected significant decrease in dry matter accumulation by weeds. These results clearly indicate that weed removal during critical period and pre-emergence application of isoproturon retard the germination of weeds and kill recruitment of germinating weed seedlings effectively thereby resulting in dry matter accumulation of weeds in wheat. Isoproturon has been found effective in reducing the dry matter production by weed was also observed by Porwal and Gupta (1987) and Panwar *et al.*, (1993). Hand weeding has earlier been reported comparable and even better to pendimethalin by Singh (1996) and Pandey *et al.* (1997).

In 1996-97, the dry matter accumulation by weeds in wheat at harvest was affected significantly due to interaction effect of preceding treatments and direct effect of treatments. Higher reduction in dry matter was noticed when isoproturon and hand weeding in wheat were preceded by metribuzin application at 0.5 kg/ha. The emergence of lesser insignificant weeds and their poor growth under these combinations might be the reasons of lower dry matter accumulation by weeds. This finding is in accordance with the findings of Tiwari *et al.* (1996) and Tiwari *et al.* (1994). Residual effect of preceding metribuzin (0.5 and 0.75 kg/ha) effected decrease in dry matter accumulation in weedy check than other treatments. This may be due to its longer biological activity in the soil.

Nutrient depletion by weeds

Residual effect of preceding weed control treatments was evident on N and K depletion by weeds in 1996-97 only. Residual effect of metribuzin at 0.5 and 0.75 kg/ha arrested N and K depletion by weeds significantly in wheat and proved superior to pendimethalin and weedy

check. Hand weeding in soybean also effected decrease in N and K depletion by weeds in wheat but its effect was not well pronounced. The lower drain of N and K under these preceding treatments may be due to lower dry matter accumulation by weeds owing to retardation of weed emergence. Saikia (1997) also found similar results in chickpea due to preceding atrazine treatments.

Depletion of major nutrient was remarkably higher in weedy check. The depletion was to the extent of 30.1 kg N, 7.9 kg P and 36.3 K/ha (Table 48). This finding is in agreement with the findings of Malik *et al.*, (1995). They reported that an intense growth of mainly dicot weeds deprived the crop of about 58 kg N, 16 kg P and 88 kg K/ha. Isoproturon and hand weeding lowered significantly nutrient drain by weeds. This may be ascribed to lower dry matter accumulation by weeds. Bhagwati *et al.*, (1989) and Malik *et al.*, (1995) observed similar effect of weed control treatments on weed biomass accumulation.

Growth and development of wheat

Residual effect of preceding weed control treatments was not conspicuous on any growth parameters like plant population, plant height and dry matter production by plants at any stage in either year (Table 49, 50, 51).

Direct effect of treatments had no marked effect on plant population, plant height and dry matter production at any stage in both the years.

Yield attributing characters

Number of tillers/m row length, spike length, number of spikelets/spike and 1000 - grain weight were not affected markedly by preceding soybean treatments at harvest in any year.

The direct effect of weed control treatments applied to wheat was well pronounced on the number of tillers/m row length and number of spikelets/spike in both the years. Isoproturon and hand weeding effected significant increase in yield attributes. This increase may be attributed to better crop growth and due to retardation of weed seed germination and killing of seedling in isoproturon and elimination of weed pressure at critical stage of crop growth in hand weeding. This could have possibly enhanced the growth process resulting in greater dry matter production ultimately effecting increase in yield attributes. Singh *et al.* (1989) and Malik *et al.*, (1989) also found substantial improvement in the effective tillers/m² and length of ear with isoproturon and hand weeding over no control of weeds. Hand weeding and isoproturon caused significant increase in 1000 - grain weight in 1996-97. Increase in this parameter may be ascribed to increase in photosynthetic activity due to optimal physiological processes and translocation of photosynthates from source to sink. Improvement in 1000 - grain with isoproturon and hand weeding has also been reported by Satao and Podole (1994) and Singh *et al.* (1989),

N, P and K uptake by wheat

N, P and K uptake by grain was not influenced due to preceding weed control treatments in any year. The non-significant variations among these treatments may be due to weed pressure below threshold level. Similar was the observations of Tiwari *et al.* (1996).

Weed control treatments applied to wheat facilitated higher nutrient uptake by grain and stover in both the years (Table 55, 56). Hand weeding and isoproturon caused identical increase. This was due to quantitatively

higher dry matter production and higher nutrient content. This finding is in accordance with the findings of Malik *et al.* (1995) and Bhagwati *et al.* (1989).

Grain yield

Residual effect of preceding weed control treatments was not evident on grain yield either in 1995-96 or 1996-97 (Table 54).

Direct effect of wheat applied weed control treatments was conspicuous. Hand weeding caused maximum increase (31.5%) followed by isoproturon (30.5%) and both proved significantly superior to weedy check. Difference between hand weeding and isoproturan was not significant. These treatments effectively controlled weeds that favoured higher dry matter production and substantial increase in number of tillers/m row length (Table 52, 53), nutrient uptake (Table 55, 56) and improvement in the yield attributing characters (Table 52, 53) owing to optimal growth and development due to favourable environment created by elimination of weeds. The finding is in agreement with the finding of Pandey *et al.* (1996). They found hand weeding (once) superior to single or combined application of herbicides. On the contrary Satao and Podole (1994) found pre-emergence isoproturon (1.0 kg/ha) equivalent to isoproturan 1.0 kg/ha + 1 hand weeding but significantly superior to hand weeding once.

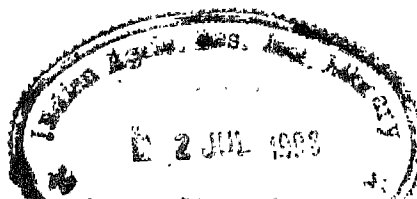
Low yield under weedy check was due to poor growth, lower nutrient availability (Table 55, 56) and poor expression of yield attributing traits owing to severe crop-weed competition (Table 52,53). The yield reduction was to the extent of 25 per cent due to unchecked weed growth. The finding is in accordance with the findings of Lal *et al.*, (1996) and Pandey

et al. (1996). They observed yield loss variation between 18 to 40 per cent due to weed infestation and ascribed the cause of such loss to the low nutrients availability and poor expression of yield attributing characters due to stress created by weed pressure.

5.3 TOTAL PRODUCTIVITY OF CROPPING SYSTEM

In soybean - wheat sequence, weed control in soybean substantially increased the total productivity of the system in terms of soybean equivalent (Table 57). Metribuzin at 0.5 kg/ha in soybean excelled to all other treatments. Next best treatments were hand weeding and higher dose of metribuzin (0.75 kg/ha). The higher grain yields of crops under these treatments (Table 26, 54) were due to insignificant crop-weed competition due to effective control of weeds. Tiwari *et al.* (1994) recorded higher grain yield of both soybean and wheat with the pre-emergence application of metribuzin at 0.5 kg/ha in soybean.

Both hand weeding and isoproturan brought about similar increase in total productivity of cropping system and proved superior to weedy check. The increase in total productivity in these treatments are due to increase in grain yield of wheat under these treatments owing to lower competition stress and considerable increase in growth factors (nutrient, light, space and soil moisture). Saikia (1997) reported that weed control in chickpea substantially increased the total productivity of maize-chickpea cropping sequence owing to increase in yield of both chickpea and maize crops.



5.4 Economics of weed control

In soybean-wheat sequence, the highest net return, net return per rupee invested and benefit : cost ratio were obtained with hand weeding in soybean and isoproturon in wheat (T5W1) and proved superior to all other treatment combinations. Next economically viable combination was metribuzin (0.5 kg/ha) application in soybean and isoproturon in wheat. Saikia (1997) also reported maximum economic return in maize-mustard sequence with the combination of hand weeding in maize and fluchloralin in mustard.

SUMMARY AND CONCLUSIONS

An experiment was conducted during *kharif* and *rabi* seasons of 1995-96 and 1996-97 at the experimental farm of Indian Agricultural Research Institute, New Delhi to study the direct and residual effect of herbicides on soybean-wheat sequence. The experiment with soybean was carried out with pendimethalin (1.0 and 1.5 kg/ha), metribuzin (0.5 and 0.75 kg/ha), handweeding twice (20 and 40 DAS) and weedy check-in randomized block design with four replications. The residual effect of preceding treatments was studied in a split-plot design with four replications on succeeding crop of wheat without disturbing the original layout. In *rabi* each soybean plot was divided into three sub-plots to which three weed control treatments viz. isoproturon 0.75 kg/ha, hand weeding once (30 DAS) and weedy check were allotted randomly. Thus, there were eighteen treatment combinations for *rabi* crop. The salient findings emanated from this investigation are briefly summarised below:

6.1 SOYBEAN

- (i) Both dicot and monocot weeds infested the soybean fields. Among the dicots *Trianthema portulacastrum*, *Digera arvensis* were dominant whereas, *Digiteria sanguinalis*, *Echinochola colonum* and *Dactyloctenium aegyptium* among monocots.
- (ii) Metribuzin (0.5 and 0.75 kg/ha) and pendimethalin (1.0 and 1.5 kg/ha) gave excellent control of *T. portulacastrum* and other weeds but latter proved ineffective against *D. arvensis*. Weed control treatments failed to arrest the population of *Cyperus rotundus*.

