# Effect of seed rate and row spacing on the efficacy of clodinafop for combating isoproturon resistant *Phalaris minor* Retz. in wheat

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## Summary

**A field investigation to study the effect of seed rate and row spacing on the efficacy of clodinafop for combating isoproturon resistant *Phalaris minor* Retz. in wheat was conducted on a sandy loam soil at Punjab Agricultural University, Ludhiana, India during growing seasons of 1999–00 and 2000–01. The results revealed that the crop sown with 50% higher seed rate (i.e. 150 kg ha$^{-1}$) produced more dry matter which in turn reduced the dry matter accumulation of *P. minor* by 35.4% resulting in increased grain yield of wheat by 12.3% over recommended seed rate. The crop planted at closer spacing of 15 cm reduced the dry matter accumulation of *P. minor* by 32.3% which increased the effective tillers of wheat by 20.8% leading to increase in grain yield of wheat by 10.5% compared to crop planted at 22.5 cm. Post-emergence application of clodinafop at its recommended dose (0.06 kg ha$^{-1}$) gave selective control of resistant *P. minor* and reduced its dry matter accumulation by 79.8% resulting into 128.9% increase in wheat grain yield over recommended dose of isoproturon (0.94 kg ha$^{-1}$).**

**Grain yield of wheat crop sown at 100 kg ha$^{-1}$ with a spacing of 15 cm was at par to the crop sown at 125 kg ha$^{-1}$ with a spacing of 22.5 cm during 2000–01. Further, the crop sown at closer row spacing of 15 cm and sprayed with 0.75 times the recommended dose of clodinafop produced grain yield at par to the crop spaced at 22.5 cm but sprayed with recommended dose of clodinafop (0.06 kg ha$^{-1}$) during 1999–00 indicating the possibility of reducing herbicide dose through closer spacing of wheat.**

**Keywords: Resistance, *Phalaris minor*, isoproturon, clodinafop, wheat, geometry, density and management.**

## Introduction

Wheat plays a major role in Indian as well as global agriculture. *Phalaris minor* Retz. is the dominant grass weed of wheat in the rice-wheat zone of North West India. The extensive use of isoproturon to control this weed has resulted in the development of resistance to this herbicide in *P. minor* (Malik and Singh 1993, Walia *et al.* 1997). Yield losses from *P. minor* alone range from 25 to 50% and, under very severe infestations, may be as high as 80 per cent (Brar and Walia 1993).

Effective control of *P. minor* biotypes, resistant to isoproturon, with post-emergence application of clodinafop (0.06 kg ha$^{-1}$) has been reported by Dhaliwal *et al.* (1998). Agronomic practices such as altering crop geometry and crop density can be effectively integrated with herbicides to allow competition to favour wheat crop. Optimizing crop geometry/density with either herbicide or mechanical weeding led to a marked reduction in weed infestation with an increase in wheat grain yield (Singh 1996). Justice *et al.* (1994) indicated that when wheat was sown in rows 7.5 cm apart, chlorsulfuron at 1.8 kg ha$^{-1}$ controlled *Lolium multiflorum* as efficiently as did 2.6 kg ha$^{-1}$ chlorsulfuron applied in 20 cm row spaced crop. Azad *et al.* (1997) has also indicated the possibility of reducing isoproturon dose from 0.75 to 0.5 kg ha$^{-1}$ by increasing wheat seed rate to 150 kg ha$^{-1}$, nitrogen to 125 kg ha$^{-1}$ and by decreasing row spacing to 15 cm. In this context, the present investigation was planned to study the effect of seeding rate and row spacing on the efficacy of clodinafop for combating isoproturon resistant *Phalaris minor* in wheat.

## Materials and methods

A field investigation was conducted at Punjab Agricultural University, Ludhiana during the growing seasons of 1999–00 and 2000–01 on a sandy loam soil having an organic carbon level of 0.31%, available nitrogen (138.4 kg N ha$^{-1}$), available phosphorous (14.6 kg $P_2O_5$ ha$^{-1}$) available potassium (144.2 kg $K_2O$ ha$^{-1}$) and a pH of 7.9. The treatments consisted six combination of three seeding rates i.e. 100 kg ha$^{-1}$ (recommended), 125 and 150 kg ha$^{-1}$, and two row spacing (15 cm and 22.5 cm) in the main plots, and three weed control treatments viz. isoproturon at 0.94 kg ha$^{-1}$ and clodinafop at 0.060 and 0.045 kg ha$^{-1}$ in sub plots. Wheat variety PBW 343 was sown on November 12, 1999 and November 04, 2000. Recommended fertilizer applications (125 kg N, 62.5 kg $P_2O_5$ and 25 kg $K_2O$ ha$^{-1}$) were made to the crop. One-half of N and all the $P_2O_5$ and $K_2O$ were applied at the time of sowing and the remaining half dose of nitrogen was given with the first irrigation. Herbicides were sprayed 30–35 days after sowing wheat with a knap sack sprayer using 250 L ha$^{-1}$ spray liquid with flat fan nozzle when *P. minor* was in 3–5 leaf stage. Data on weed population and dry matter accumulation was taken at harvest from 50 × 50 cm area and it was subjected to $\sqrt{x+1}$ transformation. The data on wheat grain yield and yield-contributing characters was taken at harvest.

