Agric. Rev., 23 (4) : 241 - 251, 2002

INTEGRATED MANAGEMENT OF *PHALARIS MINOR* IN WHEAT: RATIONALE AND APPROACHES - A REVIEW

G. Mahajan and L.S. Brar*

Punjab Agricultural University,
Regional Research Station, Gurdaspur - 143 521, India

ABSTRACT

Continuous use of isoproturon has resulted in widespread development of resistance in littleseed canary grass in wheat which was wiped out some of the productivity gains achieved since 1982. An initiative was launched by PAU, Ludhiana and CSS, HAU, Hisar in collaboration with ACIAR in 1996 to promote research towards the development of an integrated management of this weed for handling this problem. Research in integrated management of *Phalaris minor* must take all aspect of cropping system into consideration and evolve in a progressive manner. This approach must encompass the role of alternative method of weed control, influence of crop rotation, enhancement of crop competitiveness, exploitation of sowing time and methods, role of conservation tillage either alone or in combination with herbicides to control *P. minor* in wheat.

Crop production can be increased both by extensive and intensive agriculture. Favourable temperature, light regimes and availability of early maturing photosensitive crops provide scope for increasing cropping intensities. These factors also favoured rapid multiplication of weeds, which compete with crops throughout the year. Globally agriculture production losses due to weeds are thought to be in the range of 10 to 20 per cent (Auld *et al.*, 1987). Nalewaja and Arnold (1970) reported substantial reduction in yield of grain crop by weeds depending upon weed species, weed intensity and soil fertility. Weeds reduced the grain yield of wheat under optimum moisture and nutrient availability due to reduced space and light (Kolar and Bains 1976). Samra and Dhillon (1993) observed that the competition of weeds in wheat resulted in significant reduction in grain yield of crop.

The problem of *Phalaris minor* is associated with the farm areas where continuous rice-wheat cropping sequence is practiced. Although it is a problem of wheat crop when rotated with other summer season irrigated crops but the infestation is more serious where wheat follows wetland rice. Probably, these wet conditions provide congenial situation for the seeds of *P. minor* because of increased viability due to leaching of phenolic compounds (Bhan and Kumar 1998). Yield losses especially from *P. minor* alone are estimated to the tune of 25-50 per cent and in very severe infestation, the losses may go upto 80 per cent (Malik *et al.*, 1996). Experiment conducted at the Punjab Agricultural University, Ludhiana indicated that nitrogen efficiency of the crop was greatly reduced in the presence of *P. minor* (Walia 1983, Khera *et al.*, 1995). In another study, Mehra and Gill (1998) reported that *Phalaris* density of 250 plants/sqm. reduced wheat yield by 45 per cent indicating high competitive ability of this weed against wheat. In a green house study, the plant biomass and grain yield of wheat were substantially reduced when six plants of *P. minor* were grown in competition with 10 plants of wheat (Khalid and Shad 1990).

During recent years, this weed has become a main constraint in realizing the yield potential of this crop. An exploratory survey conducted jointly by the CIIMYT, IRRI and Haryana Agricultural University in Karnal and Kurukshetra district of Haryana (India), also concluded that *P. minor* was the major factor

* Department of Agronomy, PAU, Ludhiana.

responsible for regional productivity loss (Harrington *et al.*, 1992). Due to its identical growing nature and resemblance with wheat crop, its mechanical removal is quite cumbersome and costlier. A number of herbicides came in use during 1978-79 (Gill *et al.*, 1978) to control the *P. minor*. Among these isoproturon emerged as the most effective and the only available herbicide for a long time. This herbicide remained effective till 1990 but afterwards it started showing the problem of poor control of *P. minor*. The sustainability of the rice-wheat rotation has been repeatedly questioned over the past few years due to increased pressure of *P. minor* infestation in wheat crop. Moreover, with the development of resistance to isoproturon by this weed especially in rice-wheat sequence has further aggravated the problem in harnessing the aim of this crop (Malik and Singh 1995, Walia *et al.*, 1997). Alternative herbicides namely sulfosulfuron, clodinafop, tralkoxydim and fenoxaprop-p-ethyl proved effective in controlling isoproturon resistance *Phalaris* (Walia *et al.*, 1998) but there is also a risk of development of cross resistance to these herbicides. There is need to tackle the problem by devising effective and viable management techniques, otherwise wheat in other sequences adjacent to the rice-wheat growing areas could also become infested with resistant weed populations. Integrated weed management, therefore needs to be accorded a top priority for increasing wheat production (Al-Kathiri, 1994). The optimal strategy should include a decline in herbicide usage as resistance develops with a compensatory increase in the level of non-chemical control (Gorddard *et al.*, 1995). Moreover, at present the herbicide load on the soil is on the increase and development of such chemical and non-chemical approaches in combination, might help in environment friendly and economical sound coordinated management of *P. minor* infestation and to sustain the productivity of wheat crop.

