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Efficiency of mesosulfuron-methyl and clodinafop-propargyl dose for the control of *Lolium perenne* in wheat

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ABSTRACT

Increasing environmental and economic concerns have resulted in considering the potential for the successful use of herbicides at lower doses within an integrated approach to weed management. Therefore, field experiments were carried out to evaluate the efficiency of mesosulfuron-methyl and clodinafop-propargyl dose to control *Lolium perenne* in pure stand and in mixture with wheat. The herbicides at 5 different doses were assigned in a factorial arrangement (subplots) within planting systems (mainplots). *L. perenne* biomass was totally different in pure stand and in mixed planting system, irrespective of the herbicide effect. More than 3-fold decrease was caused in the *L. perenne* biomass by the presence of wheat. Mesosulfuron-methyl was more potent than clodinafop-propargyl in the *L. perenne* control. Mixed planting enhanced the herbicide performance, increasing the relative potency value of mesosulfuron-methyl. The wheat grain yield received no additional benefit from applying mesosulfuron-methyl at the full recommended dose rather than at half dose. This study demonstrates that *L. perenne* suppression involving sub-lethal herbicide dose is associated with the wheat competitiveness. Combining competitive cropping systems with reduced herbicide could be an approach to reducing weed populations over time with lower crop production costs.

1. Introduction

In Iran, herbicides have been the main means of weed control for more than 30 years and today, high-yielding agriculture heavily depends on chemical weed control (Baghestani et al., 2008). Arable lands of Iran have received a total amount of 11.1 thousand herbicides in 2006, over 5.5 thousand being applied in wheat fields (Baghestani et al., 2008). Negative effect of herbicides in the environment and the evolution of grass weed resistant to the herbicides (Gherekhloo et al., 2010) have led to a desire for less herbicide on farms. Not only are full label doses of herbicides expensive leading to unprofitable yields, they can also have harmful effects on the crop (Fykse, 1991; Grundy et al., 1996). Several studies have advocated decreasing recommended herbicide doses in order to maintain or increase yields and profits (Brain et al., 1999; Blackshaw et al., 2006; Kim et al., 2002, 2006a,b,c). Belles et al. (2000) reported that a 50% dose of tralkoxydim consistently gave an 85% *Avena fatua* L. control in barley (*Hordeum vulgare* L.). O'Donovan et al. (2001) similarly documented that tralkoxydim at below-label doses often gave good control of *A. fatua*. Walker et al. (2002) found that clodinafop-propargyl and tralkoxydim efficacy on *Avena* ludoviciana Durieu. and *Phalaris paradoxa* L. remained high at 50–75% of the recommended doses. Zhang et al. (2000) state a few reasons for the potential successful use of reduced herbicide doses including: (a) recommended doses are set to ensure adequate control over a wide spectrum of weed species, weed densities, growth stages, and environmental conditions, and (b) maximum weed control is not always necessary for optimal crop yields. However, studies found that the above-mentioned levels of control obtained by reduced doses were variable over locations and years and the use of reduced herbicide doses was not without economic risk (Kirkland et al., 2000; O'Donovan et al., 2003a,b). The best solution may be the integration of weed management practices such as competitive crops with a reduced herbicide dose that can markedly increase the odds of successful weed control (O'Donovan et al., 2003a). Many researchers believed that competitive cropping is at the heart of weed management programs (Brain et al., 1999; Mohler, 2001; Nazarko et al., 2005; Park et al., 2003) and it is considered as a key to reduce herbicide doses. Some crops are likely to be more amenable than others to the use of reduced herbicide doses (Blackshaw et al., 2006). Kirkland et al. (2000) reported that good crop yields and the highest net returns could be attained with a 50% herbicide dose in barley but that a 100% herbicide dose was

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required to attain the highest yields and net returns in lentil (*Lens culinaris* L.). This result is largely attributed to differences in the competitive abilities of the two crops. Regarding the competitiveness of winter wheat (*Triticum aestivum* L.), it is considered as a potential crop to reduce herbicide dose (Walker et al., 2002). Empirical models have been developed linking winter wheat yields with weed species competitiveness and herbicide doses (Brain et al., 1999; Kim et al., 2002, 2006a; Wagner et al., 2007). For instance, Brain et al.'s (1999) model could predict required dose to improve yield, given an initial estimate of the weed biomass within the wheat rows. In conclusion, in many cases reduced herbicide doses can be substituted for full dose application without significant reduction in crop yield.

Lolium perenne L. (Perennial ryegrass) is a dominant forage species of Europe (Martinez and Guiraud, 1990) and other humid and semi-arid parts of the world (Lucero et al., 1999). It is planted either sole or mixed with clovers (Lucero et al., 1999) and it is superior to any other forage species in agronomic characters, such as high palatability, high forage and seed production (Hill and Michaelson-Yates, 1987; Franca et al., 1998). On the other hand, some of these characteristics have made it an important weed of winter wheat and other small grain crops (Andreasen, 1990).

Mesosulfuron-methyl herbicide (chemical name: methyl 2-[3-(4, 6-dimethoxy-pyrimidin-2-yl)ure-iodosulfonyl]-4-methanesulfonamido-methyl benzoate)is a sulfonylurea indicated to control grass and some broad-leaved weeds in cereals. Clodinafop-propargyl (chemical name: prop-2-ynyl(R)-2-[4-(5-chloro-3-fluoropyridin-2-yloxy)phenoxy]propionate) is a member of the aryloxyphenoxypropionate herbicides with the primary mechanism of action of inhibiting acetyl-CoA carboxylase (ACCase) (Zimdahl, 2007) that is also used for grass control. These two herbicides are among widely applied herbicides for grass weed control in wheat fields of Iran (Deihimfard and Zand, 2006). To our knowledge, no study has evaluated the efficiency of these herbicides for the control of *L. perenne*.