In both the years metribuzin at 0.5 and 0.75 kg/ha were equally effective in arresting the total weed population and their dry matter accumulation whereas, reduction in these parameter was significantly lower in handweeding and pendimethalin at 1.0 and 1.5 kg/ha than that of metribuzin.

- (iii) Depletion of N, P and K by weeds was to the extent of 22.4 kg N, 3.3 kg P and 22.4 kg K/ha in weedy check. Weed control treatments brought down nutrient drain by 87 per cent over weedy check. However, metribuzin and hand weeding proved more potent in arresting nutrient depletion by weeds.
- (iv) In both the years, in metribuzin (0.75 kg/ha) treated plots there was phototoxicity . Phytotoxicity symptom was disappeared in about 15 days of crop emergence.
- (v) Metribuzin at 0.5 kg/ha, pendimethalin at 1.0 and 1.5 kg/ha and hand weeding twice (20 and 40) resulted in higher increase in plant height and dry matter production over metribuzin at 0.75 kg/ha and weedy check.
- (vi) Number of trifoliate leaves was maximum under hand weeding in both the years, followed by metribuzin at 0.5 kg/ha and pendimethalin at both rates. All the weed control treatments proved statistically superior to weedy check.
- (vii) Number of nodules and their dry weight 60 DAS was not affected due to weed control treatments.
- (viii) Hand weeding, metribuzin and pendimethalin caused remarkable increase in yield attributing traits viz. branches/plant, number of

pods/plant and 1000 grain weight and proved statistically superior to weedy check.

- (ix) In hand weeding, metribuzin and pendimethalin treatments nutrient uptake was identically higher than weedy check.
- (x) Hand weeding and metribuzin (0.5 kg/ha) caused almost identical but higher increase in grain and stover yield over other treatments in both the years. Pendimethalin at 1.5 and 1.0 kg/ha and metribuzin at 0.75 kg/ha resulted in substantial increase in yield and proved significantly superior to weedy check. On an average hand weeding, metribuzin at 0.5 and 0.75 kg/ha and pendimethalin at 1.0 and 1.5 kg/ha resulted in 101.9, 92.4, 77.5, 57.3 and 71.3 per cent increase in grain yield over weedy check.
- (xi) Weed control treatments augmented protein and oil yield significantly in both the years. Hand weeding caused maximum increase followed by metribuzin 0.5 kg/ha. On an average hand weeding, metribuzin at 0.5 and 0.75 kg/ha and pendimethalin at 1.0 and 1.5 kg/ha brought about 105.6, 97.3, 81.9, 61.5 and 78.9 per cent increase in protein yield and 102.2, 92.0, 76.5, 57.2 and 71.2 per cent in oil yield over weedy check.
- (xii) After harvest of soybean there was improvement in soil fertility. Available nitrogen, phosphorus and potassium contents in soil in weed control treatments were higher.
- (xiii) Bioassay method was found to be more sensitive than that of chemical method for detecting the persistence of both pendimethalin and metribuzin in soil. Pendimethalin and metribuzin dissipation

did not follow first order kinetics. The average half-life values for pendimethalin at 1.0 and 1.5 kg/ha and metribuzin at 0.5 and 0.75 kg/ha were between 24 to 25 and 44 to 49 days respectively. No residue of pendimethalin or metribuzin was detected in soybean grain in any year with their application.

6.2 WHEAT

- (i) Residual effect (treatments applied to soybean) was well pronounced on weeds population and weed dry weight in succeeding wheat crop 45 DAS and at harvest. The dicot, total weed population and their dry weight in preceding metribuzin (0.5 and 0.75 kg/ha) and hand weeding plots were lower than other treatments. Direct effect of weed control treatments on weed population and weed dry weight was evident. The residual effect of metribuzin (0.5 and 0.75 kg/ha) and direct effect of isoproturon resulted in lower total weed population and weed dry matter. Residual effect of metribuzin was well marked on total weed population and dry matter accumulation by weeds in weedy check in wheat.
- (ii) Depletion of N, P, and K by weeds was not affected significantly due to preceding treatments in 1995-96, but N and K depletion was significantly lower in 1996-97. Residual effect of metribuzin at 0.5 and 0.75 kg/ha caused significant reduction in N and K depletion by weeds. Preceding hand weeding also effected decrease but its effect was not well pronounced. In wheat, direct effect of treatments was distinguished. Isoproturon and hand weeding caused remarkably higher decrease in nutrient drain by weeds.

- (iii) Direct and residual effect of herbicides had no effect on growth and development characters of wheat.
- (iv) Number of tillers/m row length, spike length, number of spikelets/spikes and 1000- grain weight were not affected markedly by residual effect in any year. Direct effect of weed control treatments augmented number of tillers/m row length, number of spikelets/spike in both the years and 1000 grain weight only in year 1996-97. Isoproturon and handweeding caused identical increase in the above yield attributing traits over weedy check.
- (v) Depletion of N, P and K by weeds in wheat was not affected significantly due to preceding treatments. Hand weeding and isoproturon facilitated identical increase in uptake of major nutrients (N, P and K) by grain and stover over weedy check.

6.3 TOTAL PRODUCTIVITY OF CROPPING SYSTEM

Preceding metribuzin treatment applied to soybean, at 0.5 kg/ha excelled all other preceding treatments in terms of total productivity (49.86 qa/ha) of soybean - wheat sequence. The next best preceding treatments were hand weeding and metribuzin at 0.75 kg/ha. Direct effect of hand weeding and isoproturon recorded significantly higher total productivity in term of soybean equivalent over weedy check.

6.4 ECONOMICS OF WEED CONTROL

In soybean-wheat sequence, the most profitable treatment combination in respect of net return, net return per rupee invested and benefit : cost ratio was hand weeding in soybean + isoproturon in wheat (T5 W1) and the next best combination was metribuzin (0.5 kg/ha) in soybean + isoproturon in wheat (T3 W1).

Conclusions

Based on the results of present investigations, the following inference may be drawn:

- (i) Metribuzin at 0.5 and 0.75 kg/ha and pendimethalin at 1.0 and 1.5 kg/ha gave effective control of *Trianthema portulacastrum* and other dicot weeds but latter was ineffective against *Digera arvensis*. Weed control treatments failed to arrest the emergence of *Cyperus rotundus*.
- (ii) Hand weeding gave effective control of both monocot and dicot weeds in both the crops in both the years.
- (iii) Metribuzin at 0.75 kg/ha affected initial growth and development but had no affect on yield attributing traits and yield.
- (iv) Metribuzin, pendimethalin and hand weeding had no significant effect on nodules number and their dry weight.
- (v) Hand weeding and metribuzin at 0.5 kg/ha effected higher increase in grain yield in soybean. Pendimethalin at 1.0 and 1.5 kg/ha and metribuzin at 0.75 kg/ha caused significant increase over weedy check.
- (vi) Bioassay technique was found to be more sensitive to detect residue in soil of pendimethalin and metribuzin
- (vii) Residual effect of metribuzin was marked on weed population and dry matter accumulation but not on the yield of succeeding wheat crop.

- (viii) Direct effect of isoproturon and hand weeding in arresting weed population, their dry matter accumulation and nutrient depletion and in facilitating the nutrient uptake by crop and augmenting yield attributes and yield was well marked.
- (ix) In soybean-wheat sequence, the most profitable combination was hand weeding in soybean + isoproturon application in wheat. The next best combination was metribuzin (0.5 kg/ha) in soybean + isoproturon in wheat.

REFERENCES

- Agarwal, S.K., Agrawal, K.K. and Jain, K.K. (1995). Effect of herbicides and spacings on weed dynamics in soybean weed association. *World-Weeds* 2 (2) : 83-92.
- Alam, M.T., Gaffer, M.A. and Kashem, M.A. (1994). Critical period of weed competition in wheat as influenced by different seed rates. *Bangladesh J. Agric. Scientific and Industrial Res.* 29(2) : 63-70.
- Aman, S.A. and Hosmani, M.M. (1978). Effect of herbicide residues on the seedling growth of succeeding crops. In Abst. papers. All India Weed Sci. Conf. held at Coimbatore, February 3-4, 1978, pp. 28.
- Angiras, N.N. and Sharma, V. (1993). Effect of cultural manipulation and weed control methods on crop-weed competition in wheat. *Indian J. Weed Sci.*, 25(3&4) : 6-10.
- Ankegowda, A.J. (1990). Influence of soil moisture on pendimethalin availability and its differential uptake in finger millet and red gram. A M.Sc. (Agri) Thesis Univ. Agric. Sci. Bangalore.
- AOAC (1966). Association of Official Agricultural Chemist. Official methods of analysis, Washington, D.C. 9th Ed. pp. 15-16.
- Arya, M.P.S. (1995). Distribution pattern of *kharif* season weeds in U.P. hills. *Indian J. Weed Sci.*, 27(1&2) : 56-62.
- Asana, R.D. (1951). Common weeds and their control. *Indian Fmg.*, 1(4) : 13-17.
- Ashby, E. (1948). Statistical ecology, II A reassessment. *Bot. Rev.*, pp 22-224.
- Azad, B.S. and Singh, H. (1997). Effect of time, methods of application of herbicide and nitrogen on weed control in wheat. *Ann. agric. Res.*, 18(2) : 174-177.
- Bansil, P.C. (1977). Oilseeds scenario - some issues. *Indian Fmg.*, 47(6) : 4-16.

