Crop Protection 29 (2010) 364–368

Contents lists available at ScienceDirect

Crop Protection

journal homepage: www.elsevier.com/locate/cropro

Weed control, environmental impact and profitability with trifluralin plus reduced doses of imazethapyr in dry bean

Nader Soltani [a,*], Robert E. Nurse [b], Laura L. Van Eerd [a], Richard J. Vyn [a], Christy Shropshire [a], Peter H. Sikkema [a]

[a] University of Guelph, Ridgetown Campus, 120 Main Street East, Ridgetown, Ontario, Canada N0P 2C0
[b] Agriculture and Agri-Food Canada, Harrow, Ontario, Canada N0R 1G0

ARTICLE INFO

Article history:
Received 20 May 2009
Received in revised form
21 July 2009
Accepted 22 July 2009

Keywords:
Crop injury
Environmental impact quotient (EIQ)
Imazethapyr
'Montcalm'
'OAC Thunder'
Phaseolus vulgaris L.
Profit margin
Trifluralin

ABSTRACT

Field experiments were conducted in 2003, 2006, and 2007 in Ontario to determine if reduced doses of imazethapyr combined with trifluralin applied pre-plant incorporated (PPI) can be used as an economically and environmentally feasible weed management strategy for broad spectrum weed control in white and kidney bean. There was minimal injury (<5%) in white or kidney bean from imazethapyr applied alone or in combination with trifluralin, regardless of dose. The dose of imazethapyr required for 80 and 95% control of *Setaria viridis* (L.) Beauv. (green foxtail), *Chenopodium album* L. (common lambsquarters) and *Ambrosia artemisiifolia* L. (common ragweed) was reduced when combined with trifluralin (600 g ai ha^{-1}). There was a trend for increased yield of white and kidney bean with increasing doses of imazethapyr applied alone and in combination with trifluralin. Combining trifluralin with imazethapyr increased the environmental impact (EI) by more than ten-fold compared to imazethapyr alone. The lowest dose of imazethapyr used in this study resulted in the lowest environmental risk. The doses of imazethapyr that maximized profit were 38 g ai ha^{-1} for white bean and 47 g ai ha^{-1} for kidney bean. Combining imazethapyr with trifluralin will provide growers with a weed management strategy that provides acceptable weed control, with only a small increase in environmental impact, and has the potential to increase yields and net returns.

1. Introduction

Weed management is a challenge in dry bean production. Weed species that commonly cause problems in Ontario dry bean production include *Chenopodium album* L. (common lambsquarters), *Amaranthus retroflexus* L. (redroot pigweed), *Abutilon theophrasti* Medic (velvetleaf), *Sinapis arvensis* L. (wild mustard), *Ambrosia artemisiifolia* L. (common ragweed), *Solanum* spp. (annual nightshades), and *Setaria* spp. (foxtails) (OMAFRA, 2008).

There are a limited number of herbicides available for broadleaved weed control in dry bean in Ontario. Imazethapyr is the only soil-applied herbicide for broadleaved weed control that is registered for use in dry bean production. However, imazethapyr provides only marginal control of *C. album* and *A. artemisiifolia* and has a narrow margin of crop safety in some market classes of dry bean (Arnold et al., 1993; Blackshaw and Saindon, 1996; Soltani et al., 2004a,b; Wilson and Miller, 1991). Trifluralin combined with reduced doses of imazethapyr has potential to provide broad spectrum weed control in dry bean with a greater margin of crop safety. Trifluralin is a dinitroaniline herbicide that controls several annual grasses including *Setaria*, *Digitaria*, *Echinochloa*, and *Panicum* spp. and some broadleaved weeds such as *C. album* and *A. retroflexus*, including aceto-lactate synthase and triazine-tolerant biotypes (Senseman, 2007; OMAFRA, 2008). Trifluralin persistence in agricultural soils following incorporation is highly variable and is dependent on several factors including soil moisture, incorporation depth and temperature. Studies in northern latitudes in Canada have indicated trifluralin half-lives ranging from 126 to 190 days (Senseman, 2007; OMAFRA, 2008).