Need for Integrated Management

Focus on integrated weed management has been considered one of the top priority areas to reduce the menace of *P. minor* in increasing wheat yield. Competitive of the crop can be manipulated and used as a tool for integrated weed management and the core aspect of this approach is to maximize the yield benefits. In the past, the use of herbicide in rice-wheat cropping system was not accompanied by other agronomic and biological tools. A proper combination of all such practices appear to be the key ingredient of a sustainable weed management system. Thus integration of appropriate crop management practices can help mechanical/ herbicide measures to give long term gains.

Crop Rotation

Mono-cropping often causes a rapid weed shift towards highly competitive species. In continuous crop cultivation practices the weed seed bank increases enormously and a tremendous pressure of weed population develops over the crop. On the other hand, rotation of crops having dissimilar life cycle or cultivation practices breaks the cycle of weeds due to the change in ecological condition and serves as most effective of all the weed control measures. So, the change in cropping sequences may be the one of the methods and sunflower, sugarcane, winter maize, berseem or vegetable may substitute wheat. Once the wheat areas are diversified, other weeds will start multiplying. By replacing wheat with alternate crop for 2-3 years (Table 1), the population of *P. minor* was found to be reduced significantly and wheat yield was found to increase by 10-25 q/ha, even without the use of isoproturon, however, no yield advantage in wheat was achieved by replacing rice with other crops, where relative percentage of this cropping sequence was found 73 per cent w.r.t. *Phalaris minor* (Fig. 1) as compared to other cropping sequences (Bhan, 1997). It is pertient to mention that alternate crop sequences should be economically viable because it has been experienced in past that farmers may not accept any alternate technology than chemical use if economic return is not viable.

Table 1. Effect of cropping sequence on the population of *P. minor* in wheat

S.No.	Cropping sequence	*P. minor* (No./sqm.)
1	Rice-Wheat-Rice-Wheat-Rice-Wheat	54
2	Rice-Potato-Rice-Wheat-Rice-Potato	253
3	Rice-Sugarcane-Sugarcane ratoon-Wheat	4
4	Maize-Wheat-Rice-Wheat-Maize-Wheat	18
5	Sorghum-Wheat-Maize-Wheat-Sorghum-Wheat	22

Source : Bhan (1997)

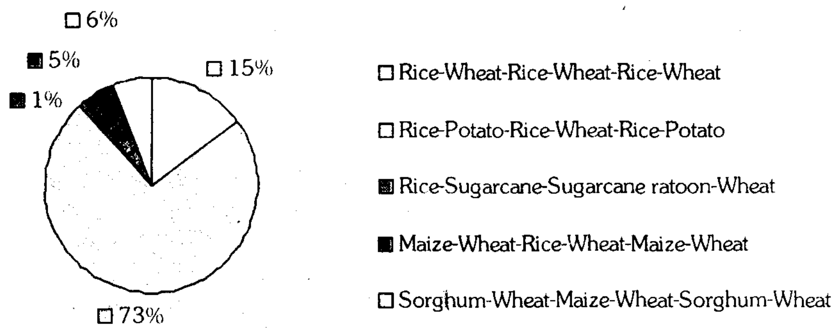

Fig. 1. Showing relative percentage of difference cropping sequences w.r.t. population of *Phalaris minor*

Tillage System

Change in tillage practices could be expected to differentially effect the shift in weed infestation and composition. Shallow and early germinating annual broadleaf and grass species may increase under reduced tillage due to concentration of seeds at or near the soil surface (Yenish *et al.*, 1992). Early germinating species are favoured by no tillage as some of these might have germinated by the time the crop is planted, thus may give a competitive edge over the later germinating weeds/crop (Aldrich and Kremer 1998). Gino (1993) further claimed that conventional tillage directly affect weed seed bank by physical mixing of soil and in turn reducing weed number. However, in another study tilled plots had 21-28 per cent more weeds per unit area than zero tillage plots (Verma and Srivastava, 1989). But reduction in tillage operation produce varying effect on weed population and in reduced tillage, about 40-80 per cent of weed seeds get accumulated in 0-5 cm soil layer resulting in more weed emergence compared to conventional tillage (Mehra 1996). Zero tillage in the rice-wheat cropping system would mean a saving in time of 2-3 weeks to prepare the land for planting wheat and this time could be used for stimulating weed emergence followed by effective control with nonselective herbicides which might result in less soil disturbance and less weed emergence (Hobbs 1997, Mahajan, 2000). In another study, Sinha *et al.* (1999) reported that weed count and weed dry biomass were higher in reduced tillage and observed higher number of effective tillers, number of grains and test weight and grain yield in more pulverized tillage than normal and reduced tillage practices. While, Stefoy and Bai (1999) reported that grass weeds were more prevalent in conventional tillage but have no effect on grain yield of wheat with different tillage systems. Wrucke and Arnold (1985) found that no tillage system typically had higher population of small seeded annual weeds while mouldboard plough system had more large seeded annual weeds.

