COMPETING ABILITY OF WHEAT GENOTYPES AGAINST RESISTANT *PHALARIS MINOR* UNDER ZERO TILLAGE

By

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DEDICATED

TO MY BELOVED PARENTS

FOR THEIR

PROFOUND AFFECTION,

INSPIRATION AND

ETERNAL SACRIFICE

CERTIFICATE – I

This is to certify that this dissertation entitled, "**Competing ability of wheat genotypes against resistant *Phalaris minor* under zero tillage** ", submitted for the degree of Master of Science in the subject of Agronomy of the Chaudhary Charan Singh Haryana Agricultural University, Hisar is a bonafide research work carried out by Mr. Bhagirath Singh Chauhan under my supervision and that no part of this thesis has been submitted for any other degree.

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

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CERTIFICATE – II

This is to certify that this dissertation entitled, **"Competing ability of wheat genotypes against resistant *Phalaris minor* under zero tillage"**, submitted by Mr. Bhagirath Singh Chauhan to the Chaudhary Charan Singh Haryana Agricultural University, Hisar in partial fulfillment of the requirements of the degree of Master of Science, in the subject of Agronomy, has been approved by the Student's Advisory Committee after an oral examination on the same.

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BSChauhan

HISAR **(BHAGIRATH SINGH CHAUHAN)**

CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER - 1

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops in the world agricultural economy and is the main source of human food next to rice. Apart from being a source of food for human beings, wheat straw is a good source of feed for a large cattle population of the country. Wheat is a predominant winter (*Rabi*) cereal crop of North – Western plain zones of India being grown in rotation with various summer (*Kharif* crops). India is producing about 68.7 million tonnes of wheat from an area of 25.4 million hectares with an average productivity of 2705 kg/ha (Anonymous, 1997). Haryana is producing about 8.56 million tonnes of wheat from 2.19 million hectares with an average productivity of 3916 kg/ha (Anonymous, 1999). But on experimental stations, the grain yield varied from 50 to 70 q/ha. It indicates that the average yield of wheat is quite low at farmer's field and there is considerable scope for improvement in its productivity. Population of

India is also increasing at much faster rate while cropped area cannot be increased at the same rate and therefore, increase in productivity remains the sole way of meeting out the food requirement of our people.

The combined efforts of Government of Haryana, Agricultural scientists, Extension agencies and farmers have brought out Green revolution in 1960's in Haryana. During the period of green revolution the production of wheat increased by more than five times and productivity by three times. The wheat production has increased mainly due to evolution of high yielding dwarf wheat varieties, balanced use of fertilizers and availability of assured irrigation facilities. However, the higher nutrient and irrigation requirements of high yielding varieties resulted into the dominance of grassy weeds particularly littleseed canary grass (*Phalaris minor* Retz.) in rice-wheat growing areas of North-West India. Herbicide use mainly isoproturon against this weed in wheat strongly shaped the large scale yield advantage and improved the economy of the farmers for more than 10 years. However, continuous use of a single herbicide, isoproturon (due to its superiority over other herbicides) together with monoculture of wheat has now trapped the farmers into the problem of resistance which got worse every year since 1992 and wiped out the gains achieved over the past 10 years starting from 1982 and has put wheat production in jeopardize particularly in North-West India (Malik and Singh, 1993). Situation was so worse that many farmers had started harvesting of their immature wheat as green fodder for cattle and yield was either, stable or declining in rice-wheat zone of the state, whereas it was increasing in the other cropping sequences in non traditional areas.

Then, based on survey, research and feedback, it was realized that an integrated approach including early sowing, stale bed technique, dry sowing, crop rotation, clean seed, alternate herbicides, herbicide rotation, roughing and competing genotypes might be the effective and viable alternatives for the management of this menace weed. Earlier reports indicate that wheat varieties with early vigour and more height can easily suppress weeds including *Phalaris minor* (Brar, 1997). Improved potency of alternate herbicides including clodinafop (60 g/ha), fenoxaprop (120 g/ha), sulfosulfuron (25 g/ha) and tralkoxydim (350 g/ha) applied 30-35 days after sowing has also been observed against resistant *P. minor* (Malik and Yadav, 1997). The target of these integrated methods must be to anyhow exhaust the soil seed bank of *P. minor.*

Zero-till sowing of wheat is becoming another popular tool amongst farmers of Haryana and Punjab in rice-wheat cropping regions and gaining importance not only for the effective management of resistant *P. minor* in wheat [due to slight soil disturbance associated with creating a narrow slot in which to place seed (and in some cases, fertilizer), Dickey, 1992] but also due to its sound economics, improved crop turnaround time and soil health (Phillips and Phillips, 1984). The per cent of agricultural land under zero-tillage in the USA, Canada, South America, Western Europe and Australia was 2.3 in 1990, 10.8 in 1995 and is estimated to be 14.0 in 2000 (Alesli, 1996). The estimated crop area under zero tillage planting systems (1995) in USA, Canada, Brazil/Argentina and Western Europe/Australia was 16.4, 5.5, 8.1 and 2.0 m ha, respectively (Alesli, 1996). Due to sincere efforts of

CCS HAU, Weed Scientists, from last four years the current wheat acreage under zero tillage system of sowing has reached from only 4 acres in 1996-97 to around 20,000 acres in 1999-2000 in different districts of rice-wheat zones of Haryana. And approximately 90 farmer's have purchased their own zero-till-seed-cum-fertilizers drills in Haryana which clearly indicates fast growing interest and possibilities of practical implication of this techniques which can easily be exploited in near future. But reports on the performance of various wheat genotypes and alternate herbicides against resistant *P. minor* under zero tillage system are very meager and needs further research. Keeping these points in view, the present investigation entitled, " Competing ability of wheat genotypes against resistant *Phalaris minor* under zero tillage" was planned with the following objectives:

1. To identify the most competing wheat genotype against resistant *Phalaris minor* under zero tillage.
2. To evaluate the performance of clodinafop and sulfosulfuron against resistant *Phalaris minor* in wheat under zero tillage.

CHAPTER - 2

REVIEW OF LITERATURE

In the present chapter an attempt has been made to present a brief account of work carried out at different locations in India and abroad pertaining to the problem under study. The relevant work done is reviewed under the following heads :

A. ***Growth behaviour of littleseed canary grass (Phalaris minor)***

B. **Yield losses in wheat due to *P. minor***

C. **Herbicide resistance in *P. minor***

D. ***Herbicide resistance management strategies:***

1. Competitive varieties/genotypes
2. Alternate herbicides
3. Crop rotation
4. Herbicide rotation
5. Early and dry sowing
6. Stale bed technique
7. Zero tillage system of wheat sowing

E. **Tillage and weed flora shift**

A. Growth behaviour of littleseed canary grass (*Phalaris minor)*

Littleseed canary grass/wild canary grass/kanki/mandusi belongs to the Poaceae family. Bhan and Bhaskar Choudhary (1976) reported that *P. minor* seeds germinated maximum at a temperature between 10 to 15°C. It took 8 to 10 days for complete germination, although seeds started germinating from 6 days of sowing. The germination percentage decreased significantly with the increase in temperature from 15 to 20°C or 20 to 25°C and seeds failed to germinate at 30°C on the maximum side and at 5°C at minimum side of temperature treatments. Mehra and Gill (1988) also reported 10 to 20°C as optimum temperature for germination of *P. minor. Phalaris* seed have been shown to remain dormant for 3-4 months after maturity (Singh and Dhawan, 1976). Chhokar and Malik (1999) also confirmed that littleseed canary grass was capable of germinating in the temperature range of 10 to 25°C and optimum was 10 to 20°C and at the end of incubation period, maximum germination was recorded at a constant temperature of 15°C. Bhan and Bhaskar Choudhary (1976) reported that late December planting of *P. minor* produced considerably more tillers per metre row length than normal November planting. However, plantings in November resulted in higher dry matter accumulation over later dates of planting and the average number of grains per panicle were significantly more in November planted plots and this resulted in higher seed production as compared to late plantings. Kumar and Kataria (1977) also reported that germination was found to be spread over 9 weeks and appeared to be initiated by the availability of soil moisture at various depths. They further revealed that the earliest germinating weeds from 3 and 4 cm soil depths tended to have more tillers and produced seeds with a greater test weight.

Hooda *et al.* (1974) reported that most canary grass seeds germinate in the top 2 cm soil layer, slightly above the sowing depth of wheat. Drennan and Bain (1987) also reported that *Phalaris* spp. seeds could germinate upto 10 cm seeding depth. Chhokar *et al.*(1999) indicated that *P. minor* showed maximum emergence at 2.5 cm seeding depth and was capable of germinating upto a seeding depth of 10 cm. Chhokar *et al.* (1999) also reported that littleseed canary grass germination was only 29.3 per cent at –4 bars and further reduced to 2.7 per cent at –6 bars and did not germinate at –8 bars.

Rao and Agarwal (1984) based on root/shoot ratio of weed and crop plants clearly showed that root/shoot ratio in *P. minor* was 1:9 compared to wheat (1:11). Weed species with greater root/shoot ratio are expected to utilize underground resources better than the crop plants indicating their greater competing ability. The number of stomata/mm^2 leaf area of *P. minor* were 105 (Rao and Agarwal, 1984) as compared to 65 in wheat. *P. minor* with more number of stomata absorb greater quantities of water from the soil and ultimately offer stiff competition to wheat for water (Rao and Agarwal, 1984). Vengris *et al.* (1953) also found that *P. minor* with greater root growth and greater number of stomata utilized the available NPK in greater quantities at the expense of the associated wheat crop.

On an average, *P. minor* plants had six leaves (Bansal and Singh, 1984) and a test weight of 2 grams (Bhan and Bhaskar Choudhary, 1976). Bansal and Singh (1984) reported that *P. minor* produced 300-400 seeds/panicle and also observed that the percentage of seed germination, number of tillers and panicles per plant were less in *P. minor* than in wild oats (*Avena ludoviciana* L.).

B. Yield losses in wheat due to *P. minor*

P. minor is a serious weed in wheat and frequently infest wheat crop particularly in rice-wheat rotation. It is a strong competitor because of its similar growth habit to that of wheat. Weeds growing in association with wheat crop not only compete for moisture, light and nutrients but for space too. Malik *et al.* (1985) observed maximum competition for light between wheat crop and *P. minor* due to higher leaf area and more leaves of *P. minor*. *P. minor,* a troublesome weed, infests wheat in north-western India and causes 25-30 per cent yield reductions (Malik *et al.*, 1996). The yield losses in wheat due to *P. minor* at various locations were found to vary from 10 to 50 per cent or even more (Gill and Brar,1977; Pandey *et al.*, 1980; Bhatia *et al.*, 1981; Yadav *et al.*, 1984). Balyan and Malik (1989) reported that wild canary grass (*P. minor*) decreased the dry weight of wheat significantly and adverse effect on dry weight was more than on the number of tillers per plant. Yield components such as heads per plant, earhead length, grains number per spike and 1000-grain weight in wheat were most commonly affected by infestation of *P. minor* (Bhatia *et al.*, 1981; Morishita and Thill, 1988; Wilson *et al.*, 1990). Afentouli and Eleftherohorinos (1996) reported that grain yield of wheat was not significantly affected by the presence of 76 plants/m^2 of either of two canary grass species i.e. littleseed canary grass (*P. minor*) or short-spiked canary grass (*P. brachystachys*), but it was reduced by 36-39 per cent by the presence of 304 canary grass plants/m^2. In rice-wheat sequence, *P. minor* population ranged from 2000 to 3000 or even more number of plants per square metre resulting into very high yield reductions (Malik and Singh, 1995).

C. Herbicide resistance in *P. minor*

Isoproturon, metaxuron and methabenzthiazuron were recommended in 1978 against *P. minor* in wheat but isoproturon was largely accepted by the farmers because of its greater efficiency and safety margins. Effective control of *P. minor* in wheat with isoproturon had also been observed at many locations elsewhere (Balyan *et al.*, 1988; Malik *et al.*, 1989; Walia and Brar, 1996) and as such this herbicide sealed a great loss to grain yield of wheat which could have been due to *P. minor.* However, continuous use of a single herbicide, isoproturon, together with monoculture of wheat has now trapped the farmers into the problem of resistance which got worse every year since 1992 and wiped out the gains achieved over the past 10 years starting from 1982 and has put wheat production in jeopardize particularly in North-West India (Malik *et al.*, 1992; Malik and Singh, 1993). Yaduraju *et al.* (1995) had also confirmed these findings. Experiments as well as farmer's opinion confirm that *P. minor* has developed resistance against isoproturon

(Malik *et al.*, 1996). Quantification of resistance (Malik and Singh, 1994) indicated that the conclusion drawn by Harrington *et al.* (1992) was an early indication of development of resistance to isoproturon in *P. minor*. Modern short-statured varieties having high harvest index survived due to isoproturon but are no longer a guarantee for high productivity because of the development of herbicide resistance in the weed (Malik *et al.*, 1995). Grain yield of wheat in farmer's field trials also declined over time due to poor efficacy of isoproturon against *P. minor* particularly in rice-straw burnt fields (Malik *et al.*, 1995). Both formulations (Arelon® and Ronak®) failed to provide adequate control of this population of *P. minor*, thereby confirming resistance of the weed to herbicides (Malik and Singh, 1995).

Malik and Singh (1995) reported that some biotypes of littleseed canary grass were resistant to isoproturon and resistant biotypes required 2 to 8 times more isoproturon than a susceptible biotype for the same level of control and it was further reported that the control of littleseed canary grass with isoproturon dropped from 78 to 21 per cent from 1990 to 1993. Resistance in *P. minor* against isoproturon was found to be of metabolic in nature (Malik *et al.*, 1995; Singh, 1996; Mayor and Mah Lard, 1997). With the development of resistance to isoproturon in the rice-wheat sequence, littleseed canary grass has again become a major constraint to wheat production (Malik and Singh, 1995). Now the problem of resistance has by and large spread throughout the rice-wheat cropping areas of the country and GR_{50} of isoproturon against few resistant biotypes has gone as high as

8-11 times compared to prestine population of *P. minor* (Malik and Yadav, 1997).

D. Herbicide resistance management strategies against *P. minor* in wheat

1. Competitive varieties/genotypes

Short statured durum wheat varieties introduced from Mexico due to their poor competitiveness resulted into enhanced infestation and dominance of *P. minor* particularly in rice-wheat growing areas of India. Research on two-gene dwarf varieties has shown that plant height is an important attribute for the competitiveness of wheat against littleseed canary grass (Paul and Gill, 1979). Studies conducted by Lyfenko *et al.* (1986) on competitive ability of 40 winter wheat genotypes in relation to weeds revealed that moderately tall varieties suppressed weeds more effectively as compared to dwarf and semi-dwarf ones. Lemerle and Cousens (1992) and Torner *et al.* (1985) also reported that competitive ability of cereals to weeds varied by different cultivars. Brar and Singh (1997) revealed that bread wheat cultivars (HD 2329 and WH 542) resulted in greater suppression of *P. minor* than durum wheat (cv. PBW 343 resulting in 23.4 and 19.1 per cent higher grain yields, respectively. Eisele (1998) in Germany concluded that shoot growth and dry matter production of *Vicia hirsuta* were reduced by N fertilizer and the more competitive wheat cultivar cv. Pegassos than cv. Grief (due to more efficient ground shading of Pegassos than Grief). Traditional tall wheat cv. Pane 247 was more competitive than the semi-dwarf cv. Anza in decreasing the number of panicles and spikelets of *Avena sterilis* with increased N dozes (Santin *et al.*, 1997). And the best indicator of competitive ability was leaf area index at the stem elongation stage i.e. more the leaf area index with greater leaf angle, the greater shading effect on weeds. Balyan *et al.* (1991) reported that HD 2285 was the most competitive cultivar of wheat against wild oat.

Barley was a much better competitor with wild oat than wheat, allowing approximately one-half the wild oat biomass and seed production (Lanning *et al.*, 1997). Christensen (1995) found that weed dry matter in the most suppressive barley variety, Ida, was 48 per cent lower than the mean weed dry matter of all varieties, whereas it was 31 per cent higher in the least suppressive variety, Grit.

Blackshaw *et al.* (1981) found that the tall spring wheat cv. Sinton was a better weed (*Setaria viridis)* competitor than the semi-dwarf cv. Norquay due to its ability to shade the row more effectively. Wicks *et al.* (1986) also reported that taller wheat cultivars were more competitive than short ones. Montgomery (1912) stated that 'Turkey Red' winter wheat was more competitive than 'Big Frame' to weeds. Challaiah *et al.* (1986) reported that 'Turkey' was the most competitive cultivar to downy brome (*Bromus tectorum)* but it had the lowest grain yield, because 'Turkey' had more tillers in the downy brome- infested plots than other cultivars resulting into shading and more suppression of downy brome growth. Ponce (1988) studied the competition between wild oat and six wheat cultivars and found that the cultivars with the largest cycle was most affected by wild oat competition.

The competitiveness of wild oat was similar for all six wheat cultivars with respect to grain weight, straw weight, number of ears and total accumulation of nitrogen. Lemerle *et al.* (1996) reported that the 'old' wheat reduced *Lolium rigidum* dry matter more than all the current types, with the exception of the F_1 hybrids. Lemerle *et al* (1996) further observed that in the absence of herbicide, dry matter production of annual ryegrass (*Lolium rigidum)* at 300 plants/m^2 at anthesis was around half with 'Dollarbird' and 'Katunga' variety compared to 'Rosella' or 'Shrike' variety in 1992 and 1993. Sandhu and Mehra (1990) screened the tall genotype (C 306) of wheat more competitive against *Chenopodium album* and *Melilotus indica* as height and dry weight of weeds reduced comparatively more than dwarf genotypes (WL 711, WL 1562). Winter wheat varieties, which exhibited earlier ground cover with denser canopy were more competitive to broad leaved weeds (Richards and Whytoch, 1993). Gogoi and Gogoi (1989) reported that wheat variety UP 262 reduced the dry matter accumulation by weeds more as compared to Sonalika, HD 2402, WH 291 and PBW 138 and HD 2402 was found least weed competitor. Balyan *et al.* (1992) observed that WH 147, WH 283 and WH 416 were the most competitive cultivars to wild oat and wheat height, dry matter accumulation and leaf area per unit during early crop growth stages were better characters than number of tillers for governing the competitive ability of wheat cultivars to wild oat. Richards (1989) reported that winter wheat cultivars having properties of early coverage of ground resulted into a suppression effect on weeds.