The trial was a split plot design using six combinations of three seed rates × two row spacing in main plots and three weed control treatments in sub-plots with four replications. Statistical analysis was done to calculate Least Significant Difference (LSD) or Critical Difference (CD) at 5% level of significance for seed rates, spacing and weed control treatments separately in order to compare differences due to treatment means. Data was subjected to analysis as detailed by Cheema and Singh (1991) in statistical package CPCS-1.

## Results

### *Effect on Phalaris minor*

The dry matter accumulation by *P. minor* was significantly reduced as seed rate increased from 100 to 150 kg ha$^{-1}$ in both the years (Table 1). On an average, sowing with 150 kg ha$^{-1}$ seed reduced the dry matter accumulation of *P. minor* by 21.7 and 33.6% compared to 125 and 100 kg seed rate ha$^{-1}$ respectively. A sowing rate of 125 kg ha$^{-1}$ resulted in 15.2% reduction in dry matter of *P. minor* compared to 100 kg ha$^{-1}$ seed rate. Closer spacing (15 cm) of wheat resulted in 32.3% reduction in dry matter accumulation by *P. minor* compared to 22.5 cm spacing. Clodinafop 0.06 and 0.045 kg ha$^{-1}$ reduced the dry matter accumulation of *P. minor* by 70.8 and 64.7% in 1999–00 and 96.2 and 78.1% in 2000–01, respectively, compared to isoproturon (0.94 kg ha$^{-1}$).

Interactions revealed that clodinafop applied at 0.045 kg ha$^{-1}$ with a seeding rate of 150 kg ha$^{-1}$ was as effective at reducing dry matter accumulation as clodinafop at 0.060 kg ha$^{-1}$ with 100 kg ha$^{-1}$ seed rate (both at recommended rates) (Table 2) during 2000–01. Isoproturon at 0.94 kg ha$^{-1}$, irrespective of seed rate, recorded significantly higher dry matter accumulation of *P. minor* compared to both levels of clodinafop. At seed rate of 100 and 125 kg ha$^{-1}$, there was significant reduction in dry matter accumulation of *P. minor* when spacing was decreased from 22.5 to 15 cm, however, at seed rate of 150 kg ha$^{-1}$ the effect of spacing were non-significant (Table 2). At 22.5 cm spacing, clodinafop at

0.060 kg ha$^{-1}$ was significantly superior to its lower dose of 0.045 kg ha$^{-1}$, while at 15 cm spacing, both were at par with respect to their effect on weed suppression during both years (Table 3). Interaction effect of seed rate with row spacing as well as herbicides was non-significant during 1999–00 crop season.

*Effect on wheat*

**Yield contributing characters** The number of effective tillers increased significantly with increase in seed rate from 100 to 150 kg ha$^{-1}$ in both the years (Table 4). Averaged over seeding rate and herbicides, the reduction in row spacing increased the number of effective tillers by 15%. Clodinafop at both rates resulted in a significantly higher population of effective tillers. The effective tillers numbers are related to weed suppression (Figure 1). Averaged over both years, an 'r' value of -0.936 indicates the inverse relationship between dry matter of weeds and effective tillers. The test weight (thousand grain weight) remained statistically uninfluenced by seeding rate, row spacing as well as herbicides during both the years except in 2000–01 the crop sprayed with isoproturon recorded significantly lower test weight compared to clodinafop treated crop (Table 4).

**Grain yield** It was observed that yield levels were generally higher during 2000–01 compared to 1999–00 (Table 4). The grain yield of wheat, averaged over row spacing and herbicides, was significantly increased when seed rate was increased from 100 to 150 kg ha$^{-1}$, while the differences in grain yield between 100 and 125 kg ha$^{-1}$, and 125 and 150 kg ha$^{-1}$ seed rate were found to be non-significant (Table 4). The higher seed rate (150 kg ha$^{-1}$) increased grain yield by 15.2 and 10.0% over 100 kg ha$^{-1}$ seed rate during 1999–00 and 2000–01, respectively. The closer spacing increased the grain yield of wheat by 14.0 and 7.8% during 1999–00 and 2000–01, respectively, over the wider spacing. The application of clodinafop at 0.06 and 0.045 kg ha$^{-1}$ recorded significantly higher grain yield of wheat compared to isoproturon 0.94 kg ha$^{-1}$ during both the years with an average increase in grain yield of 128.9% with clodinafop 0.06 kg ha$^{-1}$ and 121.9% at 0.045 kg ha$^{-1}$.

