

Ginseng Response to Graminicides

V. Souza Machado and A. Ali[§]

Department of Horticultural Science, University of Guelph Ontario, Canada N1G 2W1

(Received April 13, 1989)

Abstract—The graminicides fluzifop-*p*-butyl and sethoxydim effectively controlled annual grass weeds in 1, 2 and year old ginseng crops during a 2 year study. Ginseng plants in the graminicide treated plots showed an early senescence of the shoots; and at harvest the average root weight (g/root) and yield (kg/m²) were slightly lower in these plants than in the untreated check plots. Roots of the graminicide treated plots remained viable to regenerate shoots. The greenhouse study indicated that shoot growth and seed development in ginseng plants were more sensitive to the graminicide treatment than the roots.

Keywords—*Panax quinquefolium* L., ginseng, graminicides, fluzifop butyl, sethoxydim

Introduction

Discovery of the North American ginseng (*Panax quinquefolium* L.), a native herbaceous perennial plant, dates back to the early eighteenth century. Ginseng roots were collected from the wild and sold to China, where these roots were in demand for their herbal and medicinal properties¹. Cultivation of ginseng under artificial shade was initiated in the USA and Canada in the late nineteenth century². Ginseng cultivation in North America is presently increasing as a result of growing world demand.

A crop like ginseng which is grown for 4 to 5 years before being harvested can encounter serious pest problems including weed competition. Except for a limited use of some registered chemicals in the USA, there are no pesticides registered for use on ginseng in Canada³. Weed control traditionally involved hand weeding, a labour intensive and costly operation.⁴ Using cereal straw as a mulch to protect the young seedlings from winter injury, is often a source of heavy infestation of grass weeds especially during the first two years of crop establishment. This report examines the control of grass

weeds and the response of ginseng to the graminicides fluzifop-*p*-butyl and sethoxydim. The two year study involved field trials with 1, 2 and 3 year old ginseng growing at three sites in Southern Ontario, Canada. Also, greenhouse pot trials were conducted to evaluate viability and shoot regeneration response of the ginseng roots that were collected from the graminicide-treated plants.

Materials and Methods

Field trials

A 2 year field study involved ginseng trials on growers' sites. In 1984 three trials were conducted on 3 sites and involved 1, 2 and 3 year old ginseng plants. In 1985 four trials involving 1 year, 2 year (two trials) and 3 year ginseng plants were conducted on 3 sites. The cambered bed plots (3.4m × 1.5m) were sprayed crop postemergence with 2 rates of fluzifop-*p*-butyl(R) butyl 2-[4-(5-trifluoromethyl-2-pyridyloxy)phenoxy]propionate (250 g and 750 g/ha and sethoxydim 2-[1-(ethoxyimino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one (350 g and 800 g/ha) at which time the annual grasses including barley, oats and foxtails were at the 3-5 leaf stage. The adjuvants agral-90 (0.1% v/v) and assist oil (2 L/ha) were mixed with fluzi-

[§]Author for correspondence

fop-*p*-butyl and sethoxydim respectively. Each treatment was replicated 4 times in a simple randomized design. The graminicides were applied (580 L/ha) using a 2-nozzle compressed CO₂ powered (210 kPa pressure) sprayer. Initial grass infestation at treatment was noted and 4 weeks later the treatments were assessed for grass kill as well as injury to the ginseng plant. Grass kill as well as crop injury were rated on a scale of 0 to 100, where 0 = no visible injury and 100 = complete plant kill. Broad leaf weeds were kept at a minimum by handweeding. To assess graminicide effects on root growth, samples of ginseng roots (2 & 3 year ginseng crop-1984) were collected from the treated and untreated plots and fresh weights determined for individual roots. The roots were then dusted with thiram fungicide, mixed with moist vermiculite and stored at low temperature ($5^{\circ} \pm 1^{\circ}\text{C}$), for 4 months, for subsequent regeneration and regrowth study under greenhouse conditions. Root yield (kg/m^2) in the field, of the graminicide treated and untreated plots was also assessed in 3 year old ginseng crop. Fluzifop-*p*-butyl residues in the harvested roots were determined by gas chromatography⁵⁾ in 2 trials involving 2 and 3 year old ginseng plants.