Andersson (1983) studied the competitive ability of various cereal cultivars against weeds and found that wheat cultivars having more straw weight due to higher tillering ability imposed the effective competitiveness on weeds. Sechnyak *et al.* (1985) found that tall or medium statured varieties of wheat were most effective in respect of highest competitive ability. Gill and Mehra (1981) reported that the tall wheat genotype (plant height about 115 cm) exerted a strong suppressing effect on the weed intensity (population and dry matter) and height of *P. minor.* The three gene dwarf wheat genotypes proved very favourable for the growth and development of *P. minor.*

Sumbali and Sharma (1973) based on the performance of three wheat varieties (S 308, S 297 and RR 21) under four seed rates (60, 80, 100 and 120 kg/ha) reported that variety RR 21 was superior over S 308 and S 297 with regard to competition with weeds and increased seed rate reduced the dry matter of weeds drastically.

Govindra *et al.* (1985) reported that density and growth of *P. minor* were decreased by delay in wheat sowing but the decrease in grain yield due to delayed sowing was not compensated by decrease in density and growth of weeds.

2. Alternate herbicides

Due to introduction of high yielding dwarf wheat varieties coupled with improved irrigation and fertilizer facilities, *P. minor* became one of the most serious weed of wheat. Continuous use of isoproturon together with monocropping further resulted into more complicated problem of herbicide resistance in this weed. As isoproturon failed to provide satisfactory control and resistance evolved in 1992 onwards, recommendation of this herbicide was withdrawn from rice-wheat growing zones of Haryana. Based on number of experimental trials against resistant *P. minor* in wheat both at Research farm and farmer's fields, spray of clodinafop 60 g/ha, fenaxaprop 120 g/ha, sulfosulfuron 25 g/ha or tralkoxydim 350 g/ha at 30-35 DAS was recommended in Haryana during 1996-97.

a. Clodinafop

Dhaliwal et al. (1998) revealed that clodinafop 60 g/ha showed excellent control of various biotypes of *P. minor* during 1996-97 and 1997-98. Malik *et al.* 1997 also confirmed that clodinafop has been successful against isoproturon resistant *P. minor*. Walia *et al.* (1998) revealed that post-emergence application of clodinafop at 80 and 120 g/ha provided good control of *P. minor* and at 120 g/ha it increased the grain yield by 68.7 per cent over control (unweeded) and 34.1 per cent over two hand weedings. Bhan *et al.* (1998) found clodinafop as excellent herbicide to control *P. minor* in Jabalpur. In Haryana, Malik (1999) also suggested the use of clodinafop in rotation to avoid the likely problem of cross resistance/to control *P. minor*. In Punjab, Brar *et al.* (1999) and Walia *et al.* (1999) also observed cent per cent control of *P. minor* by the use of clodinafop 60 g/ha as post-emergence herbicide in wheat.

b. Fenoxaprop

Malik *et al.* (1997) reported that fenoxaprop was successful against isoproturon resistant *P. minor.* Walia *et al.* (1998) revealed that post-emergence application of fenoxaprop-p-ethyl at 80 ml/ha provided good control of *P. minor* and increased the grain yield by 60.4 per cent over control (unweeded) and 29.8 per cent over two hand weedings. In Punjab, Brar *et al.* (1999) and Walia *et al.* (1999) observed cent per cent control of *P. minor* by the use of fenoxaprop-p-ethyl (100 ml/ha) in wheat. The use of fenoxaprop in rotation to avoid the likely problem of cross resistance/to control *P. minor* was suggested by Malik (1999). Fenoxaprop has been found equally effective against both resistant as well as susceptible biotypes of *P. minor* (Malik and Yadav, 1997).

c. Sulfosulfuron

Euler *et al.* (1994) introduced sulfosulfuron (MON-37588) for selective control of annual and perennial grasses and annual broad leaf weeds in soft wheat and recommended 10 and 20 g a.i./ha as post-emergence alongwith surfactant to control *Agropyron repens, Aperaspica venti, Bromus* sp., *Galium aparine, Matricaria* sp. and *Stellaria media.* Sulfosulfuron was found suitable herbicide applied as post-emergence at 2 to 4 leaf stage of weeds @ 20-40 g/ha for effective control of grassy and broad leaf weeds in wheat particularly for isoproturon tolerant *P. minor* as per the trials conducted at CCS HAU, Hisar; G.B.P.U.A.T., Pantnagar and IARI in 1995 (Shukla, 1996). Sixto *et al.* (1997) studied the varietal susceptibility of wheat, barley and oat in relation to sulfosulfuron (0 to 40 g/ha) and concluded that sulfosulfuron ,(MON 37500) was good at the greatest rate for wheat, while oat tolerated 20 g/ha, a rate that damaged barley and controlled *Bromus diandrus.* Villarroya *et al.* (1997) confirmed the susceptibility of all accessions of weed in glass house even at 10 g a.i./ha and a good response to *Triticum aestivum* even at 40 g/ha and of *T. turgidum* at 20 g/ha of sulfosulfuron (MON 37500). Significant reduction in dry mass production of several dicotyledons and grassy weeds due to sulfosulfuron was recorded by Loubser (1998). While Rabert and William (1998) recommended sufosulfuron (MON 37500) for better management of downy brome in winter wheat production system and observed more than 85 per cent control of downy brome @ ranging 19 to 33 g a.i./ha applied pre or post. Patrick *et al.* (1998) also recorded best control of downy brome by sulfosulfuron (MON 37500) applied post-emergence or pre-emergence @ 35 g/ha. They noticed an increase in head density and yield of wheat with the use of sulfosulfuron (MON 37500). Dixit *et al.* (1998) at Jabalpur, found that sulfosulfuron @ 45 g/ha at 1-3 leaf stage (25 DAS) significantly reduced the population and dry matter of grassy and broad leaved weeds as compared to rest of the treatments.

Bhan *et al.* (1998) found sulfosulfuron an excellent herbicide to control *P. minor.* Dhaliwal *et al.* (1998) reported that sulfosulfuron 25 g/ha showed excellent control of various biotypes of *P. minor.* Malik *et al.* (1997) reported that sulfosulfuron has been successful against isoproturon resistant *P. minor.* Balyan (1999) reported that sulfosulfuron + surfactant at 25 g + 0.5

per cent gave 60 to 90 per cent control of grasses and satisfactory control of most of the broad leaf weeds in wheat. Brar *et al.* (1999) and Walia *et al.* (1999) observed cent per cent control of *P. minor* by the use of sulfosulfuron 25 g/ha in wheat. Gibson and Kerchove (1999) reported that removal of competition by *Bromus sterilis* was most advantageous when sulfosulfuron application (20 g a.i./ha) was made early in the spring. In Haryana, Malik (!999) suggested the use of sulfosulfuron to avoid the likely problem of cross resistance/to control *P. minor.* Sulfosulfuron has been reported equally effective against both resistant as well as susceptible biotypes of *P. minor* in Haryana (Malik and Yadav, 1997).

d. Tralkoxydim

Tralkoxydim has been reported to be an effective herbicide for achieving selective control of grassy weeds in wheat (Mirkamali, 1987; Rola, 1987; Sutton *et al.*, 1987). Panwar *et al.* (1994) reported that tralkoxydim at 0.25 kg/ha + isoproturon at 0.75 kg/ha applied 20 DAS (3-leaf stage of wild canary grass), isoproturon 1.0 kg/ha applied 35 DAS (6-leaf stage of wild canary grass) and tralkoxydim at 0.25 kg/ha + isoproturon at 0.5 kg/ha were effective in reducing sensitive wild canary grass population. Similar effects of tralkoxydim and isoproturon each applied alone, were reported earlier (Panwar *et al.*, 1989). Yadav *et al.* (1995) have found tralkoxydim @ 0.3 kg/ha very effective against nine resistant biotypes from various parts of country and one susceptible biotype of *P. minor.*

Bhan *et al.* (1998) reported that tralkoxydim was excellent to control *P. minor* at Jabalpur. In Haryana, Malik (1999) also suggested the use of tralkoxydim to avoid the likely problem of cross resistance. Balyan (1999) reported that tralkoxydim at 250 to 350 g/ha applied post-emergence provided 65 to 85 per cent control of grassy weeds in wheat. Tralkoxydim has also been reported equally effective against both resistant as well as susceptible biotypes of *P. minor* (Yadav *et al.,* 1995 and Malik and Yadav, 1997).

3. Crop rotation

Alternative crops do not merely delay resistance by allowing use of different management options, they also restore diversity in the weed flora. Some crop rotations may even be able to exhaust the soil seed bank of littleseed canary grass , thus providing a useful long-term solution. All factors that help the dominance of grasses can be changed by introducing alternative crops in place of wheat. Research in Haryana showed that in rice-wheat sequence replacement of wheat by an alternative crop is more important than the replacement of rice for delaying onset of resistance in littleseed canary grass (Malik and Singh, 1995). Banga *et al.* (1997) reported that in resistance-affected fields, where rice-wheat was continuously grown for 10 years, had littleseed canary grass population of 2350 plants/m^2 compared to 28 plants/m^2 where berseem (*Trifolium alexandrinum*) was grown for 2 years. Malik *et al.* (1996) indicated that the short-term solutions to resistant populations lies less with alternate herbicides than alternate crops (sunflower, sugarcane, berseem, winter maize and peas).

El-Hamid (1998) revealed that fresh weight of annual grassy weeds (*Phalaris* spp.) was greatly reduced in a wheat crop preceded by cotton compared to that preceded by rice and wheat yielded significantly more when preceded by cotton than when preceded by rice. Chauhan *et al.* (1997) revealed that grassy weeds, including *P. minor*, can be managed economically by introducing early maturing varieties of potato and pea as a crop between rice and late-sown wheat.

Birkas *et al.* (1998) reported that crop rotation (annual alternation of maize and winter wheat) reduced weed growth. In wheat, weed infestations were highest in monoculture and were lowest when wheat followed a vetch (*Vicia*)/oat mixture and intermediate following clover *(Trifolim)* and peas (Magyla, 1997). Crop rotations of wheat and maize with adequate fertilizers decreased the number of weed species and biomass, compared to unfertilized monoculture, where the lack of fertilizers encouraged the multiplication of *Avena* spp., *Setaria* spp., *Anagallis* spp. and *Sonchus* spp. (Ailincai *et al.*, 1997). Pallutt (1999) reported that weed emergence in winter wheat and winter barley was reduced upto 50 per cent with conservation tillage after potato and maize crops with little weed infestation. Derylo (1997) found 5.05 t/ha wheat grain yield in sugarbeet/spring barley/ legume mixture/ winter wheat rotation as compared to 4.13 t/ha in rotation of spring wheat/spring barley/oats/winter wheat. Welsh *et al.* (1999) found that crop rotation have a significant effect on weed levels with the most effective control resulting from the alternation of autumn/spring cropping as well as from the inclusion of break crops such as potatoes.

Petrauskas and Kanapinskiene (1997) showed that the weediness of winter wheat and spring barley increased when they were sown after grasses or after continuous growing. Zawislak (1997) reported that herbicides reduced weed stands in monocultures of winter wheat, winter rye, spring barley and oats by 64-68 per cent and in crop rotation systems (sugarbeet-spring barley-winter rape-winter wheat-field bean, potatoes-oats-fibre flax-winter rye-maize) by 69-96 per cent. Kleifeld *et al.*(1998) showed that infestation by grasses decreased in crop rotations of wheat, winter legume (chickpeas, peas and vetch) and summer crops (sunflowers, watermelons and maize), compared to monocropping of wheat. Malik (1996) reported that the main resistance problems include *P. minor* against isoproturon (India) and suggested that control of resistant weeds in cereals can be achieved by exhausting the existing seed bank of resistant populations through changes in crop sequences and new agronomic techniques.

4. Herbicides rotation

Continuous use of single herbicide has been the major cause of evolution of resistance in weeds. In situations like Haryana isoproturon has also become victim of its own success. Rotation of a herbicide group that has multiple site of action and low soil persistence may help to prevent or delay the resistance. There should be availability of a number of herbicides with different modesof action so that farmers have a choice to use different herbicides in different years. Gressel and Segel (1990) suggested that once the resistance has occurred it is necessary to design strategies whereby herbicide usage is stopped for a number of years until the level of resistance is below certain proportion, and than resume limited use, during certain proportion of rotation cycle. Yadav *et al.* (1995) and Malik and Yadav (1997) found that tralkoxydim and other alternate herbicides (clodinafop, fenoxaprop and sulfosulfuron) provided acceptable control of isoproturon resistant biotypes of *P. minor.* Brar *et al.* (1999) indicated that all the new herbicides i.e. clodinafop at 50-70 g/ha, fenoxaprop-p-ethyl at 80-120 g/ha and sulfosulfuron at 25-45 g/ha provided nearly 100 per cent control of isoproturon resistant *P. minor.* Panwar *et al.* (1994) earlier reported that tralkoxydim at 0.35 Kg/ha provided significantly higher grain yield than isoproturon due to effective control of *P. minor.* Importance of herbicide rotation to avoid resistance can be easily verified from the practical examples with us such as no isoproturon resistance in *P. minor* was noticed till this date at Research Farms because of herbicide rotations followed year after year and on the other hand acute problem of isoproturon resistance exists at large area in rice-wheat cropping sequence in N-W-India where this chemical alone has been in use for more than 10 years. Effective control of resistant *P. minor* in wheat could be easily achieved by adopting crop and herbicide rotations in affected areas as suggested by Malik *et al.* (1995).

5. Early and dry sowing

There is some evidence that wheat sown in early November can rapidly emerge before *Phalaris* and can exert a strong smothering effect on the weed which is usually slow in establishing under these conditions (Malik *et al.*, 1998). However, further research is required to fully exploit the potential of early sowing and other pre-sowing weed management techniques. Malik and Singh (1993) reported that late sowings may not be successful against wild canary grass as December or January sowing coincides with optimum temperature requirements for wild canary grass emergence. Likewise, first flush of P. minor has been noticed negligible or very less at farmers fields when the wheat crop was sown after drying upper soil layer as compared to the crop sown in moist fields (Malik *et al.*, 1995).

6. Stale bed technique

Pre-seeding emergence of *P. minor* can be stimulated by giving one or two light irrigations followed by weed control with non-selective herbicides or cultivation.

Malik and Singh (1993) reported that if late sowing coincides with optimum temperature requirement for wild canary grass emergence, this can be exploited by using stale seedbed technique and exhausting the soil seed reservoirs. It has also been observed in rice-wheat growing areas of Haryana and Punjab that if pre-seeding emerged plants of *P. minor* (either due to residual moisture after paddy harvest or due to one or two pre-sowing irrigations) before wheat sowing are controlled effectively by pre-seeding non-selective herbicides (glyphosate or paraquat) or cultivation, it results into great reduction of population pressure by weed.

7. Zero-tillage system of wheat sowing

Zero-tillage is a category of conservation tillage in which the soil is left undisturbed from the harvest of one crop to the seeding of the next crop, with only slight soil disturbance associated with creating a narrow slot in which to place the seed (and in some cases, fertilizer) (Dickey, 1992). Zero tillage has sound economics, improved crop turnaround time and soil health (Phillips and Phillips, 1984). Aase *et al.* (1995) reported that grain and straw yields of spring wheat with the no-tillage treatments were 80 per cent, when compared with the yield of conventional fallow-crop treatments. Huang *et al.* (1999) revealed that no-tillage wheat yield increased by 5.3 per cent on an average. Lindwall *et al.* (1995) reported that yields under zero tillage were significantly higher in 3 of the 9 study years and the management system which incorporates zero-tillage into a 3 year rotation was best suited for winter wheat production. Merill *et al.* (1996) reported that relative to conventional till, no-till generally enhanced root length / growth of wheat more than above ground growth and in each year roots penetrated to greater soil depths under no-till than under minimal-till or conventional-till. Pratley (1995) reported that in 9 of 11 years, wheat grain yield was significantly better with direct drilling averaging 15 per cent more than conventional cultivation and 10 per cent more than reduced cultivation. Arshad *et al.* (1998) indicated that no-tillage system provided better control of annual broad leaf weeds as compared to perennial weeds. Sirohi *et al.* (1999) reported that at 50 DAS the population of *P. minor* in wheat under conventional tillage was more than under zero tillage. Weber *et al.* (1999) reported that among three spring wheat cultivars cv. Henika, Ismena and Jasna; Jasna gave highest yield with no-tillage.

Thomas *et al.* (1995) reported that no-tillage and reduced tillage with stubble retention resulted in higher grain yields than other treatments. Unger (1995) also confirmed that grain yield was greater with no-till + retaining all residues on the surface i.e. 4.56 t/ha than conventional tillage (4.26 t/ha). Bonfil *et al.* (1999) concluded that crop yield and water use efficiency could be increased in arid zones with annual precipitation of less than 200 mm, through use of wheat-fallow rotation system by managing with no-tillage. Ciha (1982) indicated that average grain yields of wheat with no-tillage and conservation tillage were significantly greater than yields using conventional tillage and also reported that no-tillage increased test weights. However, Dzienia *et al.* (1998) observed that winter wheat yield was decreased by 24-26 per cent by direct drilling or use of a field cultivator compared with ploughing.