Table 2. Effect of different weed control treatments on the dry matter of *P. minor* and grain yield of wheat under zero tillage condition

S.No.	Weed control treatment	Dry matter of *P. minor* (q/ha)	Grain yield (q/ha)
1	Unweeded check	24.45	12.5
2	Glyphosate 0.50 kg/ha 3 days before sowing	12.51	25.7
3	Isoproturon 0.94 kg/ha (AFI)	6.21	32.7
4	Glyphosate 0.50 kg/ha 3 days before sowing followed by isoporturon 0.94 kg/ha (AFI)	1.23	40.8

Source : Mahajan (2000)

Selection of Cultivars

It is a common observation that a crop needs enough biomass in the early growth stage for having better competitive ability. Therefore, in context of *P. minor*, it should be deprived of the resources which may inhibit its emergence process. During early stages different varieties of wheat have different canopy structure and can utilize available resources in better way than the weeds. Research on two-gene dwarf varieties has shown that plant height is an important attribute for the competitiveness of wheat against *P. minor* (Table 3). Tall growing wheat genotype had a considerable suppressive effect on the development of this weed and caused more reduction in density, height and total dry matter of *P. minor* than dwarf varieties which allowed the vigorous growth of this weed (Gill and Mehra 1981). Brar and Singh (1997) observed that bread wheat cultivars (HD-2339 and WH-542), owing to their height, dry matter production and number of mature tillers, resulted in great suppression of *P. minor* than durum wheat (cv. PDW-34), resulting in 23.4 per cent and 19.1 per cent higher grain yield respectively. Verschwele *et al.* (1994) observed that there was a correlation between indirect estimation of interspecific crop competitiveness and measured weed suppression. A significant cultivar-shoot competition interaction was observed by Lucas *et al.* (1993) in that the yield of shorter cultivar Fewsco and Riband was reduced due to more competition offered by weeds than those of tall cultivars Moris Huntsman and Moris Widgeon. Prasad *et al.* (1999) reported that in UP-2113 genotype (tall) crop-weed competition index was lower as compared to the index of other two genotypes UP-2003 (semi-dwarf) and HD-2113 (dwarf).

Table 3. Effect of wheat genotypes on the growth of *P. minor*

Genotypes	Dry wt. of *P. minor* (q/ha)	Plant height of *P. minor* (cm)	Plant height of wheat (cm)
Tall	5.3	57	115
Medium	12.5	92	85
Dwarf	17.0	90	60

Source : Paul and Gill (1979)

Crop density/Geometry

Plant spacing, of course is affected of seeding rate. However, the effect of the crop geometry is an issue distinct from seeding rate. That is the seeding rate per land area can be obtained by either an equidistant planting pattern or by planting in rows. Theoretical analysis has shown that crop plants in an equidistant planting pattern are about twice as competitive as in a rectangular planting pattern in which distance between rows in 3.5 times distance with in the row; assuming simultaneous emergence and equal number of weed-crop plants (Fischer and Miles 1973). Sowing of wheat in both direction at closer row spacing of 15 cm is also found beneficial than sowing at 22.5 cm apart (Brar and Singh 1997). The uniform/thick plant stand of wheat with resultant increase utilization of solar energy, space and nutrients have better smothering capacity over *P. minor* than thin stand due to better canopy structure (Bhan and Kumar 1998). In a crop-weed ecosystem. Increasing the crop plants per unit area greatly facilitate weed suppression by maintaining dominant position over weeds through modification in canopy structure (Gill 1992). In another study Mahajan (2000) reported that closer spacing at 15 cm produced significantly lower dry matter of *P. minor* than normal spacing at 22.5 cm and further reported that reduction in dry matter of *Phalaris* was due to competitive stress offered by wheat crop due to more number of tillers/unit area of the wheat crop (Table 4).