Greenhouse study

Following a 4 month storage at $5^{\circ} \pm 1^{\circ}\text{C}$ the field harvested ginseng roots of the graminicide treated and untreated plots were graded for size uniformity and planted in large plastic pots (6 litre) with vermiculite. The pots were maintained in the greenhouse under shade using black polypropylene screens and monitored for shoot regeneration. The regenerated plants were intermittently watered with a diluted 20:20:20 (NPK) fertilizer solution. Following shoot growth some pots containing plants that were regenerated from roots of the fluzifop-*p*-butyl treated field plots were sprayed with fluzifop-*p*-butyl (250 g/ha). After a 12-14 weeks growth period, root and shoot weights as well as seed development were examined.

Field as well as greenhouse data was analysed using SAS Procedure GLM and the treatment

means separation involved LSD, $P = 0.05$.

Results and Discussion

Field trials

a. Grass kill and ginseng response to graminicides

Fluzifop-*p*-butyl and sethoxydim at both rates of application effectively killed annual grasses and aerial growth of the perennial quackgrass (*Elymus repense*) when present (Table 1). Visual examination of the ginseng plants indicated no shoot phytotoxicity, however, later in the season earlier senescence of the plants in graminicide treated plots was observed, which was not case with the untreated check plots.

Since ginseng is cultivated for its fleshy roots, individual root fresh weights and in one trial root yield (kg/m^2) were determined at harvest. In 1984 3 year old ginseng at harvest, indicated an average of < 10% reduction of the root yield (kg/m^2) in the graminicide treated plots relative to the untreated check plots (Table 2). The root yield (kg/m^2) differences between the graminicide treated plots and the untreated check plots, however were not statistically significant. The average root fresh weights (g/root) in the graminicide treated 3 year ginseng plots indicated slight reductions of 7% (1984) and 13% (1985) as compared to the untreated check plots. The root weight differences between the graminicide treated plots and the check plots were

Table 1. Control of grass weeds in ginseng with fluzifop-*p*-butyl and sethoxydim

Herbicide	Rate (g/ha)	¹ Grass and control(%) (1984)	(1985)
Fluzifop- <i>p</i> -butyl	250	94 ^{ab}	99 ^{ab}
Fluzifop- <i>p</i> -butyl	750	93 ^b	96 ^{ab}
Sethoxydim	350	95 ^{ab}	96 ^{ab}
Sethoxydim	850	92 ^b	100 ^a
Check (handweeded)		100 ^a	93 ^b

¹Values are means of trial sites involving ginseng in its first, second and third year of growth. Means in the same column followed by the same letter.

Table 2. Root yield and root fresh weights of 2 and 3 year ginseng plants which were sprayed with the graminicides fluazifop-*p*-butyl and sethoxydim (field trials)

Herbicide	- Rate (g/ha)	¹ Root yield (kg/m ²)		² Root fresh weight (g/root)		
		3 year ginseng (1984)	3 year ginseng (1984)	(1985)	*2 year ginseng 1985 ¹ 1985 ²	
Fluazifop- <i>p</i> -butyl	250	1.74 ^a	11.1 ^a	11.0 ^b	6.9 ^b	7.8 ^{ab}
Fluazifop- <i>p</i> -butyl	750	1.49 ^{ab}	10.7 ^a	12.0 ^{ab}	7.9 ^a	7.4 ^b
Sethoxydim	350	1.35 ^b	11.0 ^a	11.1 ^{ab}	6.8 ^b	7.4 ^b
Sethoxydim	850	1.50 ^{ab}	9.6 ^a	12.5 ^{ab}	7.8 ^a	8.5 ^a
Check (handweeded)	—	1.65 ^{ab}	11.4 ^a	13.4 ^a	7.9 ^a	7.8 ^{ab}

¹Values are means of 4 replications. Means in the same column followed by the same letter are significantly different (LSD, P = 0.05).

²Values are means of 4 replications and each replication consisted of 25 roots. Means in the same column followed by same letter are not significantly different (LSD, P = 0.05).

*The 1985 data presented is for 2 sites and is indicated by the numbers 1 and 2 as superscript to the year of trial.

statistically not significant, except for a decline observed in the plots treated with 250 g/ha fluazifop-*p*-butyl in 1985 trial (Table 2). In the 1985 trials, the average root fresh weights of the 2 year ginseng, except for a slight decline observed at site 1, showed no significant differences between the graminicide treated plots and the untreated check plots (Table 2). Since the root fresh weight reductions were observed in plots treated with the graminicides at lower rate of application as compared to the higher rates, seem anomalous and could possibly be due to factors other than the graminicides *e.g.* competition effects of broadleaf escapes, or between the ginseng plants depending on the plant density.

b. fluazifop-*p*-butyl residue in roots

Residue analysis of the 2 and 3 year ginseng roots harvested from the fluazifop-*p*-butyl treated plots indicated traces of the graminicide amounting to < 0.02 ppm (data not presented). Although fluazifop-*p*-butyl is presently not registered for ginseng, the trace amounts in the roots were considerably lower than 0.1 ppm or the "negligible" level established by Health and Welfare, Canada. These trace levels may explain the early senescence noted in the graminicide treated plots as compared to the untreated check plots.