Sharma and Kharwara (1994) found that grain yield of irrigated as well as rainfed wheat in hand weeded plots was same with minimum and conventional tillage, but was lowest with no-tillage but on the basis of cost / benefit ratio, no-tillage with chemical weedings in irrigated conditions and minimum tillage in rainfed conditions were economical in sandy loam soils.

Hughes and Mitchell (1987) found that plant populations produced in zero tilled seed beds were lower than in the conventionally cultivated seed bed, but the plant height remained unaffected.

Rao and Dao (1996) found that under no-till, grain yield was improved by 32 per cent for N banded below the seed row and 15 per cent for N banded between the rows and grain N content was increased by 33 per cent for N banded below the seed row and 25 per cent for N banded between the rows as compared to the surface broadcast treatment. Dickson *et al.* (1996) suggested that additional N and P are required to maximize yields of no-tillage wheat following rice. Blecharczyk *et al.* (1999) reported that wheat grain yield response to N fertilizer was greater with direct sowing than conventional tillage and direct sowing led to decreased number of ears, but increased number of grains per ear and 1000-grain weight as compared to conventional tillage. Javurek and Vach (1999) suggested that a higher N rate was required in direct drilling to give yields comparable to conventional tillage.

Giambelli *et al.* (1989) noticed that the number of spikes/metre, seeds/spike and 1000 grains weight were highest with direct drilling. Contrary to this, Vyn *et al.* (1991) reported that yield components did not differ significantly between no, minimum or conventional tillage systems in wheat. Halvorson *et al.* (1999) recorded grain yields of wheat greater with minimum tillage (1968 kg/ha) and no-tillage (2022 kg/ha) than with conventional tillage (1801 kg/ha). Dhillon *et al.*(1987) indicated that different preparatory tillage treatments i.e. zero, one and four did not significantly effect grain yield of wheat. Lopez-Bellido *et al.* (1996) reported that in dry conditions, wheat yield was greater under no-tillage than under conventional tillage, while the reverse was true under irrigated conditions. Janardhan and Ahmad (1993) found that grain yields were 14.2 per cent higher in conventional tilled than zero tilled plots.

An analysis of no-till system indicated that the systems using the highest herbicide application rates required the least energy because decreased herbicide application rates would require increased cultivation (Swanton *et al.*, 1996). The potential for no-tillage as a crop management practice was reviewed and found that no-tillage is equivalent to traditional tillage techniques with regard to wheat yield when the crop was sown at the same time and superior economically in terms of power use (Majid *et al.*, 1988).

Aase *et al.* (1995) reported that no-tillage annual spring wheat crop production was the most efficient crop and soil management practice from the stand point of yield, water use efficiency, soil organic carbon and bulk density in comparison to sweep tillage in autumn, disk tillage in spring and sweep tillage in spring. Venezia *et al.* (1995) reported that increase in natural mulch on the soil surface because of no-tillage and the better equilibrium between macro and micro porosity resulted in better water use efficiency and increased root development compared with other tillage treatments. Other benefits of conservation tillage such as soil and water conservation, production cost decline, fuel and labour savings, lower machinery investments and the long term benefits to soil structure, moisture and fertility have also been realized at many locations (Bull and Sandretto, 1996; Goel and Verma, 1991; Hernani *et al.*, 1989). Gauer *et al.* (1982) reported that during early and mid-season growth, the soil moisture in the seed bed of zero-tilled plots was higher than that of the conventional, regardless of whether the straw had been removed or spread on the surface. While it has also been well documented that a stubble mulch increases water use efficiency by decreasing evaporation and surface run off, by increasing infiltration and by increasing the amount of trapped snow (Moody *et al.*, 1963; Jones *et al.*, 1969 and Blevins *et al.*, 1971). Gauer *et al.* (1982) based on observations early in the winter showed that conventionally tilled soils were colder than zero-tilled soils. This was in agreement with previous work on stubble cover and zero-tillage (Hay, 1977; Schneider *et al.*, 1978).

For winter wheat, Black (1970) concluded that a wheat straw mulch over the soil surface decreased May soil temperatures, but increased both the number of moist soil days and the number of moist soil-degree days. Bonfil *et al.* (1999) reported that during growth, uncultivated soil with straw mulch increased water content in the upper soil layer and also encouraged the development of a longer root system capable of utilizing deeper water. Huang *et al.* (1999) revealed that bulk density in the 7-14 cm layer under conventional, minimal and no-tillage was 1.348, 1.412 and 1.410 g cm^{-3}, respectively. Direct sowing lowered the soil temperature in spring and increased bulk density and soil compaction (Blecharczyk *et al.* ,1999), David (1996) concluded that the overall performance of integrated weed management (using combinations of no- or reduced tillage and herbicides selected in relation to the weed flora present) was positive compared with conventional practices; soil structure was improved and risk of erosion decreased; the costs of soil cultivation were reduced and the use of less herbicide and of low-toxicity post-emergence herbicides which do not leave soil residues had a positive environmental effect.

Gauer *et al.* (1982) reported that the greatest moisture advantage under zero-tillage occurred early in the growing season, when evaporation was the dominant means of soil moisture loss. The findings are in agreement with previous work (Schneider *et al.*, 1978; Shanholtz and Lillard, 1969). In the absence of tillage, lower soil temperatures often result due to the effects of the trash cover on the surface (Van Wijk *et al.*, 1959). Because of these lower temperatures and decreased radiation flux on the soil surface, the evaporation rate decreases, resulting in higher soil moisture (Moody *et al.*, 1963; Shanholtz and Lillard, 1968 and Blevins *et al.*, 1971). When the straw was spread on the soil surface, zero-tilled fields were usually cooler than conventionally tilled fields (Gauer *et al.*, 1982). Hay (1977) reported that uncultivated soil covered by an insulating mulch of straw, had a higher moisture content and presumably had a higher bulk density than the loosened, ploughed soil; these factors reduced the amplitude of the daily temperature variation significantly. Soil moisture measurements by Jones *et al.* (1968) indicated that the dead sod mulch provided by no-tillage system was highly effective in reducing evaporation and run off from the soil surface. Blevins *et al.* (1971) reported that no-tillage treatments had higher volumetric moisture contents to a depth of 60 cm during most of the growing season of corn when compared with conventional tillage. Triplett *et al.* (1968) indicated that corn stover mulch had a beneficial effect on no-tillage corn yield and that the greater yields were associated with increased water infiltration and soil moisture.

E. Tillage and weed flora shift

Weed flora is not static rather it has shown marked changes over the years. Changes in input availability and crop sequences (from traditional to modern) have changed the component of weed flora in favour of grassy weeds (Malik et al., 1984 and Singh et al., 1992). Macchia et al.(1996) reported from the analysis of vertical soil seed distribution that ploughing cause uniform distributions; however, with zero tillage, 60 per cent of the soil seed bank stock was recovered from the upper horizon (0-15 cm). The lower layer represented, under both tillage methods less than 10 per cent of the seed bank. Dzienia et al. (1998) found that reduced tillage increased the amount of annual and perennial weeds. Feldman et al. (1998) reported that less disturbing tillage systems (non-tillage and chisel plough) allowed the build-up of a more diverse community, whereas the most disturbing one (mouldboard plough) prevented high diversity in the weed community. Blecharczyk et al. (1999) reported that reduced tillage promotes the establishment of grassy weeds such as downy brome (Bromus tectorum) and quackgrass (Elymus repens). It is being speculated, however, based on short term studies, that reduced tillage would lead to the problem of broad leaf and or perennial weeds after few years. However, long term research in relation to tillage system will be more reliable to study and confirm the shift in weed flora under a given set of situation.

CHAPTER - 3

MATERIAL AND METHODS

The field experiment entitled "Competing ability of wheat genotypes against resistant *Phalaris minor* under zero tillage", was conducted during winter (*rabi*) season of 1999-2000 at farmer's field. The materials used and techniques adopted during the course of investigation are described in this chapter in the following different sections.

3.1 MATERIALS

3.1.1 Location of the experimental site

The experiment was carried out in the rice-wheat cropping zone at the farmer's field (Sh. Nakli Ram S/O Sh. Singh Ram) seriously affected by isoproturon resistant *P. minor* in village-Tik, district-Kaithal, Haryana (India). Village Tik is located on Kaithal-Kurukshetra road at 11 km from Kaithal. The experimental site is situated at an elevation of 241 metres above mean sea level with a latitude of 29° 48' N and longitude of 76°23' E in the subtropical zone.

3.1.2 Climate and weather

The climate of experimental site (village- Tik, district-Kaithal) is semi arid subtropical. Normal annual rainfall ranges from 600 to 850 mm. About 80 per cent of the annual precipitation falls between July to September which are termed as monsoon months. Winter rains add only 5-6 per cent of the total annual rainfall and that too vary from year to year. The temperature in the region ranges from 4°C in the months of January to 44°C in May/June with hot winds blowing from west to east. The relative humidity is very high (83 %) in July/August and as low as 52 per cent in April/May. On the basis of climatic conditions, the cropping system is divided into two main crop seasons i.e. *kharif* (rainy season) and *rabi* (winter season). The cultivation time for *kharif* crops ranges from June to October and for *rabi* crops from October to April. Rice-wheat is the main cropping sequence of this area. Mean weekly meteorological data for wheat crop season from November 1999 to April 2000 recorded for the minimum and maximum temperature, rainfall, relative humidity in morning and evening and sunshine hours are presented in Table 1 and depicted in Fig. 1.

3.1.3 Soil

Soil of the area are derived from Indo-Gangetic alluvium which are very deep and clay loam in texture. Soil samples were taken before sowing

Table 1 : Mean weekly meteorological data for the month of November 1999 to April 2000

Standard weeks	Temperature (°C)		Relative humidity (%)		Sunshine (hrs.)	Rain fall (mm)
	Max.	Min.	Morn.	Even.		
44	32.1	15.8	92.0	37.0	7.7	0.0
45	29.5	13.2	78.0	34.0	7.5	0.0
46	29.6	10.5	75.0	24.0	8.3	0.0
47	27.0	8.4	85.0	27.0	7.2	0.0
48	26.0	8.7	90.0	38.0	7.5	0.0
49	23.4	8.6	97.0	49.0	6.0	0.0
50	22.8	7.2	94.0	43.0	7.7	0.0
51	22.2	6.0	83.0	64.0	6.8	0.0
52	19.8	6.2	99.0	68.0	4.5	0.0
1	15.8	5.5	98.0	78.0	2.0	0.0
2	17.3	9.8	91.0	63.0	2.0	4.0
3	18.3	4.8	93.0	49.0	8.0	0.0
4	19.4	8.1	95.0	67.0	4.8	19.3
5	20.6	8.8	90.0	62.0	3.2	38.0
6	17.5	6.6	99.0	76.0	3.2	8.2
7	19.2	5.6	97.0	63.0	8.0	0.0
8	21.2	4.2	86.0	44.0	8.7	0.0
9	25.3	8.6	84.0	41.0	4.3	0.0
10	25.3	9.3	82.0	38.0	8.8	0.0
11	27.2	10.8	81.0	40.0	9.0	0.0
12	26.1	10.5	71.0	38.0	7.6	0.0
13	32.5	14.0	87.0	35.0	9.2	0.0
14	34.5	12.5	60.0	18.0	9.8	0.0
15	38.1	16.0	59.0	19.0	9.7	0.0
16	38.6	20.8	57.0	22.0	7.6	0.0
17	37.8	21.5	56.0	25.0	9.1	0.0

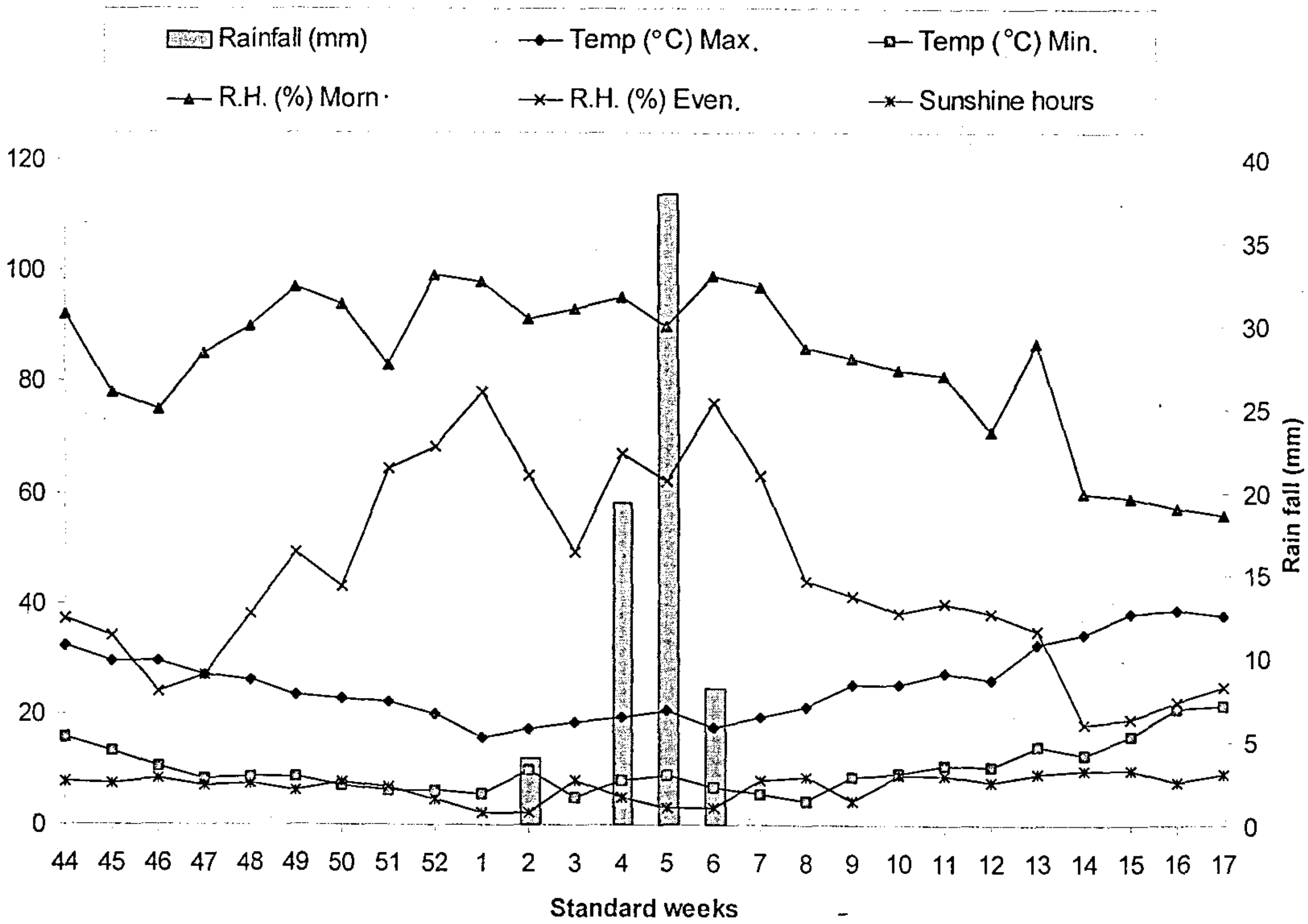


Fig. 1 : Mean weekly meteorological data during experimental period of 1999 -2000

of crop. A composite sample was prepared by mixing all soil samples and then was used to determine the physico-chemical properties of soil after grinding and sieving. The data of mechanical and chemical analysis of soil for the crop season are given in Table 2.

On the basis of mechanical and chemical analysis, the soil was categorised as clay loam in texture, slightly alkaline in reaction, low in organic carbon, low in available nitrogen, medium in available phosphorus and high in available potassium.

3.1.4 Cropping history of the experimental field

The previous history of the experimental field was as follows in Table 3.

3.1.5 Wheat genotype and herbicides

Wheat genotypes WH 157, PBW 343, WH 542 and HD 2687 was used as seeding material @ 100 kg/ha seed rate in all genotypes. Clodinafop (chemical name - (R) – 2 - [4 - (5 – chloro – 3 – fluoro – 2 – pyridyloxy) phenoxy] propionic acid, Topik® 15 % WP, Novartis Ind. Ltd.) and sulfosulfuron (chemical name - 1-(4,6 dimethoxypyrimidin–2–yl) – 3 – (2 – ethylsulfonylimidazo [1, 2–a] pyridin - 3-yl-sulfonyl)urea, Leader® 75 % WP, Monsanto) were used as herbicides.

Table 2. Physico-chemical properties of soil of experimental field

Components	0-15 cm	Methods used
A. Mechanical composition		
Sand (%)	32	International pipette method (Piper, 1966)
Silt (%)	28	
Clay (%)	40	
B. Chemical analysis		
Soil pH_2	8.1	Glass electrode pH meter method (Jackson, 1973)
EC_2 (dSm^{-1} at 25^0C)	0.31	Conductivity bridge method (Richards, 1954)
Organic carbon (%)	0.28	Walkley and Black rapid titration method (Jackson, 1973)
Available N (kg ha^{-1})	168	Alkaline permangnate method (Subbiah and Ashija, 1956)
Available P (kg ha^{-1})	12	Olsen's method (Olsen *et al.*, 1954)
Available K (Kg $ha^{-1)}$	307	Flame photometric method (Jackson, 1973)

Table 3. Cropping history of the experimental field

Year	Season		Tillage System for wheat	Stubble size of paddy(cm)	Population of resistant *Phalaris minor*/ m^2 before *spray*	Herbicides used in wheat
	Kharif	*Rabi*				
1996-1997	Paddy	Wheat	Conventional tillage	-	2000-2500	Isoproturon
1997-1998	Paddy	Wheat	*Conventional* tillage	-	*2500-3000*	*Fenoxaprop*
1998-1999	Paddy	Wheat	Zero tillage	10-15	600-800	*Sulfosulfuron
1999-2000	Paddy	Wheat	Zero tillage	15-20	250-300	*Clodinafop and Sulfosulfuron

*Glyphosate @ 0.5 % was also used as pre-seeding herbicide.