- Barevadia, T.N., Patel, B.H. and Meisuriya, M.I. (1993). Weed competition in wheat cultivar GW 503. In Proc. Indian Soc. Weed Sci. International Symposium, Hisar, November 18-20, 1993, Vol. II pp. 36-38.
- Berayon, B.F. and Mercado, B.L. (1983). Persistence of pendimethalin in the soil. *Philipp. Agri.*, **66**(44) : 367-378.
- Bhagwati, P.C., Faroda, A.S. and Malik, R.K. (1989). Influence of nitrogen and weed control on the nitrogen uptake by broad leaves weeds and wild oat in wheat. *Indian J. Weed Sci.*, **21**(3&4) : 42-48.
- Bollick, P.K., Dunigan, E.P., Kitchen, L.M. and Taylor, V. (1988). The influence of trifluralin and pendimethalin on nodulation, N (CH) fixation and seed yield of field grown soybeans. *Weed Sci.*, **36**(1) : 15-19.
- *Bowler, D.J. (1975). Beneficios economics del control de la avena loca. *Revista Agrishell.*, **8** : 3-6.
- Brar, L.S. and Walla, U.S. (1993). Bioefficacy of S-ureas against *Phalaris minor* Retz. in wheat. *Indian J. Weed Sci.*, **25**(3&4) : 1-5.
- *Buchli, M. (1936). *Okologie der Ackerunkrauter der Nordostschweiz*. Verlag Hans Huber, Berg. pp 354.
- Chandrakar, B.L. and Urkurkar, J.S. (1993). Efficacy and economics of weed control in soybean under vertisols of Chhattisgarh region. *Indian J. Weed Sci.*, **25**(3&4) : 32-35.
- Chhokar, R.S., Balyan, R.S. and Pahuja, S.S. (1997). Nutrient removal of weeds in soybean under integrated weed management. *Indian J. Agron.*, **42**(1) : 138-141.
- Chhokar, R.S., Balyan, R.S. and Pahuja, S.S. (1995). The critical period of weed competition in soybean. *Indian J. Weed Sci.*, **27**(3&4) : 197-200.
- Chhokar, R.S., Balyan, R.S. and Pahuja, S.S. (1996). Integrated weed management studies in soybean. *Indian J. Weed Sci.*, **28**(3&4) : 133-136.

- Chin, D.V. (1991). Interactive effect of herbicides and fertilizer on Soybean and their residual effect as the succeeding crop of wheat. A Ph.D. Thesis, Division of Agronomy, I.A.R.I., New Delhi - 12.
- Cochran, W.G. and Cox, G.M. (1967). Experimental Designs. John Willey & Sons, pp. 611.
- Cordes, R.C. and Bauman, T.T. (1984). Field competition between ivy leaf morning glory and soybeans - In Proc. North Central Weed Control Conf. USA.
- David, R.S., Thomas, F.P. and Westerrman, R.L. (1986). Persistence of phytotoxicity of metribuzin and its ethylthio analog. *Weed Sci.*, **34**(3) : 409-412.
- Day, E.W. (1978). Ethalfluralin. In analytical methods of pesticides and plant growth regulators. pp. 341-351. Vol 10. Acad. Press, New York (ed. Zwieg, G. and Sharma, J.).
- Dekkar, O.D. and Johnson, W.S. (1976). Oryzalin. In Analytical methods for pesticides and plant growth, regulators. Vol. 8 pp. 433-442. Acad. Press, New York.
- Deuber, R. and Signori, L.H. (1980). Effect of herbicides at the beginning of development and nodulation in soybeans. Resumos XIII Congresso Brasileiro de Herbicidas e Ervas Daninhas, Bahia, 1980. pp-99.
- Deuber, R., Camargo, P.N. and Signori, G.H. (1981). Effect of herbicides and plant populations as nodulation and yield in soybean "Santa Rosa" *Planta Daninha*. **4**(2) : 97-109
- Dhawan, R.S. and Malik, R.S. (1992). Persistence of pendimethalin in soil. In Abstracts. Annual Weed Sci. Conf. ISWS, held at Hisar, March 3-4, 1992 pp. 147.
- Douliaz, C.G. (1990). Field evaluation of various herbicides in soybeans. *Zizeantology*. **2**(3) : 177-181.
- Dubey, S.K., Jain, H.C., Kosta, H.D. and Raghu, J.S. (1984). Integrated weed management in soybean. *Indian J. Weed Sci.*, **16** (4) : 238-243.
- Dubey, M.P., Tiwari, J.P. and Trivedi, K.K. (1988). Herbicidal weed control in Soybean. *Pesticides*. **22** (7) : 21-25.

- Durigan, J.C., Victoria Filho, R., Matuo, T. and Pitelli, R.A. (1983). Period of weed competition in soybean crop cultivars Santa Rosa and IAC-2, II. Effect on morphological characteristics and seed composition. *Planta Danninha*, **6** : 86-100.
- Dwivedi, R.K., Bajpai, R.P., Choudhary, S.K. and Mishra, R.K. (1996). Integrated weed control in wheat in northern hill region of Chhattisgarh. *Indian J. Weed Sci.*, **28**(3&4) : 189-190.
- Dwivedi, R.N. and Patel, C.S. (1987). Effect of herbicides on weed control and grain yield of wheat in agroclimate condition of Nagaland. *Indian J. Weed Sci.*, **19**(3&4) : 182-185.
- Economic Survey (1996-97) Govt of India pp. 1-196.
- *Ellenberg, H. (1950). *Landwirtschaftliche Pflanzensoziologie*. Bd. I : Unkraut gemeinschaften als Zeiger fur Klima Boden. Verlag E. Ulmer, Stuttgart z. Z. Ludwigsburg. pp 141.
- Etheridge, R.E., Murdock, E.C., Stapleton, G.S. and Toler, J.E. (1996). Sicklepod control in soybean with Tamazaquin metribuzin combinations. *Weed Technol.*, **10**(1) : 78-84.
- Gardner, F.P., Pearce, R.B. and Michel, R.L. (1985). *Physiology of crop palnts*. Scientific Publishers, Jodhpur.
- Gautam, K.C. (1990). Relative efficacy of various herbicides in controlling weeds in potato and their residual effect on wheat. In Abst. papers. Biennial Conf. ISWS, held at J.N.K.V.V., Jabalpur. (M.P.), March 4-5, 1990. pp. 208-209.
- *Ghenea, L. (1964). L' influence des aminotriazines sur L' activite microbiologique du sol. Trams. Internat. Congress Soil. Sci. 8th Congr. Bucharest **35** : 857.
- Gill, H.S. and Mehra, S.P. (1981). Growth and development of *Phalaris minor* Retz., *Chenopodium album* L. and *Melilotus indica* in wheat ecosystem. In Proc. 8th Asian-Pacific Weed Sci. Soc. Conf., November 22 to 29, 1981, Bangalore, India, pp. 175-180.
- Gill, H.S., Randhawa, S.K. and Brar, L.S. (1982). Bioassay studies on the persistence of S- triazines in Soil. *J.Res. Punjab Agric. Univ.*, **19**(3) : 203-206.