Although a single application of fluazifop-*p*-butyl appears to leave trace residues in roots, and further studies are needed to examine the metabolic fate

and effects of repeated use of graminicides on residue accumulation in the roots at the time of harvest, 4 to 5 years after planting of the crop.

Greenhouse trial: shoot regeneration from roots

Shoot regeneration responses of the 2 and 3 year ginseng roots harvested from the graminicide treated field plots were similar to the roots harvested from the untreated check plots (Fig. 1), indicating that the ginseng root-viability to regenerate shoots remained unaffected by the graminicide treatments. The average root fresh and dry weights of the graminicide treated 2 and 3 year ginseng plants were slightly lower as compared to the untreated check plants, however the differences were not significant (Table 3).

Compared to the untreated plants the graminicides treated ginseng plants indicated significant reductions of the shoot fresh and dry weights especially in the 2 year ginseng plants which were repeat-treated with fluazifop-*p*-butyl (250 g/ha) in the greenhouse. Although the shoot weight differences between the graminicide treated 3 year ginseng and the untreated plants were not significant, the plants which were twice treated with fluazifop-*p*-butyl *i.e.* in the field as well as in the greenhouse, had lowest shoot fresh and dry weights (Table 3). Similarly an examination of the inflorescence and seed development in the 2 year ginseng plants revealed that the

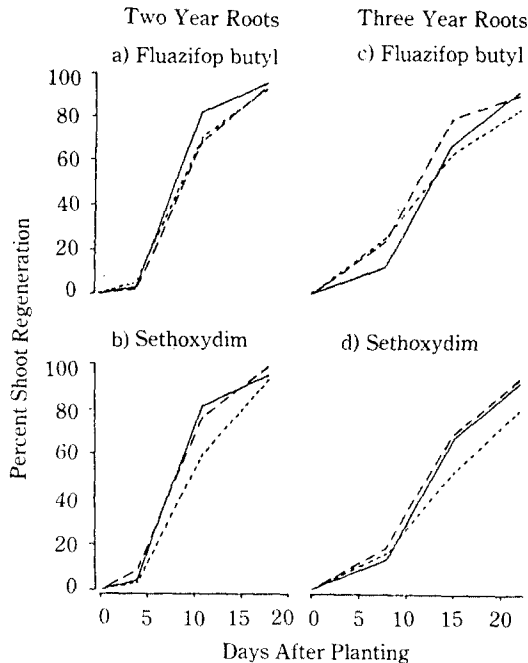


Fig. 1. Shoot emergence in two year (a,b) and three year (c,d) ginseng roots (Greenhouse trial-1985). Ginseng plants in the field were sprayed with fluzifop butyl and sethoxydim at 250, and 350 g/ha (low rates), and 750 and 800 g/ha (high rates) respectively. Herbicide treatments are indicated as follows: low rate (-----), high rate (- · -) and untreated check (—). Each treatment involved a minimum of 20 roots.

total number of seeds as well as weight were significantly lower in the graminicide treated plants. Moreover these reductions were more pronounced in these plants which were twice exposed *i.e.* in field as well as in the greenhouse, to the graminicide fluzifop-*p*-butyl. In 3 year ginseng plants though the differences were not significant between the untreated and graminicide treated plants, the total weight and number of seeds were lowest in the plants which were treated with fluzifop-*p*-butyl in the field as well as in the greenhouse (Table 3). These results indicate that in ginseng plants, the shoot growth and seed development processes are more sensitive indicators to the graminicide fluzifop-*p*-butyl than the roots. In an observational greenhouse pot trial (1985) with 1 year old ginseng plants which were sprayed at emergence, when the plants were in a partial to emerged hypocotyl stage, with fluzifop-*p*-butyl at 250 g and 750 g/ha, revealed no phytotoxic response to the graminicide. Plant mortality, shoot height and visual rating of senescence, showed no significant differences between the untreated control and plants that were treated with the graminicide (data not presented), indicating no phytotoxicity when fluzifop-*p*-butyl is applied at this stage of ginseng plant development.