- **Characterictics of genotypes**

1. WH 157

Derived from the cross NP 876-S308/Ciano's'-8156 through pedigree selection. It was released in 1978 in Haryana and 1989 in all zones for cultivation under timely sown high fertility and irrigation under salinity and alkalinity conditions. WH 157 is a double dwarf (105 cm), dark green foliage, older leaves show a tendency of tip drying, resistant to lodging, ears fusiform; glumes with slight hairiness, fully awned; amber, hard and bold grains. It has average yield of 40 q/ha and potential yield of 65 q/ha.

2. PBW 343

Derived from the cross ND/VG 9144 // KAL / BB / 3 / YCO^S / 4 / VEE 5^8 through pedigree selection. PBW 343 was released in 1995 for cultivation under irrigated conditions in the North Western Plain Zones comprising Punjab, Haryana, Delhi, Western Uttar Pradesh, Rajasthan (except Kota and Udaipur) and the foot hills of Himachal Pradesh and Jammu and Kashmir. PBW 343 is a double dwarf variety (mean 100 cm), tillering profusely and is resistant to lodging. Spikes are dense, awned and have smooth, white glumes. Grains are medium, bold, amber and hard. It has a long duration maturity in ≈155 days with mean yield of 48.5 q/ha (Nanda *et al.*, 1998).

3. WH 542

Derived from the cross Jupateco/Blueja/Ures through pedigree selection. WH 542 was released in 1992 for cultivation under timely sown high fertility and irrigation conditions of North Western Plain Zones. WH 542 is a semi-dwarf (90 cm) semi-erect, high tillering and compact plant, strong straw, short leaves, dense, square and white spike with short awn, hard shining grains of medium size. It has average yield of 58 q/ha and potential yield of 80 q/ha.

4. HD 2687

Derived from the cross CPAN 2009 / HD 2329 through pedigree selection. It has high tillering, strong straw, erect leaves, amber grain of medium size. HD 2687 is a semi-dwarf with high yield potential and it has been released by IARI, New Delhi.

3.2 METHODS

3.2.1 Experimental details

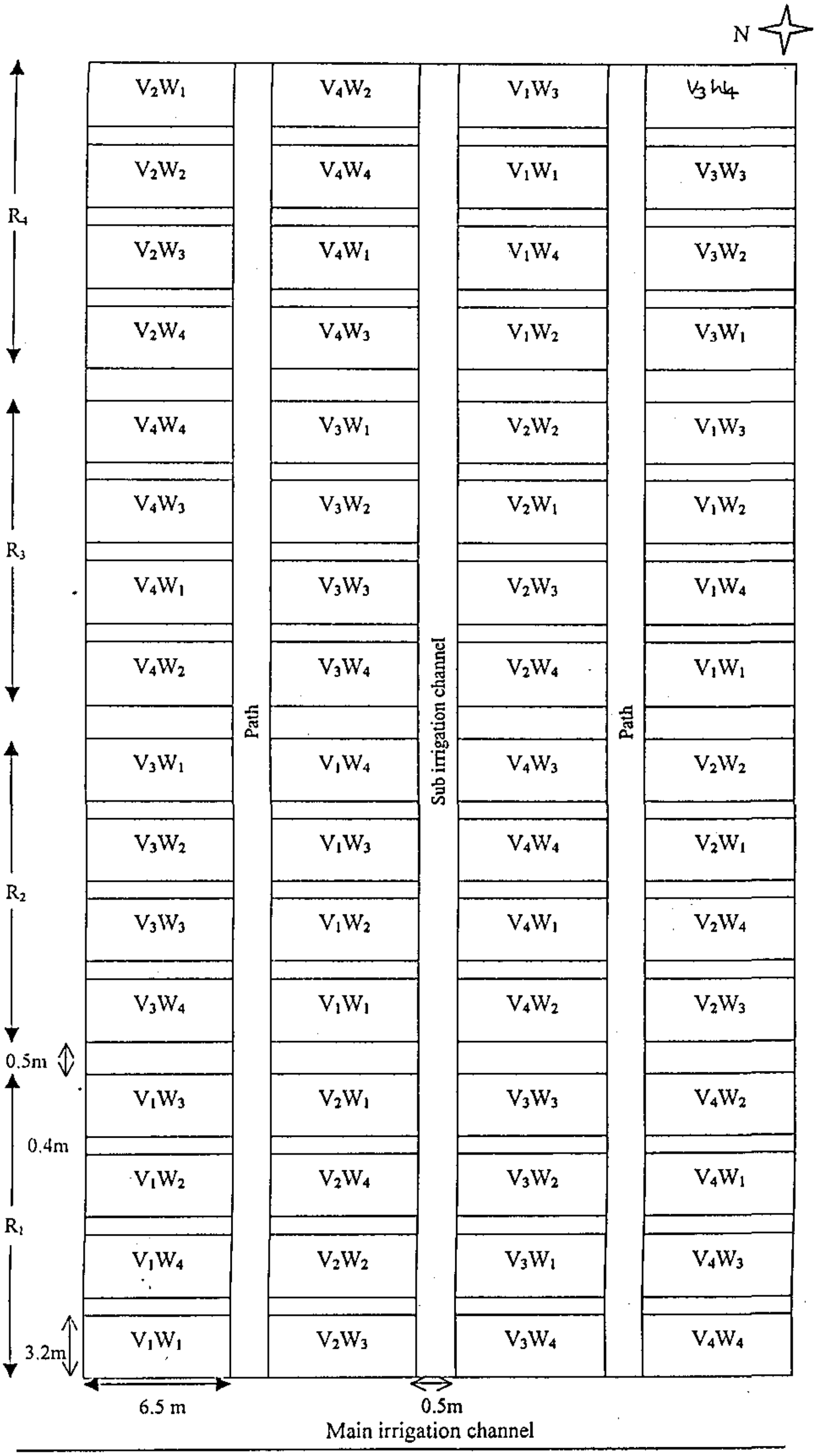
The experiment was laid out in split-plot design keeping wheat genotypes WH 157, PBW 343, WH 542 and HD 2687 in main plots and weed control treatments clodinafop (60 g a.i./ha), sulfosulfuron (25 g a.i./ha), weedy and weed free check in subplots to study the competing ability of wheat genotypes against resistant *Phalaris minor* under zero tillage. The details of treatments are as follows and the lay out plan is depicted in Fig. 2.

A. Main plot treatments **: 4**

Wheat genotypes

V_1 = WH 157

V_2 = PBW 343



V_2W_1	Path	V_4W_2	Sub irrigation channel	V_1W_3	Path	V_3W_4
V_2W_2		V_4W_4		V_1W_1		V_3W_3
V_2W_3		V_4W_1		V_1W_4		V_3W_2
V_2W_4		V_4W_3		V_1W_2		V_3W_1
V_4W_4		V_3W_1		V_2W_2		V_1W_3
V_4W_3		V_3W_2		V_2W_1		V_1W_2
V_4W_1		V_3W_3		V_2W_3		V_1W_4
V_4W_2		V_3W_4		V_2W_4		V_1W_1
V_3W_1		V_1W_4		V_4W_3		V_2W_2
V_3W_2		V_1W_3		V_4W_4		V_2W_1
V_3W_3		V_1W_2		V_4W_1		V_2W_4
V_3W_4		V_1W_1		V_4W_2		V_2W_3
V_1W_3		V_2W_1		V_3W_3		V_4W_2
V_1W_2		V_2W_4		V_3W_2		V_4W_1
V_1W_4		V_2W_2		V_3W_1		V_4W_3
V_1W_1		V_2W_3		V_3W_4		V_4W_4

Main plot treatments
V_1 :WH 157
V_2 : PBW 343
V_3 : WH 542
V_4 : HD 2687
Size : 14 x 6.5 m^2 =91m^2

Sub plot treatments
W_1 : Clodinafop 60g/ha
W_2 : Sulfosulfuron 25g/ha
W_3 : Weedy check
W_4 : Weed free check
Size : 3.2 x 6.5m^2 = 20.8m^2

Replications : 4

Fig. 2 : Lay out plan of experiment

V_3 = WH 542

V_4 = HD 2687

B. **Sub plot treatments : 4**

Weed control treatments

W_1 = Clodinafop 60 g/ha

W_2 = Sulfosulfuron 25 g/ha

W_3 = Weedy check

W_4 = Weed free check

*Total number of treatment combinations	4 x 4 = 16
*Design	Split plot
*Number of replications	4
*Total number of plots	64
*Gross plot size	6.5 x 3.2 m^2 = 20.8 m^2
*Net plot size	5.98 x 2.2 m^2 = 13.16 m^2
*Date of sowing	7 November, 1999

3.2.2 *Field cultural operations*

The detail of cultural operations carried out during pre-and post-sowing of wheat crop in experimental field are presented in Table 4.

Table 4. Schedule of cultural operations carried out in the experimental field

Nature of operation	Time of operation	Detail of operations
A. Pre-sowing operations		
a. Use of non-selective pre-seeding herbicide	05.11.1999	Population of *Phalaris minor* before sowing was around 250-300 plants / m^2. Glyphosate (Glycel 41 % SL, Excel) @ 0.5 % solution was sprayed uniformly as pre-seeding herbicide to kill emerged population of P. minor.
b. Layout	06.11.1999	Experimental field was laid out according to treatment requirement.
c. Pre-sowing irrigation	Nil	Enough moisture was available after paddy-harvest for sowing of wheat crop and no pre- sowing irrigation was required.
d. Sowing	07.11.1999	Sowing in the experimental field having stubble of paddy crop (15-20 cm) as such was done with zero-till-seed-cum-fertilizer drill (Pant- nagar prototype model, manufactured by A.S.S. Foundary Jhandiala Guru Amritsar, Punjab) in E-W direction spaced 17.5

		cm apart (Row to Row) with 4-5 cm depth of sowing. Seed rate used for each genotype was 100 Kgha^{-1}. Recommended dose of N and P fertilizers through DAP and urea were added at sowing and thereafter as per package of practices for wheat. Urea was broadcasted while DAP was drilled at the time of sowing.
B. Post-sowing operations		
e. Final layout	10.11.1999	Well demarkated bunds and channels were prepared before emergence of crop.
f. Irrigations		
First irrigation	04.12.1999	Irrigation was given with tubewell water.
Second irrigation	13.01.2000	
Third irrigation	25.02.2000	
Rainfall received during crop season		
1st (4 mm)	13.01.2000	
2nd (1.5 mm)	25.01.2000	
3rd (10.8 mm)	26.01.2000	
4th (7.0 mm)	27.01.2000	
5th (38.0 mm)	05.02.2000	
6th (8.2 mm)	11.02.2000	
g.Top dressing of nitrogen	04.12.1999	Half dose of nitrogen through urea was top -

		dressed at the time of first irrigation.
h. Hand weeding		Number of hand weedings / hoeing operations were undertaken from time to time in the plots which have to be kept weed free throughout the crop season. *P. minor* was the main weed comprising more than 95 per cent of the weed flora and other negligible population was of *Rumex martimus* and *Lathyrus aphaca*
i. Herbicide spray	11.12.1999	Herbicides, clodinafop @ 60 g/ha, sulfosulfuron + adjuvant @ 25 g/ha + 0.5% were sprayed as per the treatments with knapsack sprayer fitted with flat fan *nozzle using 500 L* water/ha.
j. Harvesting	25.04.2000	Harvesting of wheat crop was done manually with the help of sickles and left in the field for sun drying.
k. Threshing	03.05.2000	Threshing was done with the help of mini-plot thresher. Biomass of crop was also recorded just before threshing it.

3.2.3.1.2 Plant height (cm)

Plant height is very important character which gives an idea about vegetative growth of the plant. The height was measured from the ground surface to the tip of the top leaf of the plant and after anthesis upto top of earhead. Five plants from each of three marked row/plot were selected at random. Then the average height of the 15 plants was taken at 30, 60, 90, 120 DAS and at harvest.

3.2.3.1.3 Dry matter accumulation

For this, a sample of one metre of plant row was selected, representing the whole plot. Plants from this row were harvested (above ground parts) and these were sun dried first and then samples were oven dried at 70°C ± 2°C till a constant weight was obtained at each stage i.e. 30, 60, 90, 120 DAS and at harvest.

3.2.3.2. Observation on weed (*P. minor*)

3.2.3.2.1. Weed density

Since *P. minor* was the only most dominant weed (more than 95 %) in the experimental field, all the observations were recorded only in respect of *P. minor*. The determination of intensity of *P. minor* was done by using quadrate method described by Mishra and Puri (1954). The weed density was recorded at 30, 60, 90, 120 DAS and at harvest from three randomly selected places in each plot of all the replications. The weed count was expressed as number per square metre and the original values were subjected to square root transformation before statistical analysis. The population of *P. minor* was uniform and it was around 250-300 plants/m^2 before sowing which was killed by using glyphosate @ 0.5 per cent as pre-seeding herbicide.

3.2.3.2.2 Dry matter accumulation

Weed samples in respect of *P. minor* for dry matter accumulation were collected at 30, 60, 90, 120 DAS and at harvest by placing a quadrate of 0.5 x 0.5m i.e. 0.25 m^2 at three randomly selected spots in each plot. These samples were sun dried and then dried in oven at 70°C ± 2°C for 48 hours till a constant weight has achieved. The samples were weighed and dry weight of *P. minor* was recorded and converted to weight per square metre.

3.2.3.2.3 Visual toxicity (%) on crop and *P. minor*

Visual phytotoxicity due to clodinafop and sulfosulfuron on crop and *P. minor* was observed at 30 and 60 days after spray by using 0-100 scale (where, 0= no mortality and 100 = complete mortality). Since, there was no toxicity of any herbicide on crop, the data on crop phytotoxicity has not been included herein and only the data on toxicity against *P. minor* has been recorded.

3.2.4. Observation on yield attributes

Observation on yield contributing characters like effective tillers and grains per earhead were taken from three selected row in each plot at the time of harvest. Following yield contributing characters were observed.

3.2.4.1 Effective tillers number per running metre

For this all the tillers bearing earhead at harvest were counted in all three one metre size selected rows in each plot and then average was worked out.

3.2.4.2 Earhead length

Ten earheads from three selected rows from each plot were selected at random. Length of these 10 earheads was recorded and based on this data, the average length was calculated.

3.2.4.3 Number of grains per earhead

Grains were separated from all the 10 randomly selected earheads/plot which were selected for the determination of grains number per earhead and the total number of grains were counted and number of grains per earhead was worked out.

3.2.4.4 Test weight (1000-grain weight)

A sample of 1000-grains was selected at random from each plot and the test weight was recorded at 12 per cent moisture.

3.2.5 Yield studies

3.2.5.1 Grain yield

After harvesting, the wheat crop was sun dried upto seven days. After sun drying, biological yield was obtained from each plot just before threshing with the help of spring balance. After threshing with the help of mini-plot thresher, the grain yield was measured for each net plot area. Then the grain yield was converted into the yield (Kg) per hectare.

3.2.5.2 Straw yield

The grain yield was subtracted from the total biological yield to obtain straw yield in net plot area and further it was converted into straw yield (Kg) per hectare.

3.2.6 Statistical analysis

3.2.6.1 *Analysis of variance and test of significance*

All the experimental data for various growth, yield and yield attributing characters were statistically analysed by the methods of analysis of variance (ANOVA) as described by Panse and Sukhatme (1995). The significance of treatment effects were computed with the help of 'F' (Variance ratio) test and to judge the significance of difference between means of two treatments critical difference (CD) were worked out as described by Cochran and Cox (1963).

CHAPTER 4

EXPERIMENTAL RESULTS

The experimental data recorded during the course of present investigation entitled "Competing ability of wheat genotypes against resistant *Phalaris minor* under zero tillage" conducted during *rabi* season of 1999-2000, are presented in the chapter with the help of appropriate tables.

4.1 WEED (*Phalaris minor*) STUDIES

4.1.1 *Phalaris minor* density (No. m^{-2})

The number of *P. minor* plants per square metre recorded at 30, 60, 90, 120 DAS and at harvest are given in Table 5. The perusal of the data revealed that *P. minor* density in the field increased upto 120 DAS and thereafter, it decreased in all the experimental plots. Wheat genotypes did not significantly affect the density of *P. minor* upto 30 DAS.

Table 5. **Effect of wheat genotypes and weed control treatments on density of *P.minor* (No. m^{-2}) at various growth stages of wheat**

Treatments	Days after sowing				
	30	60	90	120	at harvest
Wheat genotypes					
WH 157	10.25 (135.00)	7.57 (79.75)	7.82 (85.50)	7.93 (87.75)	7.87 (86.50)
PBW 343	10.31 (136.50)	6.78 (67.50)	6.97 (70.75)	7.06 (72.44)	7.03 (71.75)
WH 542	10.12 (131.50)	7.25 (74.50)	7.57 (81.00)	7.72 (83.63)	7.62 (82.00)
HD 2687	10.20 (133.50)	6.32 (59.75)	6.46 (62.00)	6.52 (63.00)	6.44 (61.75)
SE m ±	0.09	0.15	0.14	0.14	0.14
CD at 5 %	NS	0.45	0.47	0.47	0.46
Weed control treatments					
Clodinafop 60 g/h	13.36 (178.00)	6.66 (44.50)	6.96 (48.50)	7.10 (50.56)	6.99 (49.00)
Sulfosulfuron 25 g/ha	13.43 (180.00)	6.68 (45.00)	6.95 (48.75)	7.08 (50.75)	7.00 (49.50)
Weedy check	13.38 (179.00)	13.87 (192.00)	14.22 (202.00)	14.34 (205.50)	14.27 (203.50)
Weed free check	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
SE m ±	0.10	0.12	0.11	0.11	0.11
CD at 5 %	0.28	0.34	0.33	0.32	0.32

Original data given in parenthesis was subjected to square root ($\sqrt{x} + 0.5$) transformation before analysis.