Interactions effect indicated that in plots treated with clodinafop at 0.045 kg ha$^{-1}$, there was significant increase in grain yield of wheat when spacing was decreased from 22.5 to 15 cm, however, at recommended dose of clodinafop (0.060 kg ha$^{-1}$) grain yield was at par at both row spacing (Table 5) in 1999–00. Further, at the closer row spacing grain yield with the application of clodinafop 0.045 kg ha$^{-1}$ was at par to its recommended dose of 0.060 kg ha$^{-1}$ with a row spacing of 22.5 cm. The interaction effect was non-significant during 2000–01. The grain yield of wheat planted in closer rows and raised with 100 kg ha$^{-1}$ seeding rate was at par to that planted in wider rows and raised with 125 kg ha$^{-1}$ seed rate (Table 6). This interaction effect of seed rate and row spacing was non-significant during 1999–00.

**Table 1. Effect of different treatments on panicle number and dry matter accumulation of *Phalaris minor*.**

| Treatments | Effect on *P. minor* | | | |
|---|---|---|---|---|
| | Panicle (no. m$^{-2}$) | | Dry matter accumulation (kg ha$^{-1}$) | |
| | 99–00 | 00–01 | 99–00 | 00–01 |
| Seed rate (kg ha$^{-1}$) | | | | |
| 100 | 11.5 (146)[A] | 7.95 (89) | 38.7 (1510) | 25.5 (720) |
| 125 | 9.22 (102) | 6.26 (69) | 36.3 (1342) | 22.2 (550) |
| 150 | 8.10 (74) | 5.80 (60) | 32.3 (1081) | 19.4 (402) |
| LSD (P=0.05) | 0.3 | 0.36 | 1.7 | 1.2 |
| Row spacing (cm) | | | | |
| 15 | 8.94 (93) | 5.18 (61) | 30.8 (1063) | 19.3 (452) |
| 22.5 | 10.28 (121) | 8.16 (84) | 39.7 (1562) | 25.4 (670) |
| LSD (P=0.05) | 0.24 | 0.29 | 1.4 | 1.1 |
| Herbicides | | | | |
| Isoproturon (0.94 kg ha$^{-1}$) | 14.0 (199) | 13.04 (170) | 49.7 (2381) | 37.7 (1331) |
| Clodinafop (0.060 kg ha$^{-1}$) | 6.0 (36) | 2.34 (14) | 27.6 (702) | 11.7 (51) |
| Clodinafop (0.045 kg ha$^{-1}$) | 8.77 (87) | 4.63 (35) | 29.9 (841) | 17.6 (292) |
| LSD (P=0.05) | 0.38 | 0.32 | 1.7 | 1.2 |

[A] Figures in parentheses are means of original values. Data subjected to $\sqrt{x+1}$ transformation.

**Table 2. Interaction effect of seed rate with herbicides/row spacing on dry matter accumulation (kg ha$^{-1}$) of *Phalaris minor* at harvest during 2000–01.**

| Herbicides | Dry matter accumulation by *P. minor* (kg ha$^{-1}$) | | |
|---|---|---|---|
| | Seed rate (kg ha$^{-1}$) | | |
| | 100 | 125 | 150 |
| Isoproturon (0.94 kg ha$^{-1}$) | 40.7 (1572)[A] | 37.5 (1312) | 34.9 (1121) |
| Clodinafop (0.060 kg ha$^{-1}$) | 15.2 (161) | 1.0 (0) | 1.0 (0) |
| Clodinafop (0.045 kg ha$^{-1}$) | 21.0 (433) | 1.9 (342) | 13.4 (91) |
| LSD (P=0.05) | | 2.1 | |
| Row spacing | | | |
| 15 cm | 20.3 (535) | 19.5 (461) | 18.3 (373) |
| 22.5 cm | 30.6 (924) | 24.9 (653) | 20.6 (442) |
| LSD (P=0.05) | | 2.3 | |

[A] Figures in parentheses are means of original values. Data subjected to $\sqrt{x+1}$ transformation.