- Gogoi, A.K., Kalita, H. Pathak, A.K. and Deka, J. (1993). Critical period of crop-weed competition in rainfed wheat. *Indian J. Weed Sci.* **25**(3&4) : 90-91.
- Gupta, O.P. (1993). Weed management : principles and practices. In *Weed - crop interference. Agro. Botanical Publisher (India).* pp. 12-14.
- Gupta, O.P. (1994). Scientific Weed Management in Tropics and Sub-Tropics. Today and Tomorrow's Printer and Publisher, New Delhi. pp. 14-23.
- Halstead, S.J. and Harvey, R.G. (1986). 1986 FMC-57020 soybean efficacy trials. In *Proc. North Central Weed Control Conference, 1986, Vol. 41* : 52-53.
- Hamill, A.S., Zhang, J.H. and Swanton, C.J. (1995). Reducing herbicide use for weed control in soybean grown in two soil types in Southwestern Ontario. *Canadian J. Plant Sci.*, **75**(1) : 283-292.
- Hance, R.J. and McKone, C.E. (1976). The determination of herbicides. In Audus, L.J. (Ed.). *Herbicide Vol. 22nd Edn. Acad. Press, New York.* pp. 393-445.
- Hayden, T.A. and Martin, A.R. (1986). Common sunflower, tall waterhemp and velvet leaf competition in soybean. In *Proc. North Central Weed Control Conf. 43* : 3. (USA).
- Higgins, J.M., Whitewell, T. and Brown, S.M. (1985). Herbicide applications in wheat for weed control in no-till soybeans. In *Proc. Southern Weed Sci.*, **8** : 359-365.
- Hunt, H.R. and Arnold, B.H. (1981). Herbicides for controlling a mixed population of cocklebur and Johnson grass in soybeans. In *Proc. 34th Annual meeting Southern Weed Sci. Soc.* pp 68, (USA).
- Inder Dev (1997). Efficacy of glyphosate with or without additives/ herbicide for the control of purple nutsedge (*Cyperus rotundus* L.) A PhD. Thesis, Division of Agronomy, IARI, New Delhi-12.
- Jackson, M.L. (1967). Soil chemical analysis. Prentice Hall of India Pvt. Ltd. New Delhi.

- Jadhao, S.L. and Nalamwar, R.V. (1993). Studies on weed management in irrigated wheat as affected by plant geometry, Genotype and manual weeding. *Indian J. Weed Sci.*, **25**(3&4) : 18-21.
- Jain, H.C. and Tiwari, J.P. (1992). Influence of herbicides on the growth and yield of soybean under different spacing and seeding rates. *Indian J. Agron.*, **37**(1) : 86-89.
- Jain, H.C., Dubey, S.K. and Bisen, J.S. (1988). Influence of weed control and fertility levels on soybean. *Indian J. Weed Sci.*, **20**(2) : 68-74.
- Jain, H.C., Tiwari, J.P., Jain, K.K. and Sharma, R.K. (1995). Effect of herbicides on nutrient uptake by soybean crop and weeds under different row spacing and seeding rates. **2**(3&4) : 197-201.
- Jain, K.K. and Tiwari, J.P. (1993). Floristic composition of soybean - weed ecosystem and influence of tillage on weed dynamics. *Indian J. Weed Sci.*, **25**(3&4) : 44-48.
- Jain, K.K. and Tiwari, J.P. (1995). Effect of herbicides and tillage operations on weeds, yield attributes and yield of soybean. *Indian J. Weed Sci.*, **27**(1&2) : 32-35.
- Jain, N.K., Jain, H.C. and Rawat, G.S. (1991). Effect of herbicides on rainfed groundnut and soybean. *Indian J. Weed Sci.*, **23**(3&4) : 80-81.
- Jain, S.C., Dubey, R.M. and Upadhyay, M.S. (1972). Note on use of herbicides to control weeds in soybean in Madhya Pradesh. *Indian J. Agron.*, **17**(1) : 59-60.
- Jayakumar, Mohammed Ali, A. and Subramanian, S. (1988). Studies on residues of herbicides applied in cotton by bioassay techniques. *Indian J. Weed Sci.*, **20**(2) : 23-28.
- Jayakumar, R., Kempuchetty, N., Sankaran, S. and Palaniappan, S.P. (1992). Dynamics of pendimethalin in different soil types. In Abstracts. Annual Weed Sci. Conf. ISWS, Held at Hissar, March 3-4, 1992. pp. 148.
- Jensen, K.I.N., Ivany, J.A. and Kimball, E.R. (1989). Effect of canopy and incorporation on metribuzin persistence in soil. *Canadian J. Soil. Sci.*, **69**(3) : 711-714.

- Kandap, S.M., Reddy, B.B., Audinarayana, M., Rao, A.R. and Reddy, G.B. (1987). Weed flora of Telengana region of Andhra Pradesh. *Indian J. Weed Sci.*, **19**(1&2) : 83-93.
- *Konstantinovic, B., Dimitrijevic, M. and Samota, D. (1984). Investigation on weed control in Soybean crops. *Znanost i Praksa u Poljoprivredi Prehrambenoj Technol.* **14** (3&4) : 323-334.
- Kulshrestha, G. (1982). Hydrolysis of isoproturon in aqueous medium and its persistence in soil and plants. *Indian J. Weed Sci.*, **14**(2) : 96-102.
- Kulshrestha, G. (1983). Persistence of the herbicide isoproturon in soil. *Aspects-of-Applied-Biology*. No. **4** : 413-422.
- Kulshrestha, G. and Singh, S.B. (1992). Influence of soil moisture and microbial activity on pendimethalin degradation. *Bull. Environ. Contam. Toxicol.*, **48** : 269-274.
- Kulshrestha, G. and Yaduraju, N.T. (1987). Persistence of pendimethalin in soil following pre-emergence application to wheat. *Indian J. Agron.*, **32** (3) : 271-274.
- Kulshrestha, G., Yaduraju, N.T. and Mani, V.S. (1977). Relative toxicity of S- triazine to certain rabi crops. Abstracts of papers. *Ann. Conf. Indian Soc. Weed Sci.*, Parbhani (MS).
- Kumar, S. and Singh, G. (1997). Efficacy and selectivity of tralkoxydim alone or in combination with isoproturon in wheat. *Indian J. Agron.*, **42**(2) : 306-309.
- Kurmawanshi, S.M., Sharma, R.S. and Sahu, T.R. (1995). Studies on economic variability of weed control with herbicides. *Indian J. Weed Sci.*, **27**(3&4) : 110-113.
- Lal, R.B., Verma, A.K., Singh, R. and Ahuja, K.N. (1996). Weed management in irrigated wheat. *Indian J. Agron.*, **41** (3) : 406-408.
- Lal, S.S. (1990). Direct and residual effect of varying levels of herbicide for controlling the weeds in potato - blackgram crop sequence. In *Abst. papers. Biennial Conf. ISWS, held at J.N. Krishi Vishwa Vidyalaya, Jabalpur, (M.P.). March 4-5, 1990. pp. 124-125.*

- Lof, H. (1976). Water use efficiency and competition between arid zone annuals, especially the grasses *Phalaris minor* and *Hordeum murinum*. Agric. Res. Rep., 853. Wageningen, pp. 109.
- Lokras, V.G., Singh, V.K., Bisen, C.R. and Tiwari, J.P. (1987). Chemical weed control in soybean. *Indian J. Weed Sci.*, 17(4) : 45-48.
- Malik, R.S., Malik, R.K., Panwar, R.S. and Bhan, V.M. (1989). The influence of surfactant on the performance of grass herbicides applied under complex weed flora situations in wheat. *Indian J. Agron.* 32(2) : 217-222.
- Malik, R.S., Yadav, S.K., Malik, R.K. and Panwar, R.S. (1995). Effect of herbicides and fertilizer levels and weed control and nutrient uptake by wheat and associated weeds. *Indian J. Weed Sci.*, 27(3&4) : 164-166.
- Mani, V.S. (1975). Nutrient drain by weeds growth in crop fields. *Ferti. News.* 20 : 21-27.
- Mani, V.S. (1978). Chemical weed control in potato-wheat relay. In Abst. papers. All India Weed Sci. Conf. held at Coimbatore, February, 3-4, 1978. pp. 34.
- Melville, D.R., Rabb, J.L., Willis, L.D. Jr., Moppert, K.B. and Harger, T.R. (1979). Soybean weed control research. Annual Res. Report, Red River Valley Agril. Expt. Station. 1979. pp. 248-249.
- Misra, R. (1973). Ecology Work Book. Oxford and IBH Pub. Co., New Delhi, pp 31-50.
- Mukhopadhyay, S.K., Verma, R.D. and Bhardwaj, R.B.L. (1962). Weed control in wheat crop in India. *Indian J. Agron.*, 6(4) : 331-337.
- Munger, P.H. (1986). Water relations and morphological aspects of soybean - velvet leaf interspecific competition. *Dissertation Abstracts International, B.* 47(4) : 1337.
- Muniyappa, T.V., Prasad, T.V.R. and Murthy, K.K. (1986). Critical stages of crop weed competition and chemical weed control in soybean. *Indian J. Weed Sci.*, 18(1) : 34-38.