Due to initial removal of weeds from weed free check, there was no plant of *P. minor* in weed free check at 30 DAS whereas density of this weed on an average was around 179 plants/m^2 in other plots (supposed to be treated with clodinafop and sulfosulfuron) which were at par to weedy check at 30 DAS.

Among wheat genotypes, PBW 343 recorded significantly lower population than WH 157 and WH 542, at 60, 90, 120 DAS and at harvest, however, WH 157 and WH 542 were at par with each other. But PBW 343 recorded significantly higher population than HD 2687 at these growth stages.

Among weed control treatments (Table 5), clodinafop 60 g/ha was found at par with sulfosulfuron 25 g/ha; and weedy and weed free check recorded significantly higher and lower *P. minor* population, respectively, than other treatments at all the growth stages except at 30 DAS where the differences were non-significant. On an average herbicides reduced *P. minor* population to the extent of 75.93 per cent at various growth stages.

The magnitude of control of *P. minor* with respect to its population with herbicides seems to be slightly lower because of emergence of succeeding flushes of this weed after first irrigation.

The interaction effect of genotypes and weed control treatments on *P. minor* population was found significant at 60 DAS (Fig. 3) which indicated that among wheat genotypes, weedy check treatment allowed significantly higher *P. minor* population as compared to clodinafop 60 g/ha and

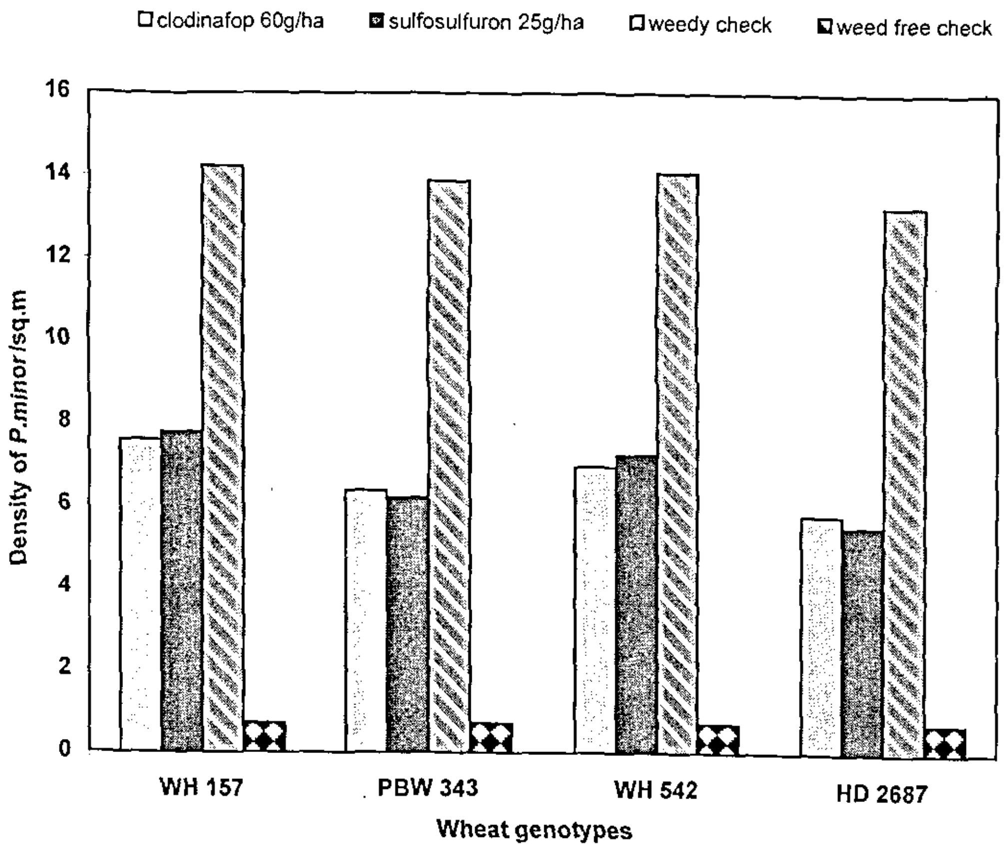


Fig.3 The interaction of genotypes and weed control treatments on density of *P. minor*/sq.m

sulfosulfuron 25 g/ha, which were at par with each other in respect of each individual variety.

The density of *P. minor* under clodinafop 60 g/ha was significantly higher in WH 157 to all wheat genotypes, except WH 542, while population of this weed was lowest in HD 2687, however, it was at par with PBW 343 and density of resistant *P. minor* in PBW 343 was at par with WH 542. Almost similar trend was assumed among different genotypes under weedy check and sulfosulfuron except that density of resistant *P. minor* was significantly higher in PBW 343 compared to HD 2687 under the treatment of sulfosulfuron 25 g/ha. Similar trend was assumed under weedy check, while density of *P. minor* was significantly higher in WH 542 compared to PBW 343 under the treatment of sulfosulfuron 25 g/ha (Fig. 3).

4.1.2 Dry matter accumulation (g m^{-2}) by *P. minor*

The perusal of the data given in Table 6 revealed that dry weight of resistant *P. minor* continuously increased from 30 DAS to harvest. The dry weight of *P. minor* was not significantly affected by various genotypes and weed control treatments upto 30 DAS. Whereas among genotypes at later growth stages, it was significantly higher in plots grown with WH 157 than all other genotypes except WH 542. Wheat genotype PBW 343 recorded significantly lower dry weight of *P. minor* as compared to WH 157 and WH 542. Whereas HD 2687 recorded significantly lowest dry weight amongst all genotypes at 60, 90, 120 DAS and at harvest. At harvest, dry weight of *P. minor* in plots with HD 2687 was around 28.02, 13.09 and 24.26 per cent

Table 6. Effect of genotypes and weed control treatments on dry matter accumulation (gm^{-2}) by *P.minor* at various growth stages by wheat

Treatments	**Days after sowing**				
	30	**60**	**90**	**120**	**at harvest**
Wheat genotypes					
WH 157	1.53	9.82	52.50	74.47	75.48
PBW 343	1.54	8.31	44.68	61.47	62.51
WH 542	1.52	9.26	50.96	70.96	71.73
HD 2687	1.52	7.70	39.25	53.63	54.33
SE m ±	0.06	0.18	1.57	0.83	1.54
CD at 5 %	NS	0.59	5.00	5.62	4.94
Weed control treatments					
Clodinafop 60 g/ha	2.03	3.60	15.48	42.98	44.18
Sulfosulfuron 25 g/ha	2.05	3.63	15.54	43.18	44.11
Weedy check	2.03	27.85	156.37	174.37	175.75
Weed free check	0.00	0.00	0.00	0.00	0.00
SE m ±	0.08	0.16	1.41	1.56	1.39
CD at 5 %	0.24	0.47	4.12	4.56	4.05

lower than the plot where WH 157, PBW 343 and WH 542 were grown, respectively.

Performance of clodinafop 60 g/ha was statistically similar to sulfosulfuron 25 g/ha in terms of dry weight reduction of resistant *P. minor* at all the growth stages of wheat (Table 6). These herbicides reduced the dry weight of *P. minor* to the extent of 87.02, 90.08, 75.29 and 74.88 per cent as compared to weedy check at 30, 60, 90 days after spray and at harvest, respectively. Dry weight of *P. minor* was significantly more in weedy check as compared to other weed control treatments at all the growth stages except at 30 DAS. In weed free treatments, *P. minor* was removed as and when required and it was not allowed to grow throughout the crop season.

The interaction effect of genotypes and weed control treatments on dry matter accumulation by resistant *P. minor* was significant at harvest (Fig. 4). Among wheat genotypes, clodinafop 60 g/ha and sulfosulfuron 25 g/ha were found at par with each other in respect of dry weight reduction of *P. minor* and weedy check recorded significantly higher dry matter of *P. minor* than both the herbicidal treatments. On an average, clodinafop 60 g/ha and sulfosulfuron 25 g/ha reduced 74.88 per cent dry weight of *P. minor* among different genotypes as compared to weedy check at harvest.

The dry weight of resistant *P. minor* under clodinafop 60 g/ha was significantly higher in WH 157 to all wheat genotypes except WH 542. While dry matter of this weed was lowest in HD 2687 but statistically it was at par with PBW 343 which in turn was at par with WH 542. Almost similar trend was noticed among different genotypes under sulfosulfuron and weedy

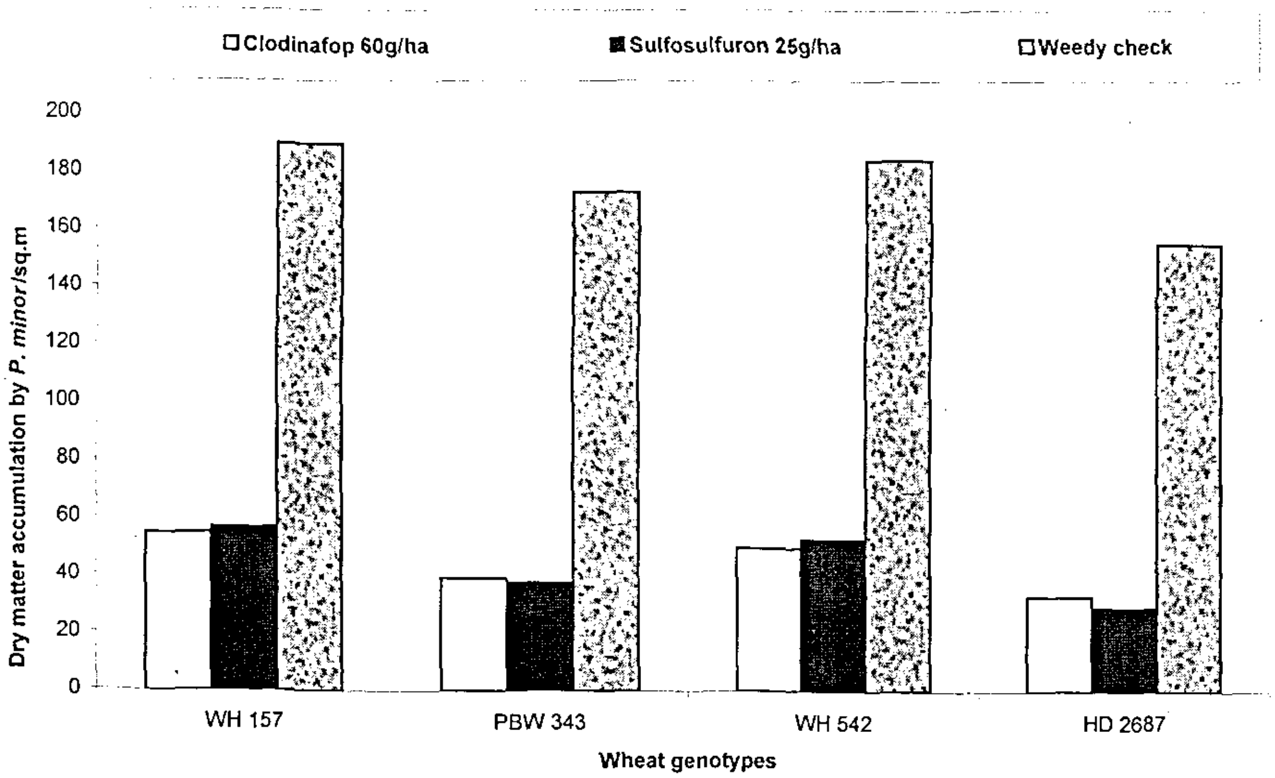


Fig. 4 The interaction of genotypes and weed control treatments on dry matter accumulation by *P. minor*/sq.m

check except that dry matter accumulation by *P. minor* was significantly higher in PBW 343 compared to HD 2687 under the treatment of weedy check. While PBW 343 allowed significantly lower dry matter accumulation by *P. minor* as compared to WH 542 under sulfosulfuron 25 g/ha and weedy check treatment (Fig. 4).

4.1.3 Visual toxicity (%) on *P. minor*

Data on visual phytotoxicity (%) on *P. minor* recorded at 30 and 60 days after spray (Table 7) indicated that phytotoxicity levels against resistant *P. minor* among various wheat genotypes due to various weed control treatments was non-significant. Among weed control treatments, weed free check was found statistically superior over other treatments because due to frequent weedings no weed was allowed to grow throughout the crop season. Clodinafop 60 g/ha was found at par with sulfosulfuron 25 g/ha providing around 87-90 per cent toxicity against *P. minor* at 30 and 60 days after spray and all these treatments were found statistically superior over weedy check.

4.2 CROP STUDIES

4.2.1 GROWTH STUDIES

4.2.1 Plant stand per running metre row length (mrl)

The data pertaining to number of plants per running metre row length recorded at 30 and 60 DAS (Table 8) revealed that there was no significant difference in terms of wheat plants/mrl among various genotypes and weed

Table 7. Effect of genotypes and weed control treatments in terms of visual toxicity (%) on *P.minor* at 30 and 60 days after spray.

Treatments	Days after spray	
	30	60
A. Wheat genotypes		
1. WH 157	59.17 (70.75)	57.40 (68.94)
2. PBW 343	58.60 (70.19)	56.89 (68.38)
3. WH 542	58.44 (70.06)	57.10 (68.63)
4. HD 2687	58.30 (69.88)	56.84 (63.64)
SE m ±	1.75	1.49
CD at 5 %	NS	NS
B. Weed control treatments		
1. Clodinafop 60 g/ha	72.19 (90.44)	69.08 (87.13)
2. Sulfosulfuron 25 g/ha	72.29 (90.44)	69.15 (87.06)
3. Weedy check	0.00 (0.00)	0.00 (0.00)
4. Weed free check	90.00 (100.00)	90.00 (100.00)
S.E. m ±	1.18	1.08
C.D. at 5 %	3.38	3.12

Original data given in parenthesis was subjected to arc sin transformation before analysis.

Table 8. Wheat plants per running metre row length (mrl) as affected by genotypes and weed control treatments

	Days after sowing	
Treatments	**30**	**60**
Wheat genotypes		
WH 157	25.38	25.38
PBW 343	24.60	24.62
WH 542	25.95	25.97
HD 2687	24.45	24.48
SE m ±	0.66	0.67
CD at 5 %	NS	NS
Weed Control treatments		
Clodinafop 60 g/ha	24.92	24.96
Sulfosulfuron 25 g/ha	25.19	25.20
Weedy check	25.11	25.11
Weed free check	25.16	25.18
SE m ±	0.60	0.62
CD at 5 %	NS	NS

control treatments at 30 and 60 DAS and it varied between 24.45 to 25.97 plants/mrl. Since tillering was profused and generally no significant variation expected at later growth stages, the data on this aspect was not recorded thereafter.

4.2.1.2 Plant height (cm)

Height of wheat plant as affected by genotypes and weed control treatments at different growth stages has been depicted in Table 9. The differences in plant height were non-significant among various wheat genotypes and weed control treatments at 30 DAS.

Among wheat genotypes, WH 157 attained plant height statistically at par with PBW 343 and HD 2687 at all the growth stages. The plant height in HD 2687 had an edge over other genotypes at all the growth stages except at 30 DAS though the differences were non-significant. WH 542 recorded significantly lowest height at all the growth stages except at 30 DAS.

Among weed control treatments, clodinafop 60 g/ha was found at par with sulfosulfuron 25 g/ha in terms of plant height (Table 9) and these were at par with weed free check at all growth stages. In general, the plant height was more in weed free check and significantly less in weedy check as compared to other treatments at 60, 90, 120 DAS and at harvest.

4.2.1.3 Dry matter accumulation per running metre row length (mrl) by wheat

The perusal of data on dry matter accumulation by wheat plants per running metre row length recorded at 30, 60, 90, 120 DAS and at harvest

Table 9. **Effect of genotypes and weed control treatments on the height (cm) of wheat plant at different crop stages**

Treatments	**Days after sowing**				
	30	**60**	**90**	**120**	**At harvest**
Wheat genotypes					
WH 157	19.88	43.04	89.11	99.04	98.23
PBW 343	19.57	44.00	89.02	95.93	95.18
WH 542	19.36	39.58	79.74	86.75	85.86
HD 2687	19.70	44.49	90.28	99.85	99.44
SE m±	0.60	1.05	2.29	2.52	2.42
CD at 5 %	NS	3.38	7.28	8.10	7.80
Weed Control Treatments					
Clodinafop 60 g/ha	19.51	43.67	87.69	95.58	94.93
Sulfosufuron 25 g/ha	19.69	43.62	87.69	95.96	95.20
Weedy check	19.64	39.81	83.94	92.71	91.86
Weed free check	19.68	44.10	88.83	97.31	96.72
SE m±	0.50	0.54	1.00	1.04	1.01
CD at 5%	NS	1.59	2.85	2.98	2.92

(Table 10) indicated that dry matter accumulation by wheat plants increased with the corresponding advancement of crop stages and it was maximum at harvest in all the treatments. The magnitude of increase in dry matter accumulation was higher at 60 DAS followed by at 90 and 120 DAS and there was not much increase thereafter. The differences in dry matter accumulation among various genotypes and weed control treatments were non-significant at 30 DAS.

Among wheat genotypes, HD 2687 recorded significantly highest dry matter accumulation at all the growth stages except at 30 DAS. It was followed by PBW 343 which recorded significantly higher dry matter accumulation compared to WH 157 and WH 542 at 60, 90, 120 DAS and at harvest. However, WH 157 and WH 542 were found statistically at par with each other at all the growth stages (Table 10).

Among weed control treatments (Table 10),clodiinafop 60 g/ha, sulfosulfuron 25 g/ha and weed free check were found statistically at par in terms of dry matter accumulation when compared with each other at all the growth stages. Whereas significantly lowest dry matter accumulation by wheat plants was obtained in weedy check at 60, 90, 120 DAS and at harvest. On an average, the dry matter accumulation by wheat plants/mrl was around 11.74, 6.67, 18.31 and 18.49 per cent higher in herbicide treated plots as compared to weedy check at 60, 90, 120 DAS and at harvest, respectively.