Table 4. Effect of planting pattern on the dry matter of P. minor, effective tillers and grain yield of wheat (Mean of 2 years)

Planting pattern	Dry matter of *P. minor* (q/ha)	Effective tillers/sqm	Grain yield (q/ha)
15 cm	4.7 (21.7)	358	43.0
22.5 cm	5.1 (26.0)	283	37.8
LSD (0.05)	0.16	17.3	0.96

Source : Mahajan (2000)

Time of sowing

The manipulation of sowing date of wheat play an important role in the management of weeds in wheat. Since wheat is being sown over a period of two months, the emergence and growth of weeds in relation to planting time may influence the competition of weeds and efficacy of herbicides (Chester 1993). The result of field experiments conducted over a number of years at Punjab Agricultural University showed that wheat crop sown in Nov.-Dec. have more problem of grassy weeds (Anonymous 1992-93) than the broad leaf weeds. The emergence rate of *P. minor* increased with delayed sowing of wheat because of a decline in temperature (Tiwari 1990). Malik and Singh (1993) also concluded that during the late sowing of wheat (Dec./ Jan.) the prevailing temperature favours the emergence and the growth of *P. minor* and thus crop suffer badly in respect of its yield. Mahajan *et al.* (2000) observed that with the availability of genotypes PBW-343 and WH-542 which can tolerate higher temperature condition during October, there is possibility of offering great competition to the crop for the suppression of *P. minor* as it emerges during the month of November, and by the time crop covers the weeds. They reported that 25th October sown crop owing to their more dry matter production caused 26.9% reduction in dry matter accumulation by *P. minor* and hence, resulted in 21.6% higher grain yield over 10th November sown crop (Table 5).

Table 5. Effect of date of sowing on dry matter accumulation by *P. minor* at harvest stage and grain yield of wheat.

Date of sowing	Dry matter of *P. minor* (q/ha)		Effective tillers/sqm		Grain yield (q/ha)	
	1997-98	1998-99	1997-98	1998-99	1997-98	1998-99
25th Oct.	4.7 (22.3)	4.9 (24.1)	381	407	47.2	50.9
10th Nov.	5.7 (30.9)	5.7 (32.7)	284	311	37.3	41.8
25th Nov.	4.3 (18.4)	4.5 (20.0)	258	284	30.0	35.6
LSD (0.05)	0.27	0.25	27.5	27.1	2.15	2.48

Source : Mahajan *et al.* (2000)

Water management

Water is a crucial input to ensure crop productivity and to realize full benefits of other costly input. Neither water stress at any stage of growth nor excess water supply is desired. Moisture is one of the resource, which may be manipulated for the disadvantage of *P. minor*. It is required to ensure adequate moisture in the surface zone of soil which gets dried soon after sowing. *P. minor* seeds should be encouraged to emerge before sowing in the fields where wheat has planned to be sown. Two pre-sowing irrigation may be given to encourage the first flush of *P. minor* to emerge. It will be better if after final seed bed preparation, wheat should be sown by drilling method. Under such situation, the already emerged population of *P. minor* will be controlled by drilling and new flushes will emerge only after first irrigation (Bhan and Kumar, 1999). Hooda and Agarwal (1991) found that at three irrigation level (2,4 and 6 irrigation), the population density of *P. minor* and other weeds generally decreased as iirigation increased. Weed dry weight generally increased as irrigation increased, from 6.7-30.3 g/sqm with 2 irrigation to 7.7-35.3 g/sqm with 6 irrigation.

Fertilizer management

Effect of mineral fertilization and weed growth in crops is not well established though both of them compete for the same nutrient pool. Increasing the level of soil fertility can alter the competition between crops and weeds. Optimum nitrogen application in combination with herbicides suppressed the growth of *P. minor*, wild oats in wheat (Walia and Gill 1985, Brar and Chopra 1987) besides improving nitrogen use efficiency. The application of fertilizers in excess encourages weed growth and should be avoided. The proper management of nutrients in wheat can reduce the weed competition. It has been observed that under low fertility conditions competition of weeds is more, therefore, use of higher dose of nutrients could prove useful in compensation of loss. Further, method of fertilizer application i.e. drilling of fertilizers in the root zone is more beneficial than broadcast application. The broadcast method of application provide more favourable, condition for the weed growth (Table 6).