- Naik, K.R., Gogulwar, N.M. and Tiwari, J.P. (1997). Effect of weed control under different moisture regime and nitrogen at wheat. *Indian J. Agron.*, **42**(2) : 300-305.
- Nandal, D.P. and Singh C.M. (1994). Weed management in direct sown puddled rice-wheat cropping system. *Indian J. Weed Sci.*, **26**(1&2) : 21-26.
- Nimje, P.M. (1996). Planting pattern and weed management in pigeonpea + soybean intercropping system. *Ann. agric. Res.*, **17**(4) : 347-352.
- Nordmeyer, H. and Pestermer, W. (1995). Laboratory degradation and sorption experiments of pesticides in soil profiles. *Zeitschriftfur Kulturtechnik und Landentwicklung*. **36**(1) : 6-10.
- Padmavati Devi, M., Reddy, C.N., Reddy, N.V., Reddy, D.J. and Babu, T.R. (1997). Degradation and movement of pendimethalin in and metolachlor applied in soybean. Abstracts of papers. 7th Biennial Conf. ISWS. held at Ludhiana, February 19-21, 1997. pp. 89.
- Padmavati devi, Reddy, V.N. and Reddy, C.N. (1994). Sensitive bioassays for detection of pendimethalin residues in soil. *Indian J. Weed Sci.*, **26**(1&2) : 56-57.
- Panda, S.C., Pattanaik, A., Rath, B.S., Tripathy, R.K. and Behera, B. (1996). Response of wheat to crop geometry and weed management. *Indian J. Agron.*, **41**(4) : 553-557.
- Pandey, J., Sharma, R., Singh, R.P and Subhash Chander (1996). Effect of time and method of isoproturon application on weed and yield of wheat. *Indian J. Agron.*, **41**(4) : 573-576.
- Pandey, J., Singh, K.D.N. and Sharma, N.N. (1981). Effect of herbicides on yield, water use efficiency and nutrient economy in rainfed maize. In Proc 8th Asian - Pacific Weed Sci. Sco. Conf. Bangalore, November 22-29, pp. 73-77.
- Pandey Jitendra, Sharma Rajbir and Verma, A.K. (1996). effects of dose and time of chorimuran-ethyl on weeds and yield of soybean. *Annals agric. Res.*, **17**(2) : 205-208.
- Panwar, R.S., Malik, R.K. and Balyan, R.S. (1993). Influence of fluroxypyr, isoproturon and 2, 4-D on weed control in wheat. *Indian J. Weed Sci.*, **25**(3&4) : 65-70

- Panwar, R.S., Malik, R.K. and Bhan, V.M. (1988). Effect of dicamba in combination with isoproturon and 2, 4-D in wheat. *Indian J. Weed Sci.*, **20** p(2) 41-45.
- Panwar, R.S., Malik, R.K. and Rathi, S.S. (1995). Effect of tralkoxydim and its combination with isoproturon on the control of weeds in wheat. *Indian J. Weed Sci.*, **27**(1&2) 36-38.
- Parochetti, J.U. and Dec, G.W. (1978). Photodecomposition of eleven dintroaniline herbicides. *Weed Sci.*, **26** 153-156.
- Paroda, R.S. (1996). New paradigms. The Hindu Survey of Indian Agriculture. pp. 17-28.
- Patel, H.C. and Upadhyay, P.N. (1990). Integrated weed management in irrigated wheat. *Indian J. Weed Sci.*, **22**(1&2) 89-91.
- Patel, R.B. and Barevadia, T.N. (1997). Carry over effect of various herbicides applied to green gram on succeeding crops. In Abstracts of papers. 7th Biennial Conf. ISWS, held at Ludhiana, February, 19-21, 1997. pp. 95.
- Patil, B.M., Satao, R.N. and Lahriya, G.S. (1996). Weed control in soybean. *Indian J. Weed Sci.*, **28**(3&4) 212-215.
- Piper, G.S. (1966). Soil and Plant analysis. Hans Publishers, Bombay, pp 225.
- Ponnuswamy, K., Jaganathan, R., Kandaswami, O.S. and Bala Subramaniam (1996). Critical period of weed competition in Soybean. *Madras Agric. J.*, **83**(7) 469-470.
- Porwal, M.K. and Gupta, O.P. (1987). Evaluation of herbicide mixture for control of mixed growth of weeds in wheat. *Indian J. Weed Sci.*, **19**(3&4) 201-206.
- Praharaj, C.S. and Dhingra, K.K. (1995). Effect of pendimethalin on rhizobial efficiency in soybean. *Indian J. Weed Sci.*, **27**(3&4) 201-204.
- *Rafael, J.O.V., Maia, A.C. and Souza, IF. de. (1976). Herbicide evaluation in soybean Cv. Santa Roso in Uberada, Minas Gerais, Brazil. Trabajos Resumenes, III Congreso Association Latinoamericana de Malezas "ALAM" y VIII Reunion Argentina de Malezas y su control "Asam", Mar del Plata. **2** 257-266.

- Rahman, M.A., Gaffer, M.A. and Bhuiya, M.S.U. (1990). Critical period of weed competition in wheat. *Bangladesh J. Scientific and Industrial Res.*, **25**(1&4) : 37-44.
- Rajagopalan, S. (1996). Correcting the imbalance. *The Hindu Survey of Indian Agriculture*. pp. 39-46.
- Rana, M.C. and Angiras, N.N. (1996). Efficacy of Imazethapyr in controlling weeds in soybean. *India J. Weed Sci.*, **28**(3&4) : 140-143.
- Randhawa, S.K. and Sandhu, K.S. (1989). Persistence in soil of isoproturon applied for weed control in wheat. **21**(1&2) : 80-82.
- Regnier, E.E. and Stoller, E.W. (1989). The effects of soybean, jimson weed and velvet leaf. *Weed Sci.*, **37**(2) : 187-195.
- Ries, S.K., Schweizer, C.J. and Chmiel (1968). The increase in protein content and yield of simazine treated crops in Michigan and Costa Rica. *Bioscience*. **18** : 205-208.
- Saavedra, K., Torres, L.S., Bermejo, E.H. and Hildago, B. (1990). Influence of environmental factors on the weed flora in crops in the Guadalquivir valley. *Weed Res.*, **30** : 363-374.
- Saeed, S.A., Hussain, M. and Bajwa, A.M. (1987). Cereal weeds and their management in Punjab. *Progressive Farming*. **7**(1) : 26-29.
- Saikia, T.P. (1997). Direct and residual effect of herbicides on maize and succeeding chickpea and mustard. A Ph. D. Thesis, Division of Agronomy, IARI, Pusa, New Delhi.
- Saraswat, V.N. and Mishra, J.S. (1996). Recent development in weed control research in wheat. *Plant Protection Quarterly*. **11**(3) : 114-121.
- Satao, R.N. and Padole, S.G. (1994). Effect of weed control and growth and yield of late sown wheat. *Indian J. Agron.*, **39**(4) : 645-647.

- Savage, K.E. (1977). Metribuzin persistence in soil. *Weed Sci.*, **25**(1) : 55-59.
- Savage, K.E. (1978). Persistence of several dinitroaniline herbicides as affected by soil moisture. *Weed Sci.*, **26**(5) : 465-471.
- Savage, K.E. (1980). Metribuzin persistence in soil surface. In Proc. 33rd Annual Meeting. *Southern Weed Sci. Soc.*, 1980, pp. 228.
- Savage, K.E. and Jordan, T.N. (1980). Persistence of three dinitroaniline herbicides on the soil surface. *Weed Sci.*, **28**(1) : 105-110.
- Sawarkar, S.D., Pannase, S.K. and Goydani, B.M. (1995). Economic analysis of wheat and chickpea based crop sequence. *Indian J. Agron.*, **40**(1) : 1-3.
- Sekhar, J., Singh C.M., Badiyala and Gautum, S. (1989). Weed management studies in wheat under high hill temperate zone of Himachal Pradesh. *Indian J. weed Sci.*, **21**(3&4) : 78-79.
- Shahi, H.N. (1978). Competitive effects of *Chenopodium album* for soil moisture and nutrients in wheat. *International Pest Control*, **24**(4) : 14-16.
- Sharma, R. and Pandey, J. (1997). Effect of various formulations of isoproturon on weeds and yield of wheat. *Ann. agric. Res.*, **18**(2) : 246-247.
- Sharma, R. and Pandey, J. (1997). Studies on isoproturon resistance in different biotypes of *Phalaris minor* Retz. *Ann Agric. Res.*, **18**(3) : 344-347.
- Sharma, R.K. and Sandhu, K.S. (1985). Residual effect of simazine and atrazine applied to maize and potato on succeeding bread wheat crop. *J. Res. Punjab Agric. Univ.*, **16**(1&2) : 19-26.
- Sharma, R.S., Kewat, M.L. and Jain, K.K. (1995). Identification of problematic weeds in Jabalpur region of Madhya Pradesh. *Indian J. Weed Sci.*, **27**(1&2) : 19-23.
- Shishodiya, S.K., Singh, J.N. and Singh, G. (1988). Weed control efficacy of fomesafen and fluazipop-p-butyl in soybean. *Indian J. Weed Sci.*, **20**(4) : 79-80.