4.2.2 YIELD ATTRIBUTES

The data pertaining to the impact of different wheat genotypes and weed control treatments on yield attributes (effective number of tillers per

Table 10. Dry matter accumulation (g) by wheat plants per running metre row length (mrl) at different crop stages as affected by genotypes and weed control treatments

Treatments	Days after sowing				
	30	60	90	120	At harvest
Wheat genotypes					
WH 157	8.64	95.31	190.77	304.79	306.96
PBW 343	8.68	101.66	207.19	324.54	326.78
WH 542	8.59	96.01	192.07	308.10	309.95
HD 2687	8.81	107.14	253.45	377.84	381.11
SE m±	0.20	1.68	3.76	5.12	5.16
CD at 5 %	NS	5.40	12.00	16.40	16.50
Weed Control Treatments					
Clodinafop 60 g/ha	8.63	102.32	217.78	341.08	343.04
Sulfosufuron 25 g/ha	8.71	102.29	217.69	340.73	343.59
Weedy check	8.68	91.56	186.63	288.14	289.73
Weed free check	8.70	103.96	221.38	345.32	348.44
SE m±	0.08	1.11	2.22	3.51	3.54
CD at 5%	NS	3.16	6.39	10.04	10.14

running metre row length, number of grains per earhead, earhead length and test weight) was recorded at harvest and has been presented in Table 11.

4.2.2.1 Effective tillers (no./mrl)

Among wheat genotypes, the maximum number of effective tillers (86.05/mrl) were obtained in HD 2687 (Table 11), which were statistically at par with PBW 343 (83.35/mrl). HD 2687 and PBW 343 both were found statistically superior over WH 157 (67.93/mrl) and WH 542 (71.41/mrl) in terms of number of effective tillers/mrl whereas WH 157 was found statistically at par with WH 542.

Clodinafop 60 g/ha (78.03/mrl) and sulfosulfuron 25 g/ha (78.00/mrl) significantly improved the number of effective tillers over weedy check treatment (74.06/mrl). The highest number of effective tillers (78.64/mrl) were obtained in the plots which were maintained weed free throughout the crop season. However, it was found to be statistically at par with both the herbicidal treatments (Table 11).

4.2.2.2 Number of grains per earhead

The data on number of grains per earhead recorded in respect of various treatments presented in Table 11 revealed that maximum and significantly higher number of grains per earhead were obtained in WH 542 (55.25) compared to other wheat genotypes. Next best was HD 2687 which recorded significantly more grains (48.43) per earhead as compared to

Table 11. Effect of genotypes and weed control treatments on yield attributing characters of wheat

Treatments	Effective tillers (No./mrl)	Grains per earhead (No.)	Earhead length (cm)	Test weight (g)
Wheat genotypes				
WH 157	67.93	44.26	9.98	43.00
PBW 343	83.35	43.95	9.82	42.64
WH 542	71.41	55.25	10.40	35.83
HD 2687	86.05	48.43	10.30	43.22
SE m±	1.48	1.06	0.19	0.37
CD at 5 %	4.77	3.40	NS	2.83
Weed Control Treatments				
Clodinafop 60 g/ha	78.03	48.41	10.21	41.47
Sulfosufuron 25 g/ha	78.00	48.35	10.20	41.43
Weedy check	74.06	46.13	9.74	39.82
Weed free check	78.64	49.00	10.34	41.98
SE m±	0.71	0.48	0.08	0.40
CD at 5%	2.04	1.35	0.25	1.17

WH 157 (44.26) and PBW 343 (43.95) and WH 157 was found statistically at par with PBW 343 in this respect.

The number of grains (48.35-49.00) per earhead counted in plots treated with clodinafop 60 g/ha, sulfosulfuron 25 g/ha or in weed free check, being statistically at par amongst each other, were found to be significantly more as compared to weedy check (46.13, Table 11).

4.2.2.3 Earhead length

Data given in Table 11 revealed that the differences in terms of length of earhead among different wheat genotypes were non-significant.

Among weed control treatments; clodinafop 60 g/ha (10.21 cm), sulfosulfuron 25 g/ha (10.20 cm) and weed free check (10.34 cm), being statistically at par amongst each other in respect of earhead length, were significantly superior over weedy check (9.74 cm).

4.2.2.4 1000-grain weight

The data related to 1000-grain weight (test weight) of wheat presented in Table 11 revealed that HD 2687 attained maximum test weight (43.22 g) and found at par with WH 157 (43.00 g) and PBW 343 (42.64 g). Whereas WH 542 was found significantly poor in terms of test weight (35.83 g) attained compared to all other genotypes.

Among weed control treatments, clodinafop 60 g/ha (41.47 g), sulfosulfuron 25 g/ha (41.43 g) and weed free check (41.98 g), being statistically at par amongst each other, were found statistically superior over weedy check (39.82 g) treatment in terms of 1000-grain weight.

4.2.3 YIELDS OF WHEAT

The data pertaining to grain and straw yield of wheat as affected by genotypes and weed control treatments under zero tillage were recorded at harvest during 1999-2000 have been presented in Table 12.

4.2.3.1 Grain yield

The perusal of data given in Table 12 revealed that wheat genotype HD 2687 recorded significantly highest grain yield (6709 Kg/ha). WH 157 (5514 Kg/ha) and WH 542 (5597 Kg/ha) produced statistically similar grain yields while PBW 343 (5891 Kg/ha) was significantly superior over WH 157 and WH 542. The grain yield of HD 2687 was 13.89, 19.87 and 21.67 per cent higher than PBW 343, WH 542 and WH 157, respectively. PBW 343 provided 6.84 and 5.25 per cent higher grain yield compared to WH 157 and WH 542, respectively.

Among weed control treatments; clodinafop 60 g/ha (6272 Kg/ha), sulfosulfuron 25 g/ha (6268 Kg/ha) and weed free treatment (6346 Kg/ha) resulted into statistically similar grain yields. The treatment of weedy check resulted into significantly lowest grain yield (4825 Kg/ha). On an average the herbicidal treatments increased grain yield to the extent of 29.95 per cent as compared to weedy check.

Table 12. Effect of genotypes and weed control treatments on grain and straw yield of wheat

Treatments	Grain Yield (Kg/ha)	Straw Yield (Kg/ha)
Wheat genotypes		
WH 157	5514	8482
PBW 343	5891	9197
WH 542	5597	8538
HD 2687	6709	10566
SE m ±	91	174
CD at 5 %	290	557
Weed Control treatments		
Clodinafop 60 g/ha	6272	9744
Sulfosulfuron 25 g/ha	6268	9742
Weedy check	4825	7431
Weed free check	6346	9866
SE m ±	38	73
CD at 5 %	109	209

The interactional effects of genotypes and weed control treatments in respect of grain yield (Fig. 5) indicated that at the level of each individual genotype the grain yield of wheat was statistically at par among all weed control treatments except in weedy check. Grain yield in unweeded plots was significantly lower in respect of all wheat genotypes.

Wheat genotypes WH 157, PBW 343 and WH 542 produced similar grain yields under various weed control treatments except that under sulfosulfuron 25 g/ha and weedy check PBW 343 resulted into significantly higher grain yields compared to aforesaid two genotypes (Fig. 5). Among various wheat genotypes, HD 2687 resulted into significantly higher grain yields under all the weed control treatments.

The magnitude of grain yield increase in significantly highest yielding genotype HD 2687 was 12.31, 15.66, 58.68 and 12.64 per cent more compared to the lowest yielding genotype WH 157 under clodinafop 60 g/ha, sulfosulfuron 25 g/ha, weedy and weed free checks, respectively.

The magnitude of grain yield increase in PBW 343 next best genotype was 0.79, 5.6, 28.89 and 0.21 per cent higher than lowest grain yielding genotype WH 157 under clodinafop 60 g/ha, sulfosulfuron 25 g/ha, weedy and weed free check, respectively. The trend of grain yield in WH 542 was very close and just statistically similar to WH 157 under various weed control treatments.

4.2.3.2 Straw yield

The perusal of data given in Table 12 revealed that wheat genotype HD 2687 recorded significantly highest straw yield (10566 Kg/ha). WH 157

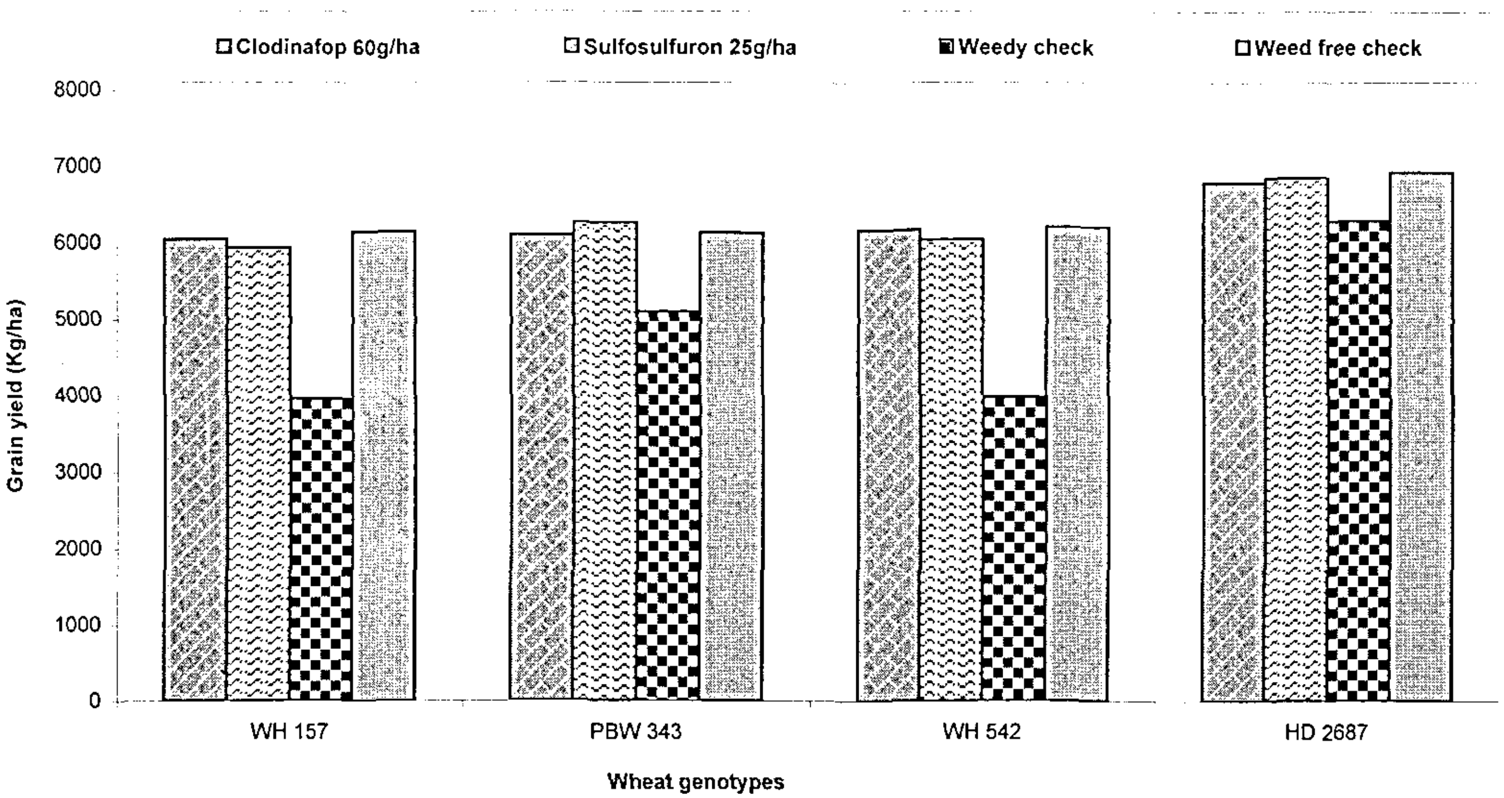


Fig. 5 The interaction of genotypes and weed control treatments on grain yield (Kg/ha) of wheat

(8482 Kg/ha) and WH 542 (8538 Kg/ha) produced statistically similar straw yields while PBW 343 (9197 Kg/ha) was significantly superior over WH 157 and WH 542. The straw yield of HD 2687 was 14.89, 23.75 and 24.57 per cent higher than PBW 343, WH 542 and WH 157, respectively.

Among weed control treatments; clodinafop 60 g/ha, sulfosulfuron 25 g/ha and weed free treatment being statistically at par resulted into 9744, 9742 and 9866 Kg/ha straw yields, respectively. The treatment of weedy check resulted into significantly lowest straw yield (7431 Kg/ha). On an average the herbicidal treatments increased straw yield to the extent of 31.11 per cent as compared to weedy check.

The interactional effects of genotypes and weed control treatments in respect of straw yield (Fig. 6) indicated that at the level of each individual genotype the straw yield of wheat was statistically at par among all weed control treatments except in weedy check. Straw yield in unweeded plots was significantly lower in respect of all wheat genotypes.

Wheat genotypes WH 157, PBW 343 and WH 542 produced similar straw yields under various weed control treatments except that under sulfosulfuron 25 g/ha and weedy check, PBW 343 resulted into significantly higher straw yields compared to aforesaid two genotypes (Fig. 6). Among various wheat genotypes HD 2687 resulted into significantly higher straw yields under all the weed control treatments.

The magnitude of straw yield increase in significantly highest yielding genotype HD 2687 was 15.39, 16.55, 63.55 and 16.60 per cent more

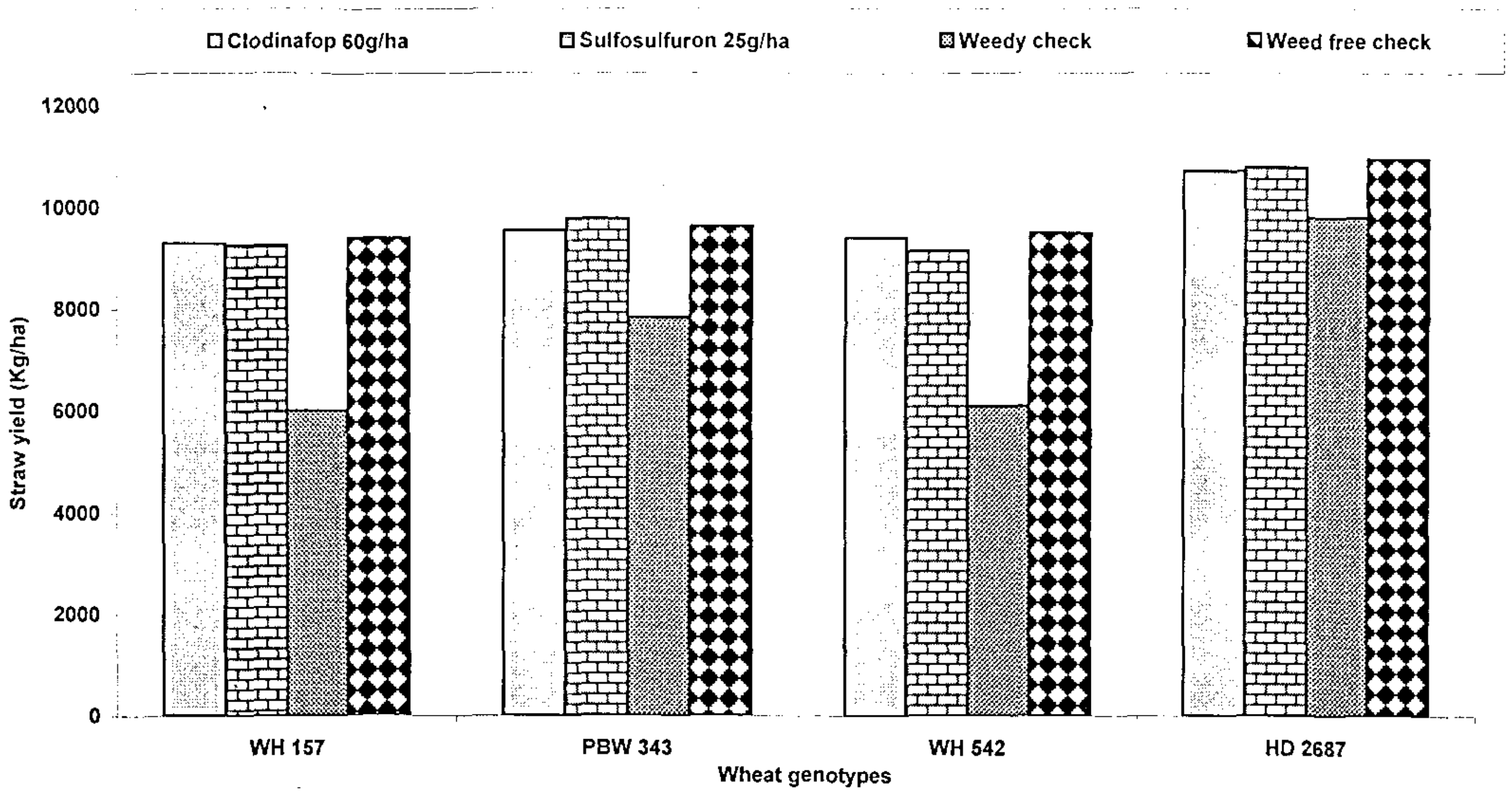


Fig. 6 The interaction of genotypes and weed control treatments on straw yield (Kg/ha) of wheat

compared to the lowest yielding genotype WH 157 under clodinafop 60 g/ha, sulfosulfuron 25 g/ha, weedy and weed free checks, respectively.

The magnitude of straw yield increase in PBW 343 next best genotype was 2.77, 5.63, 30.78, 2.52 per cent higher than lowest straw yielding WH 157 under clodinafop 60 g/ha, sulfosulfuron 25 g/ha, weedy and weed free checks, respectively. The trend of straw yield in WH 542 was very close and just statistically similar to WH 157 under various weed control treatments.