Table 6. Effect of N levels on wheat and wild oat

Nitrogen levels (kg/ha)	Dry wt. of. wild oat (q/ha)	Wheat yield (q/ha)
60	11.1	28.3
120	10.3	32.2

Source : Mehra (1996)

The results showed that when wheat and wild oats were growing together under variable nitrogen levels; wheat utilized nitrogen more efficiently at recommended level (N_{120})

whereas associated wild oats plants made better growth at low levels of nitrogen N_{60} and reduced the wheat yield by 7.7 per cent. Increased grain yield and effective control of *P. minor* with cross sowing of wheat and placement of fertilizer below the seed was noticed compared to unidirectional sowing and broadcast application of fertilizers (Ahuja and Yaduraju 1989). to apply nutrient in adequate amount and in balanced proprotions, fertilizers should be applied on soil test basis. Rana and Angiras (1995) have reported that dry weight of dominant weeds like *P. minor*, *A. fatua* and *V. sativa* in the crop of *B. compestiris* at Palampur increased with increasing rate of P while it was found opposite at Hisar in wheat field (Hooda and Agarwal 1991). They found that as the fertilizer level increased, the population density of weeds decreased from 23.6-32.0 plants/sqm. With 60 kg N+30 kg P_2O_5/ha to 23.4-49.2 plants with 120 kg N+60 kg P_2O_5 and weed dry matter increased from 7.2-32.9 g/sqm to 7.8-35.1 g/sqm. Therefore, it is desirable to work out combinations of different fertilizers in different types of soil. Malik and Singh (1993) reported that application of phosphatic fertilizers without nitrogen stimulates the growth of broadleaf weeds and contrary to it, nitrogen fertilizers stimulate the growth of grassy weeds. So, appropriate combination of nutrients and herbicides may change crop-weed competition in favour of wheat crop.

Biological method

It involves delibrate use of living organism to reduce the population of target weeds and has led to many spectacular success against weeds, insects, mites, nematode, plant pathogens and terrestrial herbicides used as biotic agents to biologically control weeds (Watson 1992). Meagre reports are available in India about the biological agents like insects and disease attacking *P. minor*. Singh and Deol (1994) from Punjab, recorded an aphid species, *Sitobion avenae*, which varies in colour from shining yellowish-green to dull green using *P. minor* as an alternate host besides barley, oat while wheat was its main host. The highest aphid population was observed around mid March when the wheat crop was in the milky grain stage and temperature ranged between 17.1 and 20.9°C. A few record of nematodes and disease infestation on *P. minor* also available from India. During survey in March, 1984 almost all wheat cv. WL 711 plants in a field in Haryana, were infected by tundu Corynebacterium tritici (*Clavibacter tritici*) in association with Anguina tritici. The infection incidence of wheat,barley and *Phalaris* was 60.8, 7.3 and 3.8 per cent, respectively, but *Avena fatua* and *Convolvulus arvensis* were not infected (Paruthi and Gupta (1987). Survey conducted at Jabalpur, Ludhiana, Karnal and Chandigarh on *P. minor* revealed that *Trichoderma viride*, a seed dresser fungus for wheat and other crops evaluated as biocontrol agent for *P. minor* (Kauraw *et al.,* 1995). In the laboratory experiment soil application of *Trichoderma viride* grown on saw dust and neem oil cake (base) 200g/sqm, delayed seed germination of *P. minor* by 2-3 days and inhibited seed germination by 50 and 40 per cent, respectively within 15 days of soil treatment, the fungus also reduced root length by 58 and 34 per cent and shoot length by 6 and 20 per cent respectively. There was no adverse effect on wheat seed/seedling. In another experiment seed treatment of *P. minor* with *Gliocladium virens* could inhibit seed germination of *P. minor* by 90 per cent compared to control. Neem seed cake appears to be a substratum for the growth of *T. viride* and *G. virens*. These two fungi seed to have potential for management of *P. minor* in wheat crop.

Allelopathic effect

Plants often release some chemical in their vicinity which inhibit, promote or otherwise modify growth of other plants growing concurrently. The integrated weed management specially through habitat manipulations and exploitation of suppressing effect of crops/crop cultivars through biochemical interaction could play an important role. There are a number of reports on the use of crops residues such a barley, wheat and rye possessing allelopathic potential and having effect on weed seed germination and seedling growth (Kim 1992). Allelopathic effect of rice stubble and straw has also been demonstrated by Tamak *et al.* (1994) against *P. minor* and other weeds. They found that 10 per cent concentration of straw-stubble extract resulted in greater inhibition of seed germination 2 days after sowing (DAS), compared to 6 and 10 DAS. Gill and Sandhu (1994) found that the residue from *P. minor* improved seed germination, root and shoot growth and dry matter production of wheat in pot culture treatment.