- Shurtleff, J.L. and Coble, H.D. (1985). Interference of certain broad leaf weed species in soybeans. *Weed Sci.*, **33**(5) : 654-657.
- Singh, A. Ahlawat, I.P.S. and Saraf, C.S. (1975). Studies on weed control in *kharif* cowpea. *Indian J. Weed Sci.*, **7**(2) : 85-88.
- Singh, B.P. and Mani, V.S. (1977). Investigations on chemical weed control in soybean. Abstracts of papers. In Proc. ISWS Conference held at APAU, Hyderabad, pp. 47-48.
- Singh, D. and Sharma, K.C. (1989). Influence of row spacing and weed management on the nutrient uptake by soybean and associated weeds. *Indian J. Weed Sci.*, **21**(3&4) : 1-6.
- Singh, G. and Singh, D. (1987). Weed control efficiency of pendimethalin and Methabenzthiazuron in soybean. *Indian J. Weed Sci.*, **19**(3&4) : 230-232.
- Singh, G. and Singh, D. (1992). Weed control efficacy of oxyfluorfen, acifluorfen, metribuzin and linuron in soybean. *Indian J. Weed Sci.*, **24**(1&2) : 97-99.
- Singh, H. and Kolar, J.S. (1994). Crop-weed competition studies in soybean. *Indian J. Weed Sci.*, **26**(1&2) : 83-86.
- Singh, H., Kolar, J.S. and Brar, L.S. (1994). Weed control in soybean. *Indian J. Weed Sci.*, **26**(3&4) : 148-151.
- Singh, R., Kali, B.D. and Negi, P.S. (1992). Integrated weed management in soybean. *Indian J. Weed Sci.*, **24**(1&2) : 94-96.
- Singh, R.P. and Reddy, B.G. (1988). Weed growth and wheat response to N levels and weed control methods. *Indian J. Weed Sci.*, **20**(4) : 1-6.
- Singh, S. and Kolar, J.S. (1992). Soil moisture and nitrogen effects on competitive ability of wild oats and wheat. In Abstr. Annual Weed Sci. Conf., March 3-4, Hissar, pp. 13.
- Singh, S., Malik, R.K. and Karwasra, R.S. (1994). Persistence of pendimethalin applied in clusterbean. *Indian J. Weed Sci.*, **26**(3&4) : 139-142.

- Singh, S., Malik, R.K., Bishnoi, L.K. and Singh, S. (1993). Effect of tank mixture of isoproturon and tralkoxydim on the control of *Phalaris* in wheat. *Indian J. Weed Sci.*, **25**(3&4) : 11-13.
- Singh, S., Malik, R.K., Balyan, R.S. and Singh, S. (1995). Distribution of weed flora of wheat in Haryana. *Indian J. Weed Sci.*, **27**(3&4) : 114-121.
- Singh, S.J., Varma, S.K., Sinha, K.K. and Mishra, S.S. (1989). Comparative efficiency of cultural and chemical methods of weed control in wheat. *Indian J. Agron.*, **34**(2) : 209-212.
- Singh, S.P. and Nepalia, V. (1997). Effect of weed control measures and levels of phosphorus on nutrient removal by soybean crop and weeds. *Ann agric. Res.*, **18**(3) : 401-403.
- Singh, S.S. and Vaishya, R.D. (1992). Studies on herbicides persistence in soil of wheat field. *Narendra Deva J. Agril. Res.*, **7**(1) : 82-86.
- Singh, T., Sandhu, K.S. and Bhatia, R.K. (1993). Weed flora of wheat fields in the Punjab. *Indian J. Weed Sci.*, **25**(1&2) : 17-21.
- Singh, V.K. and Bajpai, R.P. (1994). Influence of crop geometry and weed control method on yield and economics of rainfed soybean. *Indian J. Agron.*, **39**(4) : 671-673.
- Singh, V.K., Bajpai, R.P., Mishra, R.K. and Purohit, K.K. (1991). Chemical weed control in rainfed soybean. *Indian J. Agron.*, **36** (Supplement) : 292-294.
- Singh, V.P. (1996). Weed control in irrigated wheat under low hill valley situation in Uttar Pradesh. *Indian J. Weed Sci.*, **28**(3&4) : 130-132.
- Singh, V.P., Singh, G. and Singh, B.V. (1995). Weed control in soybean under rainfed low hill conditions. *Indian J. Weed Sci.*, **27**(3&4) : 122-126.
- Smith, A.E., Andrew, J.A. and Tara, C.M. (1995). Field persistence studies with emulsifiable concentrate and granular formulations of the herbicide pendimethalin in Saskatchewan. *J. Agric. Food Chem.*, **43** : 2988-2991.

- Subhaiah, H., Nanjappa, H.V. and Devendra, R. (1994). ED₅₀ values in bioassay techniques. *Indian J. Weed Sci.*, **26**(3&4) : 6-10.
- *Tablabaev, B. and Azimbegor, V.P. (1966). Einflues von triazines auf den NPK Gehalt in Boden. *Agrokhimiya* **11** : 115-119.
- Tewari, A.N., Singh, V. and Dubey, R.P. (1992). Weed management in Soybean Wheat Cropping Sequence. In Abstracts. Annual Weed Sci. Conf. held at Hisar, March 3-4, 1992. pp. 97.
- Thomas, J., Bhardwaj, R.B.L. and Ahuja, K.N. (1994). Performance of some herbicides in pigeon pea + cowpea - wheat cropping system. *Indian J. Weed Sci.*, **26**(3&4) : 11-17.
- Thomas, P.E.L. and Lindert, H.J.A.V. (1986). Competition between mixed weeds and soybean in Zimbabwe. *Zimbabwe Agric. J.*, **77**(5) : 215-219.
- Thornton, J.S. and Stanley, C.W. (1977). Gas chromatographic determination of sencor and metabolites in crops and soil. *J. Agric. Food Chem.*, **25**(2) : 380-386.
- Thornton, J.S., Stanley, C.W. and Schumann, S.A. (1997). 164th National Meeting of the American Chemical Society, New York, Aug. 1972, Abstracts PEST-006.
- Tiwari, A.N., Dubey, R.P. and Singh, V. (1994). Herbicidal control of weeds in soybean - wheat sequence in Parwa soil in Bundel Khand. *Indian J. Weed Sci.*, **26**(1&2) : 51-52.
- Tiwari, J.P. (1986). Weed flora of winter crops at Sehore (M.P.) India. *Indian J. Weed Sci.*, **18**(1) : 39-42.
- Tiwari, J.P. and Bisen, C.R. (1985). Competitive impact of *Phalaris* - weed ecosystem on sink co-efficient of some rabi crops. *Indian J. Weed Sci.*, **17**(4) : 21-27.
- Tiwari, J.P., Jain, H.C. and Dubey, S.K. (1988). Efficacy of fluroxypyr to control weeds in irrigated wheat. *Indian J. Weed Sci.*, **20**(2) : 35-40.
- Tiwari, J.P., Kurchania, S.P., Prasadkar, N.R. and Bhalla, C.S. (1996). Direct and residual effects of herbicides in a soybean - wheat cropping system. *Indian J. Weed Sci.*, **28**(3&4) : 150-155.

- Tiwari, J.P., Trivedi, K.K. and Dubey, M.P. (1988). Study on the effect of herbicides on soybean. *Indian J. Weed Sci.*, **20**(4) : 76-78.
- Tjitrosemito, S. (1990). A study on weed control in soybean. *Biotropia* No. 4 : 49-56.
- *Toro, J. and Zambrano, O. (1976). Influence of herbicides on nodulation induced by *Rhizobium japonicum* in soybean. Traba jos y Resumenes, III Congreso Association Latinoamericana de Malezas 'ALAM' Y VIII Reunion Argentina de Malzas Y su Control, 'ASAM' Mar del Plata, 1976, vol. 5 : 196.
- Vaishya, R.D. and Kumar, P. (1993). Effect of methods of isoproturon application on weeds in wheat. *Indian J. Weed Sci.*, **25** (3&4) : 115-116.
- Varshney, J.G. (1989). Studies on critical stage of weed removal in soybean. *Indian J. Weed Sci.*, **21**(3&4) : 49-52.
- Vencill, W.K., Wilcut, J.W. and Monks, C.D. (1995). Efficacy and economy of weed management systems for sicklepod and morning glory control in soybean. *Weed Technol.*, **9**(3) : 456-461.
- Walia, U.S., Brar, L.S. and Dhaliwal, B.K. (1996). Performance of tralkoxydim for the control of wild oats in wheat. *Indian J. Weed Sci.*, **28**(3&4) : 156-159.
- Walker, A. and Bond, W. (1977). Persistence of herbicide applications in wheat for weed control in no-till soybeans. *Zizeniology*. **2**(3) : 177-181.
- Walker, A. and Brown, P.A. (1982). Herbicide persistence and phytotoxicity of residues. In Annual Report. 1981, National Vegetable Res. Station, U.K. pp. 130-131.
- Walsh, J.D., Defelice, M.S. and Sims, B.D. (1993). Soybean herbicide carryover to grain and fibre crops. *Weed Technol.*, **7**(3) : 625-632.
- *Watanabe, Y., Sasiprapa, V. and Nordsomboon, C. (1979). Effect of duration of weed removal on growth and yield of mungbean and soybean. *Technical Bulletin Tropical Agric. Res. Center*. No. **20** : 71-77.