Imazethapyr is an imidazolinone herbicide that controls several annual grass and broadleaved weeds including *Setaria* spp, *Echinochloa crus-galli* L. Beauv. (barnyardgrass), *Panicum capillare* L. (witchgrass), *Polygonum convolulus* L. (wild buckwheat), *Polygonum persicaria* L. (ladysthumb), *C. album*, *S. arvensis*, *Solanum* spp. (nightshades), *A. retroflexus*, *A. artemisiifolia* and *A. theophrasti* including triazine-tolerant biotypes (Senseman, 2007; OMAFRA, 2008).

There is little information on the effect of trifluralin plus reduced doses of imazethapyr for weed control in dry bean.

* Corresponding author. Tel.: +1 519 674 1645; fax: +1 519 674 1600.
E-mail address: nsoltani@ridgetownc.uoguelph.ca (N. Soltani).

0261-2194/$ – see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.cropro.2009.07.011

Combining herbicides at lower than recommended doses can provide similar or better control of susceptible weeds than when each herbicide is applied individually.

Many factors are considered when selecting a weed management strategy including crop safety, weed spectrum, crop rotation, and costs. The environmental impact (EI) of herbicides should also be considered when making weed management decisions. By using lower herbicide application doses, the EI of weed control is reduced. One method to assess the EI of a pesticide is with the environmental impact quotient (EIQ) (Kovach et al., 1992, 2004). The EIQ uses toxicity (chronic, dermal, fish, bird, arthropod, and bee), leaching and surface loss potential, and soil and plant half-life to estimate the relative potential risk of pesticide active ingredients. The EIQ has been used to compare environmental risk of different pesticides and/or production systems (Brimner et al., 2005; Soltani et al., 2007; Sikkema et al., 2007). The EIQ was designed to provide growers and other decision makers with a single number that indicates the magnitude of relative risk; a higher EI indicates a greater risk of detrimental impact (Kovach et al., 1992). Identification of herbicides or herbicide combinations that provide consistent effective weed control, have low environmental impact and maximize dry bean yield and net returns would be of benefit to Ontario dry bean producers.

The first objective of this study was to determine if trifluralin combined with a reduced dose of imazathapyr (<75 g ai ha^{-1}) would provide acceptable control of common weeds in Ontario. The second objective was to determine the implications of this weed management strategy on the environmental impact, yield and net returns of white and kidney bean.

2. Materials and methods

Field studies were conducted at the Huron Research Station, Exeter, Ontario (2003, 2006 and 2007) and at the Agriculture and Agri-Food Canada Research Centre, Harrow, Ontario (2007). The soil at Exeter was a Brookston clay loam with 44% sand, 33% silt, 23% clay, 4.3% organic matter and pH of 7.7 in 2003, 34% sand, 36% silt, 30% clay, 3.6% organic matter and pH of 8.0 in 2006, and 39% sand, 37% silt, 24% clay, 4.3% organic matter and pH of 7.9 in 2007. The soil at Harrow was a Fox sandy loam with 83% sand, 5% silt, 12% clay, 2.6% organic matter and pH of 6.0. Seedbed preparation at all sites consisted of autumn moldboard plowing followed by three passes with a field cultivator in the spring. The first cultivation was used to level the seedbed prior to herbicide application. The final two cultivations were in opposite directions to incorporate the herbicides after application.

Plots were arranged in a randomized complete block design with four replications. Each plot consisted of two rows of 'OAC Thunder' white bean and two rows of 'Montcalm' kidney bean spaced 0.75 m apart in rows that were 10 m long and planted at 200,000 and 150,000 seeds ha^{-1}, respectively (Table 1).