## Discussion

Wheat grain yields were higher in 2000–01 compared to 1999–00. The higher density and dry matter accumulation of *P. minor* during 1999–00 adversely affected production of effective tillers by the crop and hence reduced grain yield. Mehra and Gill (1988) reported eight percent reduction in wheat yield with infestation of 50 *P. minor* plants m$^{-2}$ with a reduction of 60% at 250 plants m$^{-2}$. Increased wheat grain yields at higher seeding rate (150 kg ha$^{-1}$) are attributed to thick crop stand and the production of more effective tillers. The effective tiller numbers are negatively correlated with weed dry matter (Figure 1) so increased crop yields at higher seed rate (150 kg ha$^{-1}$) may also be attributed to reduced *P. minor* density. The role of

**Table 3. Interaction effect of row spacing and herbicides on dry matter accumulation (kg ha$^{-1}$) of *Phalaris minor* at harvest during 1999–00 and 2000–01.**

| | Dry matter accumulation by *P. minor* (kg ha$^{-1}$) | | |
|---|---|---|---|
| | Isoproturon (0.94 kg ha$^{-1}$) | Clodinafop (0.060 kg ha$^{-1}$) | Clodinafop (0.045 kg ha$^{-1}$) |
| Row spacing | | 1999–00 | |
| 15 cm | 48.0 (2211)[A] | 23.8 (491) | 23.5 (462) |
| 22.5 cm | 51.4 (2553) | 31.4 (917) | 35.0 (1221) |
| LSD (P=0.05) | | 2.5 | |
| | | 2000–01 | |
| 15 cm | 38.0 (1362) | 1.0 (0) | 1.0 (0) |
| 22.5 cm | 37.4 (1313) | 13.4 (118) | 25.3 (583) |
| LSD (P=0.05) | | 3.5 | |

[A] Figures in parentheses are means of original values. Data subjected to √x+1 transformation.

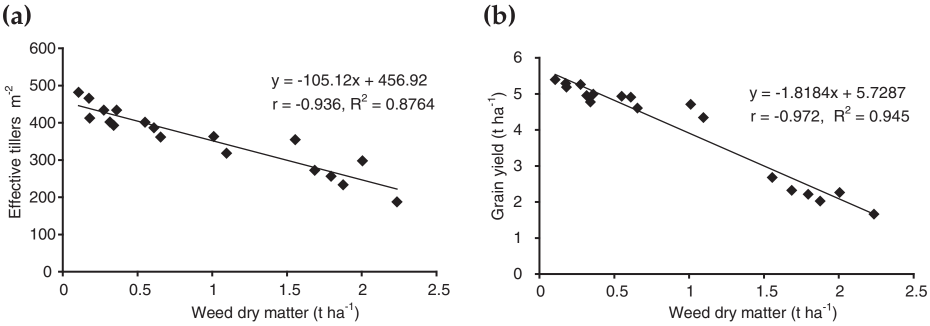


**Figure 1. The relationship between effective tiller numbers (a) and grain yield (b) of wheat with weed dry matter (averaged over two years).**

increasing crop density in reducing competitiveness and seed output by weeds has also been reported by Carlson and Hill (1985).

The crop raised in closer rows (15 cm) had more uniform distribution of crop plants compared to the crop raised in wider rows (22.5 cm). The crowding effect of wheat plants in closer rows suppresses weeds and increased wheat grain yield by 10.8%. Reduced light interception by crop plants at wider row spacing might have become the limiting factor in the production of crop biomass and effective tillers (Singh 1996). Johri *et al.* (1992) observed that the wheat canopy covered the ground more rapidly in closer rows than in wider rows, thus suppressing early weed growth.

Clodinafop at both rates gave selective kill of *P. minor* and increased the wheat grain yield by 145.0% over the standard isoproturon rate of 0.94 kg ha$^{-1}$. The absence of competition in the crop sprayed with clodinafop allowed sufficient light to reach down the lower leaves throughout the crop season (Singh 1996) thereby resulting in production of better photosynthates and hence better plant growth. Averaged over seeding rate and row spacing, clodinafop even at 75% of the recommended dose did not allow the escaped plants of *P. minor* to cause any adverse effect on grain yield of wheat.

The interaction between row spacing and herbicide dose rate in controlling *P. minor* meant that while crop raised in wider rows required recommended dose of clodinafop for adequate *P. minor* control, 75% of its recommended dose was sufficient in crop raised in closer rows.