- Watteyne, K.K. and Burnside, O.C. (1983). Selective Control of velvet leaf in soybeans using split-application of herbicides. *In Proc. North Central Weed Control Conf.* pp 44, USA.
- Webster, G.R.B., Macdonald, S.R. and Sarna, F.P. (1975). Gas-liquid chromatographic determination of sencor and its major metabolites and photoproduct. *J Agric. Food Chem.*, **23** : 74-76.
- Wiley, G.L., Williams, J.L., Bauman, T.T. and Weller, S.C. (1984). Velvet leaf competition in soybeans as influenced by row - width. *In Proc. North Central Weed Control Conf.* **39** : 36-37 (USA).
- Williams, C.S. and Hayes, R.M. (1984). Johnsongrass (*Sorghum halepense*) Competition in soybeans. *Weed Sci.*, **32**(4) : 398-401.
- *Wim Schneider, W., Bachthaler, G. and Fischbeck, G. (1990). Versuche zum konkurrenzverhalten von *Avena fatua* L. (Flug-Hafer) in Weizen (*Triticum aestivum* L.) als Grundlage gezielter Bekämpfungsmaßnahmen. *Weed Res.*, **30** : 43-52.
- Yadav, A. and Malik, R.K. (1988). Persistence of isoproturon in different soils. *Haryana Agril. Univ. J. Res.*, **18**(3) : 198-206.
- Yadav, A., Faroda, A.S., Malik, P.K., Yadav, D.B. and Kumar, Y. (1993). Degradation of pendimethalin applied in wheat under different irrigation levels. *In Proc. Int. Symp, ISWS Hisar, November, 18-20, 1993, Vol. II.* pp. 111-112.
- Yadav, S.K., Kumar, A. and Bhan, V.M. (1986). Nutrient uptake in wheat as influenced by herbicides. *Indian J. Weed Sci.*, **18**(3) : 60-61.
- *Young, F.L. (1981). Quackgrass (*Agropyron repens*) interaction in corn and soybean. *Dissertation Abstracts International, B.* **42**(6) : 2173-2174.
- Young, F.L., Wyse, D.L. and Jones, R.J. (1982). Influence of quackgrass density and duration of interference on soybean. *Weed Sci.*, **30**(6) : 614-619.
- Zafar Reshi, Siddiq, M.A.A., Sapru, B.L. and Kachroo, P. (1987). Studies on weeds of rabi crops of Kashmir Valley. *Indian J. Weed Sci.* **19**(3&4) : 171-181.
- Zimdahl, R.L., Catizoma, P. and Butcher, A.C. (1984). Degradation of pendimethalin in soil. *Weed Sci.*, **32** : 408-412.

Original not seen

Appendix - I

**Mean Weekly Meteorological data during
the *kharif* and *rabi*, 1995-96**

Month	Standard week number	Temperature °C		Relative humidity (%)		Total rainfall (mm)	Sunshine hours/ day	Mean pan evapora- tion (mm/day)
		Max.	Min.	Max.	Min.			
June	23	45.6	28.6	34	13	0.0	9.7	13.9
	24	45.1	31.1	37	19	0.0	7.6	15.7
	25	35.9	25.4	74	52	36.6	5.2	3.2
	26	38.3	28.2	71	44	0.0	9.5	8.1
July	27	40.5	30.3	60	39	0.0	6.0	9.4
	28	35.2	27.6	84	61	19.4	3.3	5.5
	29	33.8	27.2	84	70	29.4	5.7	4.4
	30	32.5	26.3	87	65	21.8	4.8	3.9
August	31	32.2	26.7	92	74	65.2	2.7	2.6
	32	30.7	26.0	93	80	120.0	2.6	2.7
	33	33.1	26.7	84	67	14.6	4.4	3.9
	34	32.2	26.0	92	80	51.8	3.4	2.7
September	35	30.7	25.1	95	77	173.4	2.5	2.4
	36	31.8	23.5	91	75	184.4	4.9	2.6
	37	32.4	19.3	87	38	0.0	7.0	3.2
	38	35.0	23.6	80	46	0.0	8.8	4.9
	39	36.0	24.0	85	37	0.0	9.5	5.5
October	40	36.5	21.8	76	29	0.0	9.9	5.8
	41	34.3	20.9	89	36	0.0	8.0	4.4
	42	32.4	14.4	73	25	0.0	6.2	3.7
	43	31.2	14.4	73	25	0.0	8.2	4.1
	44	30.1	13.8	83	27	0.0	8.2	3.7
November	45	29.7	13.1	92	29	0.0	7.2	2.4
	46	28.8	12.2	86	31	0.0	7.7	3.1
	47	26.7	9.9	91	26	0.0	6.7	2.4
	48	24.3	10.0	77	35	0.0	7.2	2.9
December	49	23.7	7.2	81	27	0.0	8.0	2.6
	50	23.4	10.1	87	38	0.0	4.7	2.5
	51	23.3	10.0	81	39	1.8	5.0	2.4
	52	20.6	5.5	97	41	0.0	3.6	1.4
January	1	21.2	6.1	98	40	0.0	3.9	1.4
	2	20.9	5.9	95	38	0.0	4.1	1.6
	3	18.5	8.5	98	54	8.0	5.0	2.0
	4	20.6	7.2	87	34	0.4	7.9	2.7
	5	21.3	4.9	90	36	0.0	7.5	3.0
February	6	22.8	9.1	91	53	0.0	5.9	2.1
	7	22.5	8.9	92	45	0.0	7.7	2.6
	8	25.6	11.1	92	42	0.0	7.7	2.6
	9	24.0	11.3	93	45	10.2	6.5	2.7
March	10	28.6	13.9	89	42	0.0	8.0	3.8
	11	30.2	17.0	76	45	0.0	6.0	5.6
	12	27.2	13.1	82	42	5.4	7.3	3.6
	13	33.0	18.0	73	30	0.0	10.4	3.8
April	14	34.3	14.4	57	31	0.0	10.4	6.1
	15	35.0	13.5	64	26	0.0	10.2	5.3
	16	37.3	15.5	61	40	0.0	8.2	5.2
	17	36.6	22.1	53	27	0.0	8.6	7.3

Appendix - I (contd.)

Mean Weekly Meteorological data during
the *kharif* and *rabi*, 1996-97

Month	Standard week number	Temperature °C		Relative humidity (%)		Total rainfall (mm)	Sun hline hour / day	Mean pan evapora- tion (mm/day)
		Max.	Min.	Max.	Min.			
June	23	40.9	26.6	67	29	-	7.6	11.6
	24	36.9	27.8	69	56	-	5.7	6.7
	25	35.7	26.6	82	58	-	5.1	5.2
	26	32.3	26.5	81	62	88.1	4.6	4.9
July	27	35.2	25.5	78.4	62.7	60.9	8.0	6.9
	28	35.4	27.7	82.1	54.1	12.0	6.6	6.1
	29	35.5	27.0	82.6	63.4	58.0	5.4	4.4
	30	33.5	26.7	86.7	69.0	62.0	5.0	4.8
August	31	31.8	26.3	87.1	73.0	112.4	2.7	4.7
	32	33.6	26.9	84.3	66.6	33.9	4.4	4.4
	33	31.3	26.2	89.7	70.4	40.7	1.3	3.3
	34	30.0	24.7	91.7	85.8	128.6	2.7	3.2
September	35	33.9	26.3	87.0	67.2	-	6.5	3.9
	36	30.7	25.1	90.0	85	90	2.2	3.3
	37	32.0	25.0	89	80	142.6	6.0	2.5
	38	33.0	24.5	82	56	-	9.2	4.0
	39	35.1	22.5	87	43	-	9.7	4.5
October	40	33.1	22.4	87	51	-	1.7	3.5
	41	33.0	19.0	80	42	-	8.7	4.0
	42	32.4	17.0	76	37	-	7.8	2.7
	43	30.0	18.0	77	44	-	4.6	1.4
	44	31.3	14.0	71	31	-	8.8	2.8
November	45	29.8	11.6	83	30	-	8.5	2.6
	46	29.1	10.8	7.5	24	-	7.9	2.3
	47	26.0	8.9	75	29	-	7.2	2.2
	48	25.0	6.5	80	23	-	6.9	1.9
December	49	23.3	5.9	73	31	-	6.1	1.5
	50	21.8	4.0	77	20	-	7.6	2.4
	51	23.2	3.5	77	35	-	4.9	1.5
	52	22.4	6.0	82	39	-	6.0	1.4
January	1	23.4	4.4	83	36	-	5.6	1.6
	2	20.5	3.0	80	32	-	6.4	1.5
	3	14.4	3.8	88	46	-	5.0	1.3
	4	18.5	6.0	91	39	-	5.6	2.1
	5	20.9	5.2	87	39	-	5.9	2.3
February	6	21.1	5.3	48	29	-	7.3	3.2
	7	22.4	7.7	76	27	-	7.0	4.5
	8	25.3	8.1	75	28	-	8.3	3.7
	9	27.7	9.9	75	37	-	5.6	4.2
March	10	21.1	12.1	79	38	-	6.7	3.8
	11	28.1	15.7	78	40	-	4.8	3.7
	12	26.4	13.9	74	60	-	7.0	4.2
	13	28.3	14.8	79	39	-	5.6	4.1
April	14	27.3	14.3	88	45	-	7.5	4.1
	15	33.3	16.5	85	33	-	9.3	5.0
	16	33.8	17.1	65	24	-	8.9	7.3
	17	37.7	18.8	45	24	-	9.0	10.0