Treatments consisted of a non-treated weedy control, a weed-free control, trifluralin PPI at 600 g ai ha^{-1}, imazethapyr PPI at 15, 30, 45, 60 and 75 g ai ha^{-1} individually and in combination with trifluralin PPI at 600 g ai ha^{-1}. Herbicides were applied with a CO_2-pressurized backpack sprayer calibrated to deliver 200 L ha^{-1} aqueous solution at 241 kPa. The boom was 2.5 m wide with six Teejet 8002 flat-fan nozzles tip (Spraying Systems Co., Wheaton, IL) spaced 0.5 m apart. Herbicides were applied 1–2 days before planting and were immediately incorporated into the soil with two lengthwise passes (in opposite directions) of an S-tine cultivator with rolling basket harrows. Weed-free controls were maintained by inter-row cultivation and hand hoeing as required.

Estimate of crop injury was evaluated 1, 2, and 4 weeks after emergence (WAE), on a scale of 0–100% (0% = no visible plant injury and 100% = total plant necrosis). Weed control was rated 4 and 8 WAE on a scale of 0–100% (0% = no control and 100% = complete control). Weed dry matter and weed population density were recorded approximately 8 WAE from a 1 m^2 area within each plot. Plants were removed at the soil surface, separated by species, and dried to a constant weight at 80 °C. Dry bean yield was determined at crop maturity (i.e. 90% golden pods) by hand harvesting the interior row of each cultivar and threshing with a plot combine. Yields were adjusted to 18% moisture.

Data were subjected to analysis of variance using the PROC MIXED procedure of SAS (Statistical Analysis Systems, 1999. Release 8.0. Cary, NC: Statistical Analysis Systems Institute). Variances were partitioned into the random effects of years, blocks within years, and their interactions with fixed effects (herbicide treatments). Significance of random effects was tested using a *Z*-test of the variance estimate and fixed effects were tested using *F*-tests. Error assumptions of the variance analyses (random, homogeneous, normal distribution of error) were confirmed using residual plots and the Shapiro–Wilk normality test. To linearize data, the dose of imazethapyr was Natural log-transformed for percent control ratings. Means were compared on the transformed scale and were converted back to original scale for presentation of results. PROC MIXED contrasts were used to compare percent weed control at 8 WAE and dry bean yield. The Type I error was set at 0.05 for all statistical comparisons.

2.1. Environmental impact

The EIQ values of trifluralin and imazethapyr were obtained from Kovach et al. (1992, 2004). Kovach et al. (1992) consider that all post-emergence applied herbicides have plant surface persistence values of three and all pre-emergence, and pre-plant incorporated herbicides a value of one. The EIQ of imazethapyr was recalculated to account for the pre-plant incorporated application method using the following Eq. (1) (Kovach et al., 1992).

$$EIQ = [C(DT \times 5 + DT \times P) + C((S+P)/2) \times SY + L + F \times R + D((S+P)/2) \times 3 + Z \times P \times 3 + B \times P \times 5]/3$$

B = beneficial arthropod toxicity; C = chronic toxicity; D = bird toxicity; DT = dermal toxicity; F = fish toxicity; L = leaching potential; P = plant surface half-life; R = surface loss potential; S = soil half-life; SY = systemicity; Z = bee toxicity.

The quantity of herbicide applied in kg ai ha^{-1} was multiplied by the EIQ to determine the EI. For combination treatments, EI values for all herbicides were summed.

2.2. Profitability analysis

Profit margins were calculated by subtracting weed control costs from gross margins (Table 2). Gross income for each plot was determined by multiplying the yield by an average price for white or kidney beans. These prices were based on averages of prices reported by Agricorp (URL: www. agricorp.com) 2003, 2006 and 2007. Weed control costs included the cost of herbicide and the cost of application. Herbicide costs were calculated based on prices reported by AGRIS (AGRIS Co-operative Ltd., 835 Park Avenue West, Chatham, ON N7M 5J6, Canada) in 2003, 2006 and 2007, and application costs were based on the average costs over the study period, as reported by OMAFRA (2003–2007). Other operating costs were assumed to be equal among treatments.

Regression analysis was used to assess the effects of varying doses of imazethapyr and of the use of trifluralin on profit margins in white and kidney bean. The quadratic relationship between profit margins and the dose of imazethapyr [based on a curve estimation tool in SPSS Software (Version 12.0. SPSS Inc., 233 S.