The objectives of this study are to determine (a) the efficiency of mesosulfuron-methyl and clodinafop-propargyl, at a range of doses in the season-long suppression of *L. perenne* in wheat, (b) the possibility of making a recommendation for reduced herbicide dose, and (c) the relationships among herbicide dose, weed suppression and crop yield.

2. Materials and methods

2.1. Study location and field experiments

Two field experiments were carried out at the Research Farm of Islamic Azad University (50°57′E, 35°34′N, altitude 1261 m with a yearly average precipitation of 241 mm), Karadj, Iran during 2006 and 2007 growing seasons. The field had been continuously under wheat cropping over past 15 years and in fallow in the preceding year of the experiments. Soil was a clay-loam with pH of 7.8 and 0.83% organic matter. The seedbed preparation consisted of moldboard plowing and tandem disking followed by land leveler smoothing in the fall. A field cultivator prepared the final seedbed. The necessary fertilizers were broadcast at planting (P_2O_5: triple super phosphate, 50 kg ha^{-1}, and N: urea 46%, 100 kg ha^{-1}) or as topdressing (50 kg N/ha, urea 46%) based on soil chemical analysis. The experimental design was a split plot factorial with four replications. Two planting systems, a single stand *L. perenne* and sown into winter wheat (mixed planting), were the main plots. Two herbicides, mesosulfuron-methyl (WG 6%, 400 g ha^{-1}) and clodinafop-propargyl (EC 8%, 0.8 L ha^{-1}) as factor 1 and a range of herbicide application consisting of 0, 1/8, 1/4, 1/2, and full recommended dose (for mesosulfuron-methyl: 0, 50, 100, 200 and 400 g ha^{-1} respectively, and for clodinafop-propargyl: 0.1, 0.2, 0.4 and 0.8 L ha^{-1}, respectively) as factor 2 were assigned in a factorial arrangement to the subplots measuring 2 m in width and 4 m in length. A hand-weeded wheat plot (weed-free crop) was included as control within each block. Wheat (*Triticum aestivum* L.) cv. Pishtaz at a plant density of 300 plants/m^2 and *L. perenne* at a plant density of 250 plants/m^2 were sown by hand on October 1st for both growing seasons. Ryegrass seed was provided from the Dose Response Working Group of EWRS. Mesosulfuron-methyl and clodinafop-propargyl were mixed with safeners mefenpyr-diethyl and cloquintocet-mexyl, respectively and were sprayed using an electric knapsack sprayer (MATABI) fitted with flooding fan spray nozzle (Goizeper S. Cooperative Company, Guipuzcoa, Spain). It was operated at a pressure of 240 kPa and a volume rate of 200 L h^{-1} at growth stage BBCH 21–29 of *L. perenne* (3–5 tillers) on March 15th and 17th 2006 and 2007, respectively. Other weeds in plots were completely removed by hand. Assessments were conducted in early June. Wheat and *L. perenne* were sampled from the two original 1 m^2 areas at maturity and oven-dried at 75°c for 48 h. Grain yield and biomass were measured for wheat and *L. perenne*.

2.2. Statistical methods

Weed and crop data were subjected to analysis of variance (ANOVA) using GLM procedure of SAS (SAS Institute, inc., SAS Campus Drive, Cary, NC 275132414.). Weed biomass and wheat yield data were subjected to a $\log(x+1)$ transformation where required. Data were back-transformed to initial values for presentation. The relationship between *L. perenne* biomass with herbicide dose, in both the planting systems, was described using the standard dose-response model (Streibig, 1980) as follows:

$$y = C + \frac{D - C}{1 + \left(\frac{x}{\mathrm{ED}_{50}}\right)^{B}} \qquad (1)$$

where y is the response variable, x is the herbicide dose, C and D represent the lower asymptote and the upper asymptote, respectively, ED_{50} is the dose eliciting 50% reduction between the upper and lower limits, and B shows the slope at the ED_{50} dose. Effective dose (ED) for any given percent weed reduction (y) was calculated using Eq. (2):

$$\mathrm{ED}_y = \mathrm{ED}_{50}\left(\frac{y}{100 - y}\right)^{\frac{1}{B}} \qquad (2)$$

where the parameters are as defined in Eq. (1). The relative potency (r) describing the biological exchange rate between two herbicides (Ritz et al., 2006) was used to compare the herbicides efficacy. When Eq. (1) is used to describe weed response to herbicide dose, the relative potency can be calculated as follows:

$$r = \frac{\mathrm{ED}_{50C}}{ED_{50M}}\exp\left[\frac{B_C - B_M}{B_C B_M}\log\left(\left(\frac{D - C}{y - C}\right) - 1\right)\right],\ C < y < D \qquad (3)$$

where model parameters are as explained in Eq. (1) with subscript C and M that denote clodinafop-propargyl and mesosulfuron-methyl, respectively. The two herbicides are equally potent to suppress *L. perenne* when $r = 1$, clodinafop-propargyl is more potent than mesosulfuron-methyl when $r < 1$ and mesosulfuron-methyl is more potent than clodinafop-propargyl when $r > 1$. Brain et al.'s (1999) approach was used to predict wheat yield based on weed biomass response to herbicide dose:

$$y = \frac{y_0}{1 + \mu\left(\frac{w_0}{1 + \left(\frac{\mathrm{dose}}{\mathrm{ED}_{50}}\right)^{B}}\right)} \qquad (4)$$