**Table 4. Effect of different treatments on grain yield and yield attributing characters of wheat.**

| | Effect on wheat | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Treatments | Effective tiller (m $^{-2}$) | | Grain no/spike | | Thousand grain wt (g) | | Grain yield (t ha$^{-1}$) | |
| | 99–00 | 00–01 | 99–00 | 00–01 | 99–00 | 00–01 | 99–00 | 00–01 |
| Seed rate (kg ha$^{-1}$) | | | | | | | | |
| 100 | 308 | 356 | 30.1 | 32.4 | 49.8 | 48.4 | 3.28 | 4.27 |
| 125 | 349 | 370 | 31.2 | 33.3 | 48.2 | 47.7 | 3.50 | 4.64 |
| 150 | 368 | 401 | 31.7 | 35.4 | 49.3 | 47.8 | 3.78 | 4.70 |
| LSD (P=0.05) | 55 | 27 | 1.2 | 2.2 | NS | NS | 0.35 | 0.37 |
| Row spacing (cm) | | | | | | | | |
| 15 | 382 | 403 | 32.8 | 34.2 | 48.9 | 47.8 | 3.75 | 4.7 |
| 22.5 | 302 | 348 | 31.5 | 33.0 | 49.4 | 48.8 | 3.29 | 4.36 |
| LSD (P=0.05) | 52 | 22 | 1.2 | 1.0 | NS | NS | 0.29 | 0.28 |
| Herbicides | | | | | | | | |
| Isoproturon (0.94 kg ha$^{-1}$) | 241 | 294 | 27.5 | 32.6 | 48.5 | 46.3 | 1.51 | 2.88 |
| Clodinafop (0.060 kg ha$^{-1}$) | 419 | 420 | 34.4 | 34.6 | 49.2 | 49.7 | 4.59 | 5.46 |
| Clodinafop (0.045 kg ha$^{-1}$) | 366 | 413 | 34.5 | 33.6 | 49.8 | 48.9 | 4.47 | 5.27 |
| LSD (P=0.05) | 49 | 26 | 3.6 | NS | NS | 2.3 | 0.30 | 0.33 |

**Table 5. Interaction effect of row spacing and herbicides on grain yield (t ha$^{-1}$) of wheat during 1999–2000.**

| Row spacing | Herbicides | | |
|---|---|---|---|
| | Isoproturon (0.94 kg ha$^{-1}$) | Clodinafop (0.060 kg ha$^{-1}$) | Clodinafop (0.045 kg ha$^{-1}$) |
| 15 cm | 1.645 | 4.843 | 4.777 |
| 22.5 cm | 1.381 | 4.337 | 4.164 |
| LSD (P=0.05) | 0.590 | | |

**Table 6. Interaction effect of seed rate and row spacing on grain yield (t ha$^{-1}$) of wheat during 2000–2001.**

| Seed rate (kg ha$^{-1}$) | Row spacing | |
|---|---|---|
| | 15 cm | 22.5 cm |
| 100 | 4.536 | 3.998 |
| 125 | 4.767 | 4.507 |
| 150 | 4.810 | 4.588 |
| LSD (P=0.05) | 0.520 | |

This indicates the possibility of reducing the dose rate of clodinafop with closer plant spacing. Justice *et al.* (1994) indicated that when wheat was sown in rows 7.5 cm apart, chlorsulfuron at 1.8 kg ha$^{-1}$ controlled *Lolium multiflorum* as efficiently as did 2.6 kg ha$^{-1}$ chlorsulfuron applied in 20 cm row spaced crop.

The interaction effect of seeding rate and row spacing on grain yield, averaged over herbicides, indicated that if the crop is planted in closer rows, the recommended seed rate is sufficient to produce optimum crop canopy for controlling the weeds under moderate level of infestation, however, the crop seed rate has to be increased by 25% to have the similar effect on grain yield of wheat if the crop is planted in wider rows. Singh *et al.* (1994) reported that sowing of wheat in closer rows (15 cm) coupled with 125 kg ha$^{-1}$ seed rate resulted in significantly higher wheat grain yield compared to sowing by conventional method (22.5 cm row spacing) combined with 150 kg ha$^{-1}$ seed rate.

The above studies indicated the possibility of reducing the dose of clodinafop by 25% i.e. from 0.06 to 0.045 kg ha$^{-1}$ by reducing row spacing from 22.5 to 15 cm, for combating isoproturon resistant Phalaris minor, without having any adverse effect on grain yield of wheat. This may help in preventing or delaying the onset of herbicide resistance and will also reduce the herbicide load on the soil. But lessons are to be learnt from overseas experience that clearly demonstrate the rapid evolution of resistance to ACCase inhibitors (clodinafop inhibit ACCase) herbicides in weeds. Monitoring protocols needs to be established urgently so that the development of resistance to this alternative herbicide can be detected early, thereby, preventing large financial losses to the local farmers.

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