Integrated technique

The introduction of semi-dwarf wheat is believed to have generated serious problem of *P. minor* and *Avena fatua* in this crop. To combat the problem of these weeds introduction of herbicidees was considered the only tool. Continuous use of herbicides led to the problem of herbicide resistance in *P. minor* (Malik and Singh 1993). A shift from herbicide use alone for management of *P. minor* to an integrated management approach would be more effective, sustainable and farmer friendly besides being environmentally safe (Bhan and Kumar 1998). Brar and Singh (1997) at PAU Research Station reported that combining genotypes with suitable pattern of sowing (closer and cross) tended to suppress *P. minor* more effectively than normal sowing pattern (22.5 cm row spacing). They further reported that combination of a suitable genotype (WH 542 or HD 2329) with a lower diclofop-methyl dose gave statistically the same yield as obtained from durum wheat coupled with a high dose of diclofop-methyl. Grundy *et al.* (1997) reported that individual species of wheat gave different levels of response to cultivar, sowing density and nitrogen, suggest that integrated approach may be successful for the control of weeds without compromising quality. Bidrectional sowing+integrated weed management and closer unidirectional sowing + integrated weed management resulted in highest grain yield 3.06 and 2.95 t/ha respectively (Pattanaik *et al.*, 1996). Research conducted in USA has shown that for early and middle sowing dates, wheat yield at the 2 x sowing rate without diclofop was equal to or greater than of 1x sowing rate with diclofop (Khan *et al.*, 1996). Mahajan *et al.* (2000) reported that 25th Oct. sown wheat crop

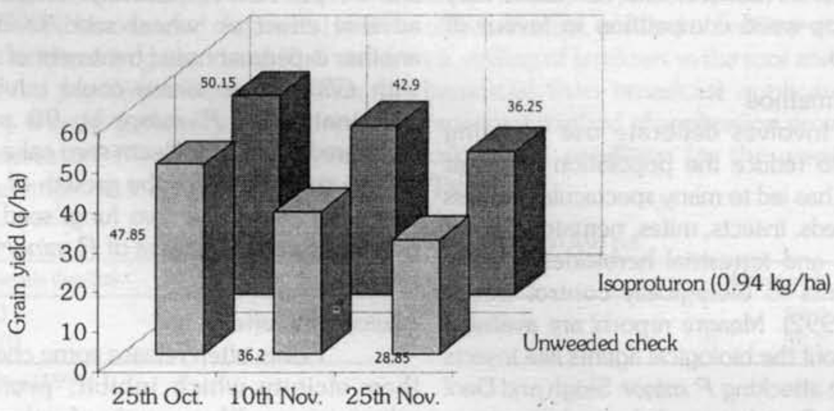

Fig. 2. Interaction effect of date of sowin and herbicides for grain yield of Wheat (Mean of 2 years)

maintained its superiority in suppressing *P. minor* even without the application of isoproturon compared with 10th November sown crop with application of isoproturon 0.94 kg/ha (Fig. 2). These study further envisaged that 25th Oct. sown crop produced more grain yield in closer spacing of 15 cm without isoproturon (0.94 kg/ha) application than normal spacing of 22.5 cm in combination of isoproturon (0.94 kg/ha) application, however, grain yield was statistically same in 10th Nov. sown crop under the same set of treatments. In another situation Singh *et al.* (1995) reported that under 10th sown crop of wheat the population of *A. fatua* reduced significantly with application of isoproturon 0.50 and 0.75 kg/ha over unweeded check, while under 20th Dec. sown crop weed population in unweeded check was same as in 30th Nov. sown crop with application of isoproturon at 0.50 and 0.75 kg/ha respectively. In another study Mahajan *et al.* (2000) reported that 25th Nov. sowing produced almost the same dry matter of *P. minor* as was produced under conventional tillage planting system but in case of crop sown on 15th Nov. 35.7 per cent reduction in dry matter of *P. minor* under zero tillage planting system was observed over conventional tillage planting system (Fig.3). They also observed that in zero tillage system under 15th Nov. sown crop, the sequential application of glyphosate 0.50 kg/ha (pre-sowing) and isoproturon (post-emergence) resulted in 20.8% higher grain yield compared to post emergence application of isoproturon (35 DAS), while in conventional tillage system the grain yield was statistically same under the same set of treatments (Fig. 4).

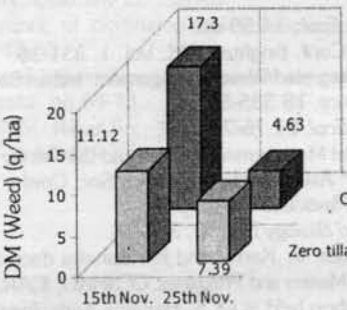

Fig. 3. Interaction effect of Tillage and Date of sowing for dry matter of *P. minor*