CHAPTER - 5

DISCUSSION

Continuously increasing Indian population has already exceeded 1000 million but there is little scope for expansion of wheat growing areas. Hence, it becomes very important that the wheat productivity in the rice-wheat high productivity zone increases at a rate greater than the population growth and addresses sustainability issue such as herbicide resistance. Rice-wheat rotation is produced on about 22 m ha of productive land in South Asia and China (Hobbs and Morris, 1996) and wheat is grown on nearly 12 m ha in rotation with rice in South Asia's Indo-Gangetic plains. The high yielding wheat varieties of the Green Revolution era are grown almost exclusively in this region, mostly under irrigated conditions and have been widely accepted due to their high responsiveness to applied fertilizers. However, it ultimately encouraged greater intensity and spread of grassy weeds particularly *Phalaris minor.*

The development and use of selective herbicide most dominantly isoproturon for effective control of *P. minor* in wheat was a major technological advance for farmers in the north-western states of India. Control of this troublesome weed often resulted in large yield responses and a major boost in the profitability of farmers in this region. However, continuous use of isoproturon alone has resulted into widespread development of resistance in *P. minor* which has wiped out some of the productivity gains achieved since 1982 and it has again become a major constraint to wheat productivity (Malik and Singh, 1995). The development of resistance again brought about a convergence of *P. minor* problem with the density levels at same level or more than the density levels that existed in late seventies (Malik *et al.*, 1995). A clear trend for decline in wheat yield in the rice-wheat zone of Haryana was observed as compared to areas where resistance was not a problem in 1994-95 and 1995-96. Currently there is a growing recognition that resistance is affecting wheat production over a large farming area estimated to be around 0.7-0.8 m ha in northern India and effective alternative weed management techniques needs to be developed urgently to tackle the problem. If the problem is not tackled now, wheat in other crop sequences adjacent to the rice-wheat growing areas could also become infested with resistant weed populations. The challenge is to integrate use of alternate herbicides with appropriate agronomic and cultural weed management techniques.

In fields affected by herbicide resistance, weed population are often extremely high causing large losses in wheat yield due to intense crop-weed competition. However, competitiveness of the crop can be manipulated and used as a tool for integrated weed management. To achieve this, there is a need to recognize the importance of agronomic (seed rate, sowing time and method, variety) and cultural practices (such as zero tillage) those enhance the competitiveness of wheat with *P. minor.*

Poor competitive ability of modern wheat varieties has increased infestation of *P. minor* since the introduction of CIMMYT-based genotypes to northern India. Researchers have established that plant height (Paul and Gill, 1979) and early canopy cover (Balyan *et al.*, 1991) are important determinants of competitiveness of wheat against weeds. With the onset of herbicide resistance and the need to develop non-chemical methods of weed control, breeders need to develop such strategies that can blend height and early canopy cover (vigour) without sacrificing yield potential.

In the past, the use of herbicide in rice-wheat cropping system was not accompanied by improved tillage, crop diversification, herbicide rotation, herbicide application techniques and training of users. A proper combination of all such practices appears to be the key ingredient of a sustainable weed management system.

Zero tillage also offers a way to manage the resistant *P. minor* problem in wheat. Refinement in the tine design in the existing rabi (postrainy) wheat seed drills has made the zero tillage seed drills perform effectively in uncultivated rice-fields. The tines are a solid and strong one piece mold, to pass through the top soil without much soil disturbances. This allows more precise seed and fertilizer placement with a row to row spacings of 17.5 cm.

The herbicide resistance problem can be used as a test bed for zero tillage technology and a significant incentive for farmers to adopt this new tillage technology and in the present investigation also it was realized to test it directly at the farmer's fields infested with resistant *P. minor.* However, if this technology is not tested directly on farmer's fields using their innovative ideas, there is a risk of considerable lag between research and on farm adoption.

This zero tillage technology has the potential to eliminate 6-10 tillage operations usually practiced under conventional tillage. This saving in time and expenses is a huge incentive for farmers to adopt pre-seeding non-selective herbicide. It is anticipated that these savings will fully cover the cost of non-selective herbicides.

In the zero tillage system wheat can be sown early by 7-10 days. There is some experimental evidence that early sown wheat is more competitive against *P. minor.* However, in situations where seed banks are enormous, it must be prudent to encourage pre-sowing weed germination by irrigating a seed bed that is uncultivated or one that has received a shallow cultivation before planting with a zero tillage drill. In the present investigation also, pre-seeding non-selective herbicide (Glycel @ 0.5 %) was used to kill emerged seedlings of resistant *P. minor* (250-300 plants/m^2) before planting with zero tillage. Moreover, this whole package of operations coupled with alternate post-emergence herbicides was applied in the present experimental field in previous year also which ultimately reduced the population of resistant *P. minor* from initial levels of 1500-2000 plants/m^2 to 200-250 plants /m^2.

Based on the above considerations, a package which offsets some of the additional cost of new herbicide against reduced tillage savings under zero tillage system is likely to appeal to farmers. Reduced tillage systems have well documented benefits to the sustainability of farming systems (eg. reduced soil erosion, improved soil structure, improved root growth and water use efficiency). In India adoption of this change, primarily due to herbicide resistance in *P. minor* is likely to be valuable for the sustainability of this intensively cropped agro ecosystem.

In the first week of November, *P. minor* can be encouraged to emerge by providing one or two pre-sowing irrigations or residual moisture prevailing in the field after paddy harvest as done in the present experimentation. The first flush of weeds was controlled by pre-seeding non-selective herbicides (Glycel @ 0.5 %) followed by direct drilling by a zero tillage planter. The second flush of weeds in this system will not be highly competitive because of less emergence due to fewer soil disturbances and that too can be easily controlled by any of recommended alternate post- emergence herbicides (clodinafop 60 g/ha, fenoxaprop 120 g/ha, sulfosulfuron 25 g/ha or tralkoxydim 350 g/ha). However, future research should focus on increasing the variety of selection pressure imposed on weed communities within the zero tillage systems (Derksen *et al.*, 1996). Research and extension activities on such alternative technologies for long term weed management solutions should be based on farmer participatory approach that can easily promote adoption of interactive techniques for solving such problems.

The reports on the performance of various wheat genotypes and alternate herbicides against resistant *P. minor* under zero tillage system are very meager. Keeping all aforesaid points in view, the present investigation entitled,"Competing ability of wheat genotypes against resistant *P. minor* under zero tillage" was undertaken during 1999-2000 directly on farmers field in village- Tik, district-Kaithal of Haryana, India. It is very important to point out here that this village comes under rice-wheat zone and wheat is severely affected by isoproturon –resistant *P. minor.* Efficacy of isoproturon against *Phalaris* biotypes collected from this village and adjoining areas ranged only between 5-34 per cent (Yadav *et al.*, 1995) and the dose required to cause 90 per cent growth reduction was 4.94 times higher than sensitive biotype in 1992 (Malik *et al.*,1996) whereas around 6.9 times higher dose of isoproturon was required to cause 50 per cent growth reduction in these biotypes in 1995 (Malik *et al.*,1995). Methabenzthiazuron was also found ineffective against *Phalaris* biotypes collected from around the experimental location (Yadav *et al.*, 1995).

Results pertaining to the present investigation are discussed in this chapter and efforts have been made to explain these in the light of information obtained by other workers.

5.1 WEED STUDIES

Among different wheat genotypes, HD 2687 allowed significantly lower population of *P. minor* to appear followed by PBW 343, WH 542 and WH 157 in the order, however, density of *P. minor* was at par among WH 157 and WH 542 (Table 5). It reflects different competitive ability of wheat genotypes against *P. minor*. Varying competing ability against weeds among different wheat genotypes have been reported earlier also by Torner *et al.* (1985) and Lemerle and Cousens (1992). The reduction in density of *P. minor* in HD 2687 was due to early canopy cover because of taller plants (Table 9) and more dry matter accumulation (Table 10) at early stages of growth. Earlier also plant height and dry matter accumulation have been reported to be important determinants for competitiveness of wheat genotypes against weed (Lyfenko *et al.*, 1986; Wicks *et al.*, 1986; Richards, 1989; Sandhu and Mehra, 1990; Balyan *et al.*, 1992). Although WH 157 is equally tall variety but density of *P. minor* was found maximum in this. This might be due to less dry matter accumulation (Table 10) and less number of tillers (Table 11) as compared to other genotypes. The wheat genotypes which attained taller plant height and more dry matter accumulation have earlier also been reported to impose adverse effects on accompanying weeds (Blackshaw, 1981; Lanning *et al.*, 1997; Santin *et al.*, 1997). Since HD 2687 followed by PBW 343, WH 542 and then WH 157 in the order attained more straw weight due to higher tillering and thus imposed effective competitiveness on *P. minor*. This is in conformity with findings of Gill and Mehra, 1981; Andersson, 1983 and Sechnyak *et al.*, 1985.

Among weed control treatments, weedy check (200 plants/m^2) recorded significantly higher population of *P. minor* at various crop growth stages (Table 5). On an average herbicides (clodinafop 60 g/ha and sulfosulfuron 25 g/ha) reduced *P. minor* intensity to the extent of 76 per cent at various growth stages. The magnitude of *Phalaris* population reduction seems to be slightly lower compared to earlier reports regarding efficiency of these herbicides (Malik and Yadav, 1997; Brar *et al.*, 1999). This might be possible because of emergence of succeeding flushes of this weed after first irrigation.

P. minor population in resistance affected rice-wheat zone was found to cross 3000-5000 plants/m^2 (Malik *et al.*, 1995) and even at experimental site it was 2500-3000 plants/m^2 in 1996-97. But now it is declining mainly because of replacement of isoproturon by effective alternate herbicides (clodinafop, fenoxaprop or sulfosulfuron) from last three years. At the experimental location also, population of *P. minor* was quite low (179 plants/m^2) in 1999-2000 before spray of post-emergence herbicides because the experimental field was subjected to alternate post-emergence herbicides since 1997-98 onwards and also wheat was sown with zero tillage seed drill in previous year (1998-99) coupled with pre-seeding non-selective herbicides and super imposed with post-emergence alternate herbicides. Zero tillage of wheat sowing allows only slight soil disturbances and thus help tremendously in reducing *P. minor* particularly first flush. As most canary grass seeds germinate in the top 2 cm soil layer slightly above the sowing depth (Hooda *et al.*, 1974 and Chhokar *et al.*, 1999). Another possible reason of comparatively lower population of *P. minor* in the present study might be due to early sowing (Nov. 07,1999) of wheat. Comparatively reduced germination of *P. minor* due to higher than optimal temperature for its germination in the first week of November have been reported earlier also (Bhan and Bhaskar Chaudhary, 1976; Singh and Dhawan, 1976 and Chhokar and Malik, 1999). This might also be possible due to better growth of wheat crop sown in the first week of November which might have not allowed much emergence of *P. minor* plants due to smothering effects (Malik *et al.*, 1998). Since the crop was sown in the first week of November, it emerged rapidly before *P. minor* and could have exerted a strong smothering effect on the weed which is usually slow in establishing under these conditions.

The density and dry weight of *P. minor* was not significantly affected upto 30 DAS by any of genotypes and weed control treatments.

Among wheat genotypes, HD 2687 allowed significantly lower dry matter accumulation by *P. minor* at 60, 90, 120 DAS and at harvest (Table 6). At harvest, dry weight of *P. minor* in plots with HD 2687 was around 13.09, 24.26 and 28.02 per cent lower than the plots where PBW 343, WH 542 and WH 157 were grown, respectively. Almost similar trend was observed at other growth stages. This might be due to more plant height and significantly higher dry matter accumulation by HD 2687 followed by PBW 343, WH 542 and WH 157 in that order. The wheat genotypes with height gain (Table 9) and more dry matter accumulation (Table 10) allowed lower number of *P. minor* plants/m^2 and consequently lower dry matter accumulation by this weed. These results are in conformity with the earlier findings elsewhere (Wicks *et al.*, 1986; Richards, 1989; Sandhu and Mehra, 1990; Balyan *et al.*, 1992).

Performance of clodinafop 60 g/ha was statistically similar to sulfosulfuron 25 g/ha in terms of dry weight reductions of resistant *P. minor* at all the growth stages of wheat (Table 6). These herbicides reduced the dry weight of *P. minor* to the extent of 87.02, 90.08, 75.29 and 74.88 per cent as compared to weedy check at 30, 60, 90 days after spray and at harvest, respectively. Similarly equal and effective efficacy of these alternate herbicides against *P. minor* have been reported earlier also by other workers (Malik and Yadav, 1997; Brar *et al.*, 1998; Dixit *et al.*, 1998; Loubser, 1998; Balyan, 1999).

The level of visual phytotoxicity due to herbicides against *P. minor* among various wheat genotypes at 30 and 60 days after spray was non-significant (Table 7). Clodinafop 60 g/ha and sulfosulfuron 25 g/ha being statistically at par resulted into around 87-90 per cent visual toxicity against resistant *P. minor* and both were superior to weedy check. Similar results have been reported by Malik and Yadav (1997), Brar *et al.* (1998) and Balyan (1999).

5.2 CROP STUDIES

5.2.1 Growth studies

There was no significant variation in terms of wheat plants/mrl among various genotypes and weed control treatments at 30 and 60 DAS (Table 8) and it varied between 24.45 to 25.97 plants/mrl. This reflects that there was similar level of germination among different wheat genotypes and also there was no phytotoxic effects of clodinafop and sulfosulfuron on any of wheat genotypes. Based on number of experimental trials at Research Farm and farmer's field in Haryana and Punjab, these herbicides were recommended in 1996-1997 against resistant *P. minor* in wheat after excluding their possible phytotoxic effects on crop. Brar *et al.* (1999) also reported these herbicides are very safe to wheat crop. Since tillering was profused and based on the pretext that no significant variation in this respect would appear (which generally happens) at later growth stages, the number of plants/mrl were not counted after 60 DAS.

Plant height (Table 9) in HD 2687 had an edge over other genotypes though the differences were non-significant with PBW 343 and WH 157. WH 542 recorded significantly lowest height. This variation might be due to different genetic constitution. Better growth in terms of plant height in HD 2687 might also be because of early and effective control of weeds (Table 5 and 6) which might have consequently resulted in lesser competition for light, moisture and nutrients between crop and weeds. Likewise, among herbicidal treatments, clodinafop 60 g/ha and sulfosulfuron 25 g/ha provided effective control of *P. minor* (Table 5 and 6) just similar to weed free check which ultimately resulted into significantly higher plant height of crop.

The dry matter accumulation by wheat plants increased with the corresponding advancement of crop stages and it was maximum at harvest in all the treatments. The magnitude of increase in dry matter accumulation *was higher at 60 DAS followed by at 90 and 120 DAS and there was not* much increase thereafter. The differences in dry matter accumulation among various genotypes and weed control treatments were non-significant at 30 DAS. Among wheat genotypes, HD 2687 recorded significantly highest dry matter accumulation (Table 10) followed by PBW 343, WH 542 and WH 157 in the trend, however, in case of WH 542 and WH 157 the differences were found non-significant. The wheat genotype HD 2687 produced 16.63, 22.96 and 24.16 per cent higher dry matter in comparison to PBW 343, WH 542 and WH 157 at harvest, respectively. Due to more density and dry weight (Table 5 and 6) of *P. minor* in WH 157, dry matter accumulation in this genotype was significantly decreased in comparison to HD 2687 and PBW 343 because dry matter accumulation is cumulative product of height and tillers. Due to comparatively taller plants and more tillers, HD 2687 produced significantly more dry matter. Higher density and dry weight of weeds (Balyan and Malik, 1989) and higher leaf area and more leaves of *P. minor* (Malik *et al.*, 1986) due to severe competitiveness were found to significantly reduced the dry matter accumulation by wheat and vice-versa.

On an average, the dry matter accumulation by wheat plants/mrl was around 11.74, 16.67, 18.31 and 18.49 per cent higher in herbicide treated plots (at par with weed free check) as compared to weedy check at 60, 90, 120 DAS and at harvest, respectively. This might have been possible due to efficient control of *P. minor* (Table 5, 6 and 7) by these herbicides. Significantly lower dry matter accumulation in all the wheat genotypes was found in the plots kept unweeded throughout the crop growth season due to maximum competition between *P. minor* and wheat. These finding are on the line similar to that observed by Malik and Yadav (1997) and Brar *et al.* (1999).

5.2.2 Yield attributes

Grain yield is a function of different yield attributing characters (Table 11) i.e. effective tillers per plant, grains per earhead, earhead length and test weight. Genotypic behaviour significantly influences various yield attributing characters. These yield attributes in wheat have also been reported to be adversely affected by infestation of weeds in general and *P. minor* in particular (Bhatia *et al.*,1981; Morishita and Thill, 1988; Wilson *et al.*, 1990).

Among wheat genotypes, the number of effective tillers/mrl (Table 11) in HD 2687 (86.05/mrl) were 3.24, 20.50 and 26.67 per cent higher than PBW 343, WH 542 and WH 157, respectively. This would have been possible due to differential competitiveness among various genotypes against *P. minor.* The genotype HD 2687 due to its superior vigour (plant height and dry matter accumulation) produced more number of effective tillers. Richards and Whytoch (1993) also reported that winter wheat varieties which exhibited earlier ground cover with denser canopy were more competitive to weeds. Clodinafop 60 g/ha and sulfosulfuron 25 g/ha, being at par with weed free check, significantly reduced density and dry weight of *P. minor* (Table 5 and 6) and as a result produced significantly higher number of effective tillers per running metre row length. Similar findings have been reported by Balyan (1999) and Brar *et al.* (1999).