Appendix - II

**Floristic Composition of Weed flora of experimental field
(Relative density and important value index (IVI) in 1995-96)**

Weed Species	Family	Common name	Relative density (%)	I.V.I
A. Kharif Season				
Dicot weeds				
- <i>Convolvulus arvensis</i> L.	Convolvulaceae	Field bind weed	0.52	6.6
- <i>Digera arvensis</i> Forsk	Amaranthaceae	Kondra	13.08	39.1
- <i>Phyllanthus niruri</i> L.	Euphorbiaceae	Niruri	5.22	22.0
- <i>Trianthema portulacastrum</i> L.	Aizoaceae	Horse purslane	42.17	95.5
Monocot weeds				
- <i>Commelina benghalensis</i> L.	Commelinaceae	Day flower	0.87	9.4
- <i>Cyperus rotundus</i> L.	Cyperaceae	Purple nutsedge	2.90	18.1
- <i>Dactyloctenium aegyptium</i> L.	Poaceae	Crow foot grass	3.01	17.0
- <i>Digitaria sanguinalis</i> L. Scop.	Poaceae	Crab grass	19.53	51.5
- <i>Echinochloa colonum</i> L. Link	Poaceae	Jungle rice	12.64	38.2
B. Rabi Season				
Dicot weeds				
- <i>Anagallis arvensis</i> L.	Primulaceae	Pimpemel	2.5	13.8
- <i>Chenopodium album</i> L.	Chenopodiaceae	Lambs quarter	41.3	92.6
- <i>Convolvulus arvensis</i> L.	Canvolvulaceae	Field bind weed	2.0	14.3
- <i>Fumaria parviflora</i> Lamk.	Fumariaceae	Fumitory	4.4	18.8
- <i>Melilotus indica</i> L.	Papilionaceae	Yellow sweet	20.1	50.9
- <i>Spergula arvensis</i> L.	Caryophyllaceae	Corn spurry	3.0	17.2
- <i>Rumex dentatus</i> L.	Polygonaceae	Sorrels	1.9	12.4
Monocots				
- <i>Avena ludoviciana</i> Dur.	Poaceae	Wild oat	18.8	48.3
- <i>Cyperus retundus</i> L.	Cyperaceae	Purple nutsedge	1.2	10.7
- <i>Phalaris minor</i> Retz.	Poaceae	Wild Canary grass	4.8	20.9

Appendix - III

Estimation of Cost of Cultivation of Soybean

S.No.	Particulars	Input (per ha)	Rate (Rs)	Cost (Rs/ha)
1.	Land preparation			
	(i) Discing	2 times	250/ha each	500.00
	(ii) Harrowing	2 times	100/ha each	200.00
2.	Seed and sowing			
	(i) Seed cost	70 kg	10/kg	700.00
	(ii) Seed treatment	250 g thiram	80/kg	20.00
	(iii) Seed inoculation	2 packet culture	15/packet	30.00
	(iv) Cost of seed treatment	1 man-day	41.50/man-day	41.50
	(v) Sowing	10 man-days	41.50/man-day	415.00
3.	Fertilizer			
	(i) Cost of fertilizer	150 kg DAP/ha	9/kg DAP	1350.00
	(ii) Cost of application	2 man/days	41.50/man-day	83.00
4.	Gap filling and thinning	4 man-days	41.50/man-day	166.00
5.	Irrigation			
	(i) Irrigation charges	one time	150/ha each	150.00
	(ii) Application cost	2 man-days	41.50/man-day	83.00
6.	Insecticidal spray			
	(i) Endosulfan	350 ml/ha a.i.	205/litre	205.00
	(ii) Cost of application	2 man-days	41.50/man-day	83.00
7.	Harvesting, threshing and cleaning	20 man-days	41.50/man-day	830.00
8.	Land rent	For 6 months	3000 ha/year	1500.00
Total cost				6356.50
Round up to				6356.00

Appendix - III (Contd.)

Estimation of Cost of Cultivation of Wheat

S.No.	Particulars	Input (per ha)	Rate (Rs)	Cost (Rs/ha)
1.	Land preparation			
	(i) Discing	2 times	250/ha each	500.00
	(ii) Harrowing	2 times	100/ha ech	200.00
2.	Seed and sowing			
	(i) Cost of seed	100 kg	7.50/kg	750.00
	(ii) Sowing and gap filling	10 man-days	41.50/man-day	415.00
3.	Fertilizer			
	(i) Cost of fertilizer	120 kg N	7.22/kg N	866.00
		60 kg P ₂ O ₅	21.88/kg P ₂ O ₅	1313.00
		40 kg K ₂ O	8.33/ kg K ₂ O	333.00
	(ii) Cost of application	2 man-days	41.50/man-day	83.00
4.	Irrigation			
	(i) Irrigation charges	5 times	150/ha each	750.00
	(ii) Cost of irrigation application	8 man-days	41.50/man-day	333.00
5.	Harvesting, threshing and cleaning	20 man-days	41.50/man-day	830.00
6.	Land rent	For 6 months	3000/ha/year	1500.00
Total cost				7873.00

Appendix - IV

Weed Shift in Wheat in Delhi

Name of weed	Source			
	Asana 1951	Mukhopadhyay et al. 1962	Gautam and Mani 1975	Present status 1997
Non-grasses				
<i>Anagallis arvensis</i>	-	-		+
<i>Argemone mexicana</i>	+	+		-
<i>Asphodelus tenuifolius</i>	+D	+D		-
<i>Carthamus oxyacantha</i>	+	+		+
<i>Chenopodium album</i>	+D	+D	+D	+D
<i>Celosia argentia</i>	+	+		-
<i>Cirsium arvense</i>	+	+		+
<i>Convolvulus arvensis</i>	+	+	+	+
<i>Digera arvensis</i>	+			S
<i>Fumaria parviflora</i>	+	+		+
<i>Justicia quinquangularis</i>	+			-
<i>Lathyrus aphaca</i>	+	+		-
<i>Launea</i> sp.	-	+		+
<i>Medicago denticulata</i>	+	+		-
<i>Melilotus alba</i>	+	+		+
<i>Melilotus indica</i>	+	+	+	+D
<i>Orobanche indica</i>	+			-
<i>Pluchea lanceolata</i>	-	+		-
<i>Phyllanthus niruri</i>	-	+		+
<i>Spergula arvensis</i>	-	+		+
<i>Vicia hirsuta</i>	+	+		-
Grasses				
<i>Avena</i> sp.	-	-	+	+D
<i>Phalaris minor</i>	-	-	+D	+
<i>Cynodon dactylon</i>	+	+		+
Sedges				
<i>Cyperus rotundus</i>	+	+D		+
<i>Cyperus esculentus</i>		+		-

+ = Present; - = Absent; D = Dominant; S = Shifted to kharif.

Appendix - IV (contd.)

Weed Shift in Soybean in Malwa region

Name of weed	Source	
	Jain et al. (1972)	Jain et al. (1991)
Non-grass		
<i>Acalypha indica</i>	-	+
<i>Aeschynomene indica</i>	-	+
<i>Alysicarpus</i> sp.	-	+
<i>Commelina benghalensis</i>	-	+
<i>Corchorus acutangulus</i>	+	+
<i>Digera arvensis</i>	+	+
<i>Euphorbia hypertifolia</i>	+	+
<i>Justicia simplex</i>	-	+
<i>Lagascea mollis</i>	-	+
<i>Leucas cephalotes</i>	+	-
<i>Portulaca quadrifida</i>	+	-
<i>Phyllanthus niruri</i>	+	+
<i>Sonchus oleraceous</i>	+	+
<i>Setaria glauca</i>	+	-
<i>Trilanthema monogyna</i>	+	-
Grasses		
<i>Cynodon dactylon</i>	+	-
<i>Digitaria sanguinalis</i>	+	-
<i>Paspalum</i> sp.	-	+
<i>Panicum</i> sp.	-	+
Segdes		
<i>Cyperus rotundus</i>	+D	+D

+ = Present; - = Absent; D = Dominant.

T-6275