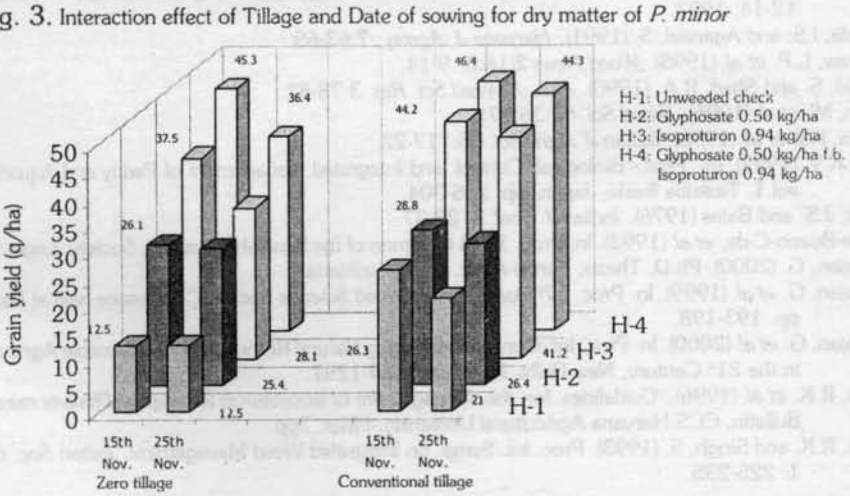

Fig. 4. Showing interaction effect of Tillage, Date of sowing and Herbicides treatment for Grain yield of Wheat.

CONCLUSION

Herbicide resistance in *P. minor* to isoproturon is a major threat to sustain wheat productivity in Northern India. A major compaign is needed to develop integrated weed management practices to curtail this problem and restrict its movement to other non-affected areas. This require an integrated approach between public and private sectors research and extension agencies involving extension participation of farmers. To succcessfully implement an integrated management, extension personnel must be much more than weed scouts. They must be competently trained in agronomy and ecology. Adequate resources and the support of government agencies is needed to ensure that improved weed control options are available and adopted by the farmers.

REFERENCES

Ahuja, K.N. and Yaduraju, N.T. (1989). *Indian J. Agron.*, 34:318-21.

Aldrich, R.J. and Kremer, R.J. (1998). In: Principle in Weed Management (2nd ed.) Panima Publishing Corp./ New Delhi/Bangalore pp 361-84.

Al-Kathiri, C.R. (1985). *Indian J. Pl. Prot.*, 22:5-8

Anonymous (1992-93). Annual Report. Deptt. of Agronomy, PAU, Ludhiana pp 132-33.

Auld, B.A. *et al.* (1987). In: Weed Control Economics; Academic Press, London

Bhan, V.M. (1997). In: Pak-US weed Control Workshop-cum-First Annual Conf., Pak. Soc. Weed Sci. Islamabad pp 76-89.

Bhan, V.M. and Kumar Sushil (1998). In: Proc. Int. Symp. Ecological Agriculture and Sustainable Development, Chandigarh pp 400-415.

Brar, L.S. and Chopra, S.K. (1987). *Indian J. Ecol.*, 14:59-66.

Brar, L.S. and Singh, S. (1997). In: Proc. Int. Conf. Brighten, UK. Vol. 1. 331-36.

Chester, L.F. (1993). In: Proc. Int. Symp. on Integrated Weed Management. Indian Soc. Weed Sci., Hisar vol.1:5-15.

Fischer, R.A. and Miles, (1973). *Math Bioscience.* 18:335-50.

Gill, D.S. and Sandhu, K.S. (1994). *Indian J. Ecol.* 21:75-78.

Gill, H.S. (1992). In : Proc. Int. Workshop Weed Management of Asia and the Pacific Region. Special Supp 7:15-26

Gill, H.S. and Mehra, S.P. (1981). In: Proc. 8th Asian Pacific Weed Sci. Soc. Conf.: 17-22.

Gill, H.S.; Walia, U.S. and Brar, L.S. (1978). *Pesticides* 12(4):83-94.

Grundy, A.C. *et al.* (1997). *Aspects of Applied Biology* No. 50, 367-74.

Harrington, L.W. *et al.* (1992). Wheat and Rice in Karnal and Kurukshetra districts, Haryana, India. Exploratory survey report. Hisar, New Delhi, India, Mexico and Phillipines, CCSHAU, ICAR, CIMMYT and IRRI. pp 40-42.

Hobbs, P. (1997). In: Wheat Workers Workshop held at CCS, Haryana Agricultural University, Hisar, India, Aug. 12-14, 1997.

Hooda, I.S. and Agarwal, S. (1991). *Haryana J. Agron.*, 7:63-69.

Kauraw, L.P. *et al.* (1995). *Weed News* 2(1&2): 9-14.

Khalid, S. and Shad, R.A. (1990). *Pak. J. Weed Sci. Res.* 3:78-82.

Khan, M. *et al.* (1996). *Weed Sci.* 44:362-72.

Khera, K.I. *et al.* (1995). *Indian J. Agri. Sci.* 65:717-22.