Results in this study indicate that depending on

Table 3. Root weights, shoot weights and seed formation in ginseng plants (greenhouse trial). The plants were regenerated of the roots harvested from field plots which were treated with fluzifop-*p*-butyl or sethoxydim at low rates (+) of 250 and 350 g/ha respectively; or high rates (+ +) of 750 and 850 g/ha respectively. The check plots involved no graminicide (-) treatments. Values are means of 6 replications and each replication consisted of 4 roots.

Herbicide	Applied		2 year ginseng						3 year ginseng					
			Root (g)		Shoot (g)		Seeds		Root		Shoot (g)		Seeds	
			Field	G-house	FW	DW	FW	DW	FW	#	FW	DW	FW	DW
Fluzifop- <i>p</i> -butyl	+	+	8.3 ^a	2.4 ^a	2.4 ^{bc}	0.80 ^{ab}	1.6 ^b	88 ^{abc}	15.7 ^a	4.0 ^a	4.0 ^a	1.0 ^{ab}	4.3 ^{ab}	97 ^{ab}
Fluzifop- <i>p</i> -butyl	+	+	7.2 ^a	2.3 ^a	1.7 ^c	0.46 ^c	1.1 ^b	66 ^c	11.2 ^a	3.4 ^a	2.3 ^b	0.5 ^c	1.4 ^c	47 ^{cd}
Fluzifop- <i>p</i> -butyl	+	+	7.2 ^a	2.2 ^a	2.7 ^{ab}	0.74 ^{ab}	1.4 ^b	88 ^{bc}	12.8 ^a	3.6 ^a	2.8 ^{ab}	0.7 ^{abc}	2.5 ^{bc}	90 ^{abc}
Fluzifop- <i>p</i> -butyl	+	+	7.6 ^a	2.5 ^a	2.4 ^{bc}	0.62 ^{abc}	1.0 ^b	75 ^c	13.5 ^a	4.0 ^a	2.6 ^{ab}	0.6 ^{bc}	2.0 ^{bc}	68 ^{bc}
Sethoxydim	+	-	7.0 ^a	2.1 ^a	2.6 ^{ab}	0.65 ^{bc}	1.3 ^b	83 ^c	15.7 ^a	4.0 ^a	4.1 ^a	1.0 ^a	5.0 ^a	126 ^a
Sethoxydim	+	-	7.5 ^a	2.2 ^a	3.4 ^a	0.77 ^{ab}	2.0 ^{ab}	126 ^{ab}	13.6 ^a	3.6 ^a	3.6 ^{ab}	0.9 ^{abc}	3.3 ^{abc}	114 ^a
Check (weeded)	-	-	8.5 ^a	2.5 ^a	3.4 ^a	0.82 ^a	2.7 ^a	130 ^a	14.6 ^a	3.9 ^a	3.3 ^{ab}	0.9 ^{abc}	3.1 ^{abc}	79 ^{ab}

Means in the same column followed by same letter are not significantly difference (LSD, P = 0.05).

(FW = fresh weight, DW = dry weight, and # = number).

the developmental stage, ginseng plants exposed to the graminicides, especially fluazifop-*p*-butyl, exhibit some sensitivity which could affect shoot growth and seed development. Compared to a relatively advanced stage of ginseng shoot development, fluazifop-*p*-butyl treatment of the young emerging shoots indicated no phytotoxicity, which may be related to a reduced interception and uptake of the graminicides due to a minimal shoot area.

Ginseng root seem to be less sensitive indicator to graminicides than the shoots, because of known translocation patterns⁶⁾ and a trend indicating a slight decline in average root weights of the graminicide treated plants, could be a result of effects on the shoot.

In light of these results it is proposed that although the graminicides fluazifop-*p*-butyl and sethoxydim are primarily grass killers, their effects on ginseng shoot growth and seed development could not be entirely ruled out. Provided the minimal effects of these graminicides are acceptable for economic production of ginseng roots, care must be exercised in their repeated use especially when optimal seed production is desired.

Acknowledgements

The authors gratefully acknowledge the co-operation extended by W. Hellyer, G. Nelson, D. Curry and N. Schira for providing the experimental sites on their ginseng gardens, and J.T.A. Proctor for his encouragement during the course of this study. Assistance of the O.M.A.F. Pesticide Residue Laboratory for residue analysis is acknowledged and the Ontario Ministry of Agriculture and Food for their support.

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