WH 542 (55.25) recorded 14.08, 24.83 and 25.71 per cent higher number of grains per earhead (Table 11) than HD 2687, WH 157 and PBW 343, respectively. This would have been possible due to comparatively longer earheads and smaller grain size (lowest 1000-grain weight) in WH 542 as compared to all other genotypes. The number of grains (48.35-49.00) per earhead counted in plots treated with clodinafop 60 g/ha, sulfosulfuron 25 g/ha or in weed free check, being statistically at par amongst each other, were found to be significantly more as compared to weedy check (46.13).

Earhead length (9.82-10.40 cm) was not significantly affected by genotypes. Application of clodinafop 60 g/ha and sulfosulfuron 25 g/ha increased the earhead length to an extent of 4.83 and 4.72 per cent over weedy check. It clearly reflects that *P. minor* present in the unweeded check reduced earhead length among all genotypes.

The differences in respect of 1000-grain weight (Table 11) amongst wheat genotypes could be attributed mainly to the genetic constitution of respective genotypes and partly to environmental and growing conditions. The genotypes having bold grains resulted into more test weight than small grain genotypes. The trend in terms of 1000-grain weight among wheat genotypes followed was HD 2687 > WH 157 > PBW 343 > WH 542 reflecting that HD 2687 attained maximum test weight (43.22 g) and WH 542 recorded lowest test weight (35.83 g).

Among weed control treatments, clodinafop 60 g/ha (41.47 g), sulfosulfuron 25 g/ha (41.43 g) and weed free check (41.98 g), being statistically at par amongst each other, were found statistically superior over weedy check (39.82 g) treatment in terms of 1000-grain weight. The decrease (4-5 %) in test weight in weedy check plots might be due to severe competition imposed by *P. minor* which might have resulted into shrivelling of grains.

Number of earheads per plant, earhead length, grains per spike and test weight (Table 11) as have been found to be affected in the present investigation due to *P. minor* were also reported to be affected similarly at several other locations (Morishita and Thill, 1988; Bhatia *et al.*, 1989; Wilson *et al.*, 1990).

5.2.3 Yield

Grain yield among different wheat genotypes varied significantly (Table 12). This might be because of differential competing ability of these genotypes against *P. minor* as indicated earlier (Table 5, 6 and 7) and differential genetic make-up and yield potential capacity. The grain yield of HD 2687 (6709 Kg/ha) was 13.89, 19.87 and 21.67 per cent higher than PBW 343, WH 542 and WH 157, respectively. PBW 343 provided 6.84 and 5.25 per cent higher grain yield compared to WH 157 and WH 542, respectively. Weber *et al.* (1999) also reported that among three spring wheat cultivars under zero tillage, Jasna gave highest yield compared to Henika and Ismena. Almost similar trend was observed in terms of straw yield among various genotypes. The straw yield of HD 2687 (10566 Kg/ha) was 14.89, 23.75 and 24.57 per cent higher than PBW 343, WH 542 and WH 157, respectively.

The variety (HD 2687) which attained dense canopy cover in terms of plant height and dry matter accumulation imposed stiff competition against *P. minor* and consequently resulted into superior yield attributes (effective tillers/mrl and 1000-grain weight) and ultimately into significantly higher grain and straw yields. Next best yielding variety was PBW 343 followed by WH 542 and WH 157. The variation among wheat genotypes in terms of grain and straw yields was due to their differential genetic constitution and also due to their differential competing ability against resistant *P. minor.* WH 157 though attained statistically similar plant height as it was in case of HD 2687 but it resulted in lesser dry weight accumulation and poor grain and straw yields. Challaiah *et al.* (1986) also found similar behaviour of 'Turkey' wheat variety against *Bromus tectorum.*

Among weed control treatments; clodinafop 60 g/ha and sulfosulfuron 25 g/ha, being at par with weed free check (6346 Kg/ha), resulted into significantly higher grain yield over weedy check. Similar trend was observed in respect of straw yield. On an average the herbicidal treatments increased grain and straw yields to the extent of 29.95 and 31.11 per cent as compared to weedy check. These results are in conformity with the earlier findings (Malik and Yadav, 1997; Brar *et al.*, 1998 and Balyan *et al.*, 1999) regarding improved efficacy of alternate herbicide (clodinafop and sulfosulfuron) already recommended for farmer's use in conventionally sown wheat against resistant *P. minor.* Based on this investigation, it is confirmed that aforesaid alternate herbicides are equally effective against resistant *P. minor* in wheat under zero tillage system of sowing. The yield loss caused by around 200 plants/m^2 of resistant *P. minor* in the present investigation was approximately 30 per cent. Similarly the yield of wheat was found to reduce 36-39 per cent by the presence of 304 canary grass plants/m^2, whereas, the grain yield was not significantly affected by the presence of 76 plants/m^2 (Elefthrohorinos, 1996). Malik *et al.* (1996) also reported 25-30 per cent yield reductions in wheat due to *P. minor* and it might go as high as 10-50 per cent (Gill and Brar, 1977). Similarly heavy reductions in grain and straw yields of wheat due to weeds have also been observed elsewhere (Pandey *et al.*, 1980; Bhatia *et al.*, 1981; Andersson, 1983 and Yadav *et al.*, 1984). Malik *et al.* (1995) observed 3000-5000 and even more plants/m^2 of resistant *P. minor* causing heavy yield losses and sometimes leading to immature harvesting of wheat crop.

Since the present investigation doesn't involve the treatment of conventional tillage, the data on wheat yields under this system were not included herein. But based on number of research trails at farmer's field during 1996, 1997, 1998 and also during the current year (1999-2000) by the HAU Scientists in Haryana, the yield levels realized by the farmers under conventional sowing of wheat just adjacent to the present experimental field were by and large lower, in some cases equal but in none more than zero till sown wheat. Similarly higher yields under no-tillage wheat were observed at different locations (Majid *et al.*, 1988; Lindwal *et al.*, 1995; Pratley, 1995; Thomas *et al.*, 1995; Unger, 1995; Merill *et al.*, 1996; Halvorson *et al.*, 1999; Huang *et al.*, 1999). Ciha (1982) indicated that average grain yields of wheat with no-tillage and conservation tillage were significantly greater than yields using conventional tillage and also reported that no-tillage increased test weight. Sirohi *et al.* (1999) reported that at 50 DAS the population of *P. minor* in wheat under conventional tillage was more than under zero tillage, might be due to less soil disturbances (Dickey, 1992) and consequently higher yields under zero tillage. Giambelli *et al.* (1989) noticed that the number of spikes/metre, seeds/spike and 1000-grain weight were highest with direct drilling. Contrary to this, Ahmad (1993); Aase *et al.* (1995) and Dzienia *et al.* (1998) reported lower grain yields of winter wheat by direct drilling/no-tillage or use of a field cultivator compared with conventional sowing in crop rotations other than rice-wheat. However, Sharma and Kharwara (1994) found that grain yield of irrigated as well as rainfed wheat in hand weeded plots was lowest with no-tillage compared to conventional tillage but on the basis of cost/benefit ratio, no-tillage with chemical weedings in irrigated conditions was economical in sandy loam soils. *Other benefits of conservation tillage such as soil and water* conservation, production cost decline, fuel and labour savings, lower machinery investments and the long term benefits to soil structure, moisture and fertility have also been realized at many locations (Gauer *et al.*, 1982; Hernani, *et al.*, 1989; Goel and Verma, 1991; Bull and Sandretto, 1996).

It is speculated that changes in input availability and crop sequences (from traditional to modern) might change the component of weed flora (Malik *et al.*, 1984; Singh *et al.*, 1992). Reduced tillage might increase the amount of annual and perennial weeds (Dzienia *et al.*, 1998; Blecharczyk *et al.*, 1999) after few years. Feldman *et al.*(1998) reported the build- up of a more diverse community due to no-tillage. However, long term research in relation to tillage systems will be more reliable to study and confirm the shift in weed flora under a given set of situations.

Huang *et al.* (1999) revealed the bulk density in the 7-14 cm layer under conventional, minimal and no-tillage was 1.348, 1.412 and 1.410 g/cm^3, respectively. Contrary to this, Blecharczyk *et al.* (1999) found lower bulk density and soil compaction under direct sowing of wheat.

Several workers have suggested that additional N and P would be required to maximize yields of no-tillage wheat following rice (Dickson *et al.*, 1996 and Blecharczyk *et al.*, 1999). David (1996) concluded that the overall performance of integrated weed management (using combinations of no or reduced tillage and herbicides selected in relation to the weed flora present) was positive compared with conventional practices; soil structure was improved and risk of erosion decreased; the costs of soil cultivation were reduced and the use of less herbicides and of low-toxicity post-emergence herbicides which do not leave soil residues had a positive environmental effect.

Since the present investigation was carried out under higher yielding environment at the farmers field infested with comparatively less number of resistant *P. minor* plants/m^2 (200) as compared to the other situation in resistance affected rice-wheat zones where 3000-5000 or even more plants of *P. minor* per square metre generally prevail. Based on the response of farmers it is speculated that zero tillage sowing of wheat is likely to cover tremendously more area at fast rate in Haryana, Punjab and other adjoining rice–wheat growing states. So this warrants to plan and undertake future research on competing ability of these wheat genotypes under zero tillage coupled with pre-seeding and post-emergence herbicides under situations of high infestation to draw any final and valuable conclusions.

CHAPTER - 6

SUMMARY AND CONCLUSION

The experiment entitled, "Competing ability of wheat genotypes against resistant *P.minor* under zero tillage" was conducted during rabi (winter) season of 1999-2000 in the rice-wheat cropping zone affected with isoproturon resistant *P. minor* at the farmer's field, village-Tik, district-Kaithal, Haryana. The experiment consisting of combinations of four wheat genotypes *viz.,* WH 157, PBW 343, WH 542 and HD 2687 in main plots and four weed control treatments *viz.*, clodinafop 60 g/ha, sulfosulfuron 25 g/ha, weedy and weed free check in sub plots was laid out in split-plot design with four replications. The results obtained are summarised below :

6.1 WEED STUDIES

6.1.1 Effect of wheat genotypes on resistant *P.minor*

i. Density and dry weight of *P. minor* was not significantly affected by genotypes upto 30 DAS.

ii. Population of *P. minor* among different varieties at 60, 90, 120 DAS and at harvest was significantly low in HD 2687 followed by PBW 343 and it was maximum in WH 157 which was at par with WH 542.

iii. Dry matter of *P. minor* at 60, 90, 120 DAS and at harvest was significantly higher in plots with genotype WH 157 which was at par with WH 542 and significantly lowest in HD 2687 and next in that order followed by PBW 343.

iv. There was no significant variation with respect to visual toxicity (%) on *P. minor* due to any genotype.

6.1.2 Effect of weed control treatments against resistant *P. minor*

i. Because spray was done at 35 DAS and not at 30 DAS, the dry matter accumulation by *P.minor* at 30 DAS was statistical similar amongst different weed control treatments except weed free check.

ii. Clodinafop 60 g/ha was found at par with sulfosulfuron 25 g/ha in controlling resistant *P. minor* population at 60, 90, 120 DAS and at harvest and these were at par with weed free check. Herbicidal treatments on an average reduced the density of *P. minor* to the extent of 75.4-76.7 per cent as compared to weedy check at 60 DAS and thereafter. The magnitude of control of *P. minor* with respect to its population with herbicides seems to be slightly lower because of emergence of succeeding flushes of this weed after first irrigation.

iii. Among interaction effect, density of resistant *P. minor* was significantly higher in PBW 343 compared to HD 2687 under the treatment of sulfosulfuron 25 g/ha and dry matter accumulation by *P. minor* was significantly higher in PBW 343 compared to HD 2687 under the treatment of weedy check.

iv. Visual toxicity due to herbicidal treatments was similar and it was upto the extent of 90.44 and 87.10 per cent at 30 and 60 days after spray.

6.2 CROP STUDIES

6.2.1 Growth studies

6.2.1.1 Effect of genotypes

i. Plant population on an average ranged from 24.47 to 25.96 plants/mrl and it was statistically similar under different genotypes.

Ii. Genotype HD 2687 produced comparatively taller plants at all growth stages except at 30 DAS than other genotypes but the differences were non-significant when compared to PBW 343 and WH 157. Whereas average plant height in WH 542 was smaller than other genotypes at various growth stages.

iii. Among various genotypes, the dry matter accumulation by wheat plants/mrl was significantly higher in HD 2687 and next followed in that order by PBW 343, WH 542 and then WH 157. However, dry matter accumulation by WH 157 and WH 542 was statistically similar.

6.2.1.2 Effect of weed control treatments

i. Plant population of wheat genotypes recorded at 30 and 60 DAS was not significantly affected by any weed control treatment.

ii. The plant height recorded at 60, 90, 120 DAS and at harvest was more in weed free check which was found at par in plots treated with clodinafop 60 g/ha and sulfosulfuron 25 g/ha but significantly less in the plots which were kept unweeded throughtout the crop growing season.

iii. Dry matter accumulated by wheat plants at various growth stages did not differ significantly under clodinafop 60 g/ha, sulfosulfuron 25 g/ha and weed free treatments. The lowest dry matter accumulated by wheat was obtained in weedy check at all growth stages. On an average, the dry matter accumulation by wheat plants at 60, 90, 120 DAS and at harvest due to herbicides increased to the extent of 11.74, 16.67; 18.31 and 18.49 per cent as compared to weedy check, respectively.

6.2.2 Yield attributes

6.2.2.1 Effect of genotypes

i. Wheat genotypes HD 2687 (86.05/mrl) and PBW 343 (83.35/mrl) being at par recorded significantly higher number of effective tillers than other genotypes. The number of effective tillers were significantly lowest in WH 157 (67.93) closely followed by WH 542 (71.41/mrl), which were at par with each other.

ii. The number of grains per earhead were significantly more in WH 542 (55.25) closely followed by HD 2687 (48.43), WH 157 (44.26) and PBW 343 (43.95) in the descending order. However, WH 157 and PBW 343 produced statistically similar grains per earhead. Earhead length was not significantly affected by genotypes.

iii. The maximum test weight (1000-grain weight) was obtained in HD 2687 (43.22 g) followed by WH 157 (43.00) and PBW 343 (42.64 g), however, these genotypes were found statistically at par amongst each other. Statistically lowest test weight was obtained in WH 542 (35. 83 g).

6.2.2.2 Effect of weed control treatments

i. The number of effective tillers/mrl were 78.03, 78.00 and 78.64 due to clodinafop 60 g/ha, sulfosulfuron 25 g/ha and weed free check, respectively. However, statistically these weed control treatments were at par in respect of number of effective tillers produced per metre row length. Weedy check produced significantly lowest effective tillers (74.06/mrl).

ii. Weed free check (49.00), clodinafop 60 g/ha (48.41) and sulfosulfuron 25 g/ha (48.35), being statistically at par amongst each other, produced significantly more number of grains per earhead over weedy check (46.13).

iii. Earhead length was statistically at par among the plots treated with clodinafop 60 g/ha (10.21 cm), sulfosulfuron 25 g/ha (10.20 cm) and weed free check (10.34 cm) but significantly smallest earhead length was obtained in unweeded plots (9.74 cm).

iv. Clodinafop 60 g/ha (41.47 g), sulfosulfuron 25 g/ha (41.43 g) and weed free check (41.98 g), being at par, resulted into significant improvement in the test weight compared to weedy check (39.82 g).

6.2.3 Grain and straw yield of wheat

6.2.3.1 Effect of genotypes

i. Among various wheat genotypes, HD 2687 produced significantly higher grain yield (6709 Kg/ha). It was significantly superior over PBW 343 (5891 Kg/ha), WH 542 (5597 Kg/ha) and WH 157 (5514 Kg/ha). However, WH 542 and WH 157 were found statistically at par with each other in this respect but significantly poor than PBW 343.

ii. The wheat genotype HD 2687 produced significantly higher straw yield (10566 Kg/ha). It was significantly superior over PBW 343 (9197 Kg/ha), WH 542 (8538 Kg/ha) and WH 157 (8482 Kg/ha). However, WH 542 and WH 157 were found statistically at par with each other in this respect but poor than PBW 343.

6.2.3.2 Effect of weed control treatments

i. Clodinafop 60 g/ha, sulfosulfuron 25 g/ha and weed free check, being at par amongst each other, produced significantly higher grain and straw yield over weedy check. The magnitude of increase in grain and straw yield of wheat on an average due to herbicidal treatments was 29.95 and 31.11 per cent more as compared to weedy check.

ii. *Among interaction effect, wheat genotypes* WH 157, PBW 343 *and* WH 542 produced similar grain yields under various weed control treatments except that under sulfosulfuron 25 g/ha and weedy check PBW 343 resulted into significantly higher grain yield compared to aforesaid two genotypes and similar trend was observed in terms of straw yield.

CONCLUSION

The results obtained based on present investigation clearly revealed that wheat genotype HD 2687 due to its more initial growth in terms of height, dry weight accumulation and profused tillering proved best competitor against resistant *P. minor* in terms of reducing its density and dry weight under zero tillage system of wheat sowing. As a result it produced significantly more effective tillers/mrl, 1000-grain weight and ultimately resulted in significantly higher grain and straw yields. The next best wheat genotype in all respects under prevailing situation was PBW 343 which was superior over WH 542 and WH 157 in that order. The other genotypes WH 542 and WH 157 proved weak competitor against resistant *P. minor* and there by resulted both into poor grain and straw yields.

The alternate herbicides, clodinafop 60 g/ha and sulfosulfuron 25 g/ha being statistically at par with weed free treatment resulted into excellent

(87-90 %) control of isoproturon resistant *P. minor* and on an average the grain and straw yields of wheat under zero tillage due to these herbicides were found to be increased to the extent of 29.95 and 31.11 per cent, respectively.

Based on the results of present investigation, it becomes evident that differential competitiveness of wheat genotypes under zero tillage coupled with effective pre-seeding (only where required) and post-emergence alternate herbicides might play an important role in realizing yield potentials by combating resistant *P. minor* in rice-wheat growing areas. However, further research is required to confirm these findings under the situation of high *P. minor* infestation in wheat.

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