Kim, K.V. (1992). In: Proc.- Biological Control and Integrated Management of Paddy and Aquatic Weeds in Asia, vol.1, Tsukuba Ibarki, Japan, pp. 285-304.

Kolar, J.S. and Bains (1976). *Indian J. Ecol.* 3: 28-37.

Lucas-Bueno-C-de. *et al.* (1993). In: Proc. 1993 Congress of the Spanish Weed Sci. Society. Lugo, Spain, 303-306.

Mahajan, G. (2000). Ph.D. Thesis, Punab Agric. Univ. Ludhiana.

Mahajan, G. *et al.* (1999). In: Proc. 17th Asian Pacific Weed Science Society Conference held at Bangkok, Thailand, pp. 193-198.

Mahajan, G. *et al.* (2000). In: Proc. Int. Conf. on Managing Natural Resources for Sustainable Agricultural Production in the 21st Century, New Delhi, India, pp.1289-1291.

Malik, R.K. *et al.* (1996). Guidelines for the Management of Isoproturon Resistance *Phalaris minor* in Wheat. Ext. Bulletin, CCS Haryana Agricultural University, Hisar. 7pp

Malik, R.K. and Singh, S. (1993). Proc. Int. Symp. on Integrated Weed Management. *Indian Soc. of Weed Sci.*, vol. 1: 225-235.

Mehra, S.P. (1996). In: Specialized Trg., Prog. Identifications and Mgmt. of weeds, Insects, Pests and Diseases in Wheat". (Dec. 10-13, 1996).

Mehra, S.P. and Gill, H.S. (1988). *PAU J. Res.*, 25:529-33.

Nalewaja, J.D. and Arnold, W.E. (1970). In: Ist FAO Int. Weed Control Conf. Univ. California, Dans pp 17 (cf Weed Abstr. 1970, 20 (7): 2483.

Paruthi, I.J. and Gupta, D.C. (1987). *HAU J. Res.* 17:78-79.

Pattanaik, A. *et al.* (1996). *Environ. and Ecol.* 14: 631-35.

Paul, S. and Gill, H.S. (1979). *Trop. Ecology* 20: 186-91.

Prasad, R. *et al.* (1999). In: Abst. of 8th Biennial Conf. of Indian Soc. Weed Sci. held at BHU Varanasi pp-26.

Rana, M.C. and Angiras, N.N. (1995). *Indian J. Agric. Sci.* 65:250-55.

Samra, J.S. and Dhillon, I.S. (1993). *Indian J. Weed Sci.* 25:102-103.

Singh, S. and Deol, G.S. (1994). *PAU J. Res.* 31:412-20.

Singh, G. *et al.* (1995). *Ann. Agri. Res.* 15:448-51.

Sinha, K.K. *et al.* (1999). In: Abst. of the 8th Biennial Conf. of *Indian Soc. Weed Sci.* held at B.H.U. Varanasi pp-34.

Ste-Foy, Saskatoon and Yai, B. (1999). In: Abstr. 1999, Meeting Weed Sci. Soc. America vol. 39:23.

Tamak, J.C. *et al.* (1994). *Crop Res.* 8:186-89.

Tiwari, A.N. (1990). Final Technical Report. All India Coordinated Research Programme on Weed Control (Oct. 1985-March 1990) Centre Gujrat, Kanpur, India: Chandra Shekhar Azad Uni. of Agriculture & Technology.

Verma, H.N. and Srivastava, V.C. (1989). *Indian J. Agron.* 34:170-79.

Verschwele, A. *et al.* (1994). Indirect weed control by selection of wheat cultivar. Maitrise des adventices par vote non chemique. Communication de la quartrieme conf. Internationale I.F.D A.M. Dijon, Frans. 5-9 July 1993, 1994, Ed 2, 285-89.

Walia, U.S. (1983). Ph. D. Thesis PAU, Ludhiana.

Walia, U.S. and Gill, H.S. (1985). *Trop. Pest. Mgmt.*, 31: 226-31.

Walia, U.S. *et al.* (1997). *Plant Prot. Quarterly* 12:138-40.

Walia, U.S. *et al.* (1998). Performance of clodinafop and fenoxaprop-p-ethyl for the control of *P. minor* in wheat. *Indian J. Weed Sci.* 31:48-50.

Watson, A.K. (1992). Biological and other alternative control measures. In: Proc. Ist Intl. Weed Control Congress. Vol.1, Melbourne, Australia, pp 64-73.

Wrucke, M.A. and Arnold, We (1985). *Weed Sci.*, 33:853-56.

Yenish, J.P. *et al.* (1992). *Weed Sci.*, 40:429-33.