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Evaluation of Herbicides for Management of Weeds in Cultivation of *Panax quinquefolius* L.

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Abstract : Nine herbicide products (fluazifop-p-butyl, clethodim, MCPA-sodium, 2,4-D amine, chlorthal dimethyl, diquat, glyphosate, ethalfluralin and oryzalin) were evaluated for use on ginseng (*Panax quinquefolius*). Products varied in their ability to suppress weeds and certain materials were phytotoxic to ginseng in some trials. Chlorthal dimethyl (broadleaf weeds), MCPA-sodium (broadleaf weeds), fluazifop-p-butyl (grass weeds), and clethodim (grass weeds) were found to be effective as weed control agents and did not adversely affect ginseng growth. Other products tested were either not efficacious or were phytotoxic to ginseng in some trials. Weed populations were mainly introduced into the planting sites via the straw mulches used in ginseng cultivation.

Key words : American ginseng, North American ginseng, cultivation, yield.

Introduction

Limited information is available with respect to the use of herbicides for weed management in the cultivation of *Panax* species.[1] Recent expansion of acreage planted to *P. quinquefolius* L. in North America has increased the demand for herbicide products as a means of reducing labor costs. The objective of the work reported here was to evaluate the following herbicide products for weed control in ginseng: chlorthal dimethyl (Dacthal; ISK-Biotech, London, ON, Canada), oryzalin (Surflan: Dow AgroSciences, Calgary, AB, Canada), ethalfluralin (Edge; Dow AgroSciences, Calgary, AB, Canada), MCPA-sodium (2-methyl-4-chlorophenoxyacetic acid), 2,4-D amine, fluazifop-p-butyl (Fusilade II; Zeneca, Grimsby, ON, Canada), clethodim (Select; Rhône-Poulenc, Guelph, ON, Canada), diquat (Reglone; Zeneca, Grimsby, ON, Canada), and glyphosate (Roundup; Monsanto, Mississauga, ON, Canada). Response of ginseng to these products was also recorded.

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Materials and Methods

Research plots were established at the Delhi research farm (Delhi, ON, Canada) of the Southern Crop Protection and Food Research Centre (Agriculture and Agri-Food Canada). Sites were located on a Fox loamy sand (brunisolic grey-brown luvisol; 85% sand, 1% organic matter, pH 6.2). Following standard practice,[2] the site was fumigated by soil injection with 340 L/ha of Vorlex Plus CP (AgrEvo Canada, Regina, SK; contains 17% methyl isothiocyanate, 15% chloropicrin, and 34% 1,3-dichloropropene and related compounds) in the September prior to seeding. Fertilizer was incorporated at rates determined from standard soil tests. Raised beds were planted with stratified seed in late October or early November of 1987~1991 at rates ranging from 84 to 101 kg/ha, based on expected germination and seed size. For each garden, a commercial 12 row seeder was calibrated to provide a row spacing of 10 cm with approximately 2.5 cm seed spacing within the row. To obtain a more uniform, yet species-diverse weed population, weed seed screenings from a local commercial seed cleaning facility were spread over each plot after seeding in some trials.

A 5 cm deep mulch layer of cereal straw was applied upon completion of planting and weed seed application. The mulch layer was replenished with a thin layer of straw at the end of the second year of growth after the ginseng had senesced in each trial. For each garden, a wood lathe shade structure, approximately 2 metres high and designed for an 85% reduction in light penetration, was installed in the spring following planting.

A randomized complete block design with four replications of each treatment was used in all experiments. Plot size was 1.88 m by 1.68 m.; the greater dimension being the bed width. All herbicide treatments were applied with a backpack sprayer (Model T4, R & D Sprayers Inc., Opelousas, LA, U.S.A.), calibrated to deliver a volume of 450 L/ha at 276 kPa using a 9506E flat fan, evenflow nozzle, in the first and second growing seasons only. Both weed pre- and post-emergent products were evaluated. In different experiments, herbicides were applied before and/or after ginseng emergence in April (Ap), May (My), June (Jn), July (Jy), August (Au) or October (Oc). The herbicide products applied in each experiment were as follows:

Exp. 43-1: chlorthal dimethyl, clethodim, fluazifop-p-butyl; Exp. 43-2: 2,4-D amine; Exp. 43-3: MCPA-sodium (4-chloro-o-tolyoxyacetic acid); Exp. 43-10: oryzalin, ethalfluralin; and Exp. 43-10A: diquat, glyphosate, 2,4-D amine. The product rates and dates of application are listed for each experiment in Table 1 (Exp. 43-1), 6 (Exp 43-2), 11 (Exp. 43-3), 16 (Exp. 43-10), and 21 (Exp. 43-10A), respectively. Certain herbicide products (clethodim, fluazifop-p-butyl, diquat, and glyphosate) were applied in combination with surfactants. The surfactant application rate (see Tables 1, 16, and 21) is expressed as a percentage (v/v) of the water application volume (450 *l*/ha).

Timely applications of fungicides (iprodione, chlorothalonil, mancozeb, metalaxyl) were made throughout each growing season to manage several common fungal diseases of ginseng. No insecticides were used on the crop.

Weed growth measurements for each plot were obtained by recording the accumulated fresh weight of grass and/or broadleaf weeds harvested over each grow-

Table 1. Exp 43-1: Pre and post-crop-emergence herbicide application treatments

Treatments [z]	Rate kg ai/ha	Application date Trial 1 * 1989/90	Trial 2 * 1990/91	Trial 3 * 1991/92
1. chlorthal dimethyl-1st appl.	9	Ap 26/Ap 25	Ap 25/Ap 16	Ap 16/Ap 14
chlorthal dimethyl-2nd appl.	9	Jn 16/Jn 8	Jn 8/Jn 5	Jn 5/Jn 10
chlorthal dimethyl-3rd appl.	9	Au 21/Au 24	Au 24/Au 30	Au 3/Au 4
2. chlorthal dimethyl-1st appl.	9	Ap 26/Ap 25	Ap 25/Ap 16	Ap 16/Ap 14
chlorthal dimethyl-2nd appl.	4.5	Jn 16/Jn 8	Jn 8/Jn 5	Jn 5/Jn 10
3. clethodim+16255[†]-1st appl.	0.24+0.5%[†]	My 31/My 8	My 18/My 21	My 21/My 6
clethodim+16255-2nd appl.	0.24+0.5%	Au 21/– **	Jy 3/Jy 31	Jy 19/Au 4
4. fluazifop-p-butyl+S.O.C.[#]-1st appl.	0.25+1%[#]	My 31/My 8	My 18/My 21	My 21/My 6
fluazifop-p-butyl+S.O.C.-2nd appl.	0.25+1%	Au 21/–	Jy 3/Jy 31	Jy 19/Au 4
5. check, weed-free[‡]	–**	–	–	–
6. check, weedy[α]	–	–	–	–

[z] products were applied at the dates indicated during the seedling year and second year of plant growth. For a given treatment, either 2 or 3 applications were made per year. Ginseng normally emerges through the mulch layer during May and June. Trials were seeded with ginseng in October 1988, 1989, and 1990, for trials 1, 2, and 3, respectively.

[†] 16255-the surfactant Amigo (Chevron Chemical, Burlington, ON, Canada) was applied at 0.5% (v/v) of the water application volume (450 *l*/ha).

[#] S.O.C.-the surfactant Superior Oil Concentrate (Zeneca, Grimsby, ON, Canada) was applied at 1% (v/v) of the water application volume (450 *l*/ha).

[‡] weed-free checks were hand-weeded as required during the growing season.

[α] weedy check plots were weeded once per year, at the end of the growing season.

* mulches used were wheat, oat, and barley straws in trials 1, 2, and 3, respectively.

** '–' indicates that no product was applied.

Table 2. Exp 43-1: Total broadleaf and grass weed means (g/plot) over four years in three trials

Treatments[a]	Broadleaf weeds (g/plot)[y]			Grass weeds (g/plot)[y]		
	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
1. chlorthal dimethyl (3x)	120.5b	115.8b	925.0b	116.6a	164.7b	80.3b
2. chlorthal dimethyl (2x)	136.4b	93.8b	902.3b	83.0a	89.6b	71.3b
3. clethodim + 16255† (2x)	ND	ND	ND	1.2b	16.4b	25.0b
4. fluazifop-p-butyl+S.O.C.# (2x)	ND	ND	ND	3.2b	8.6b	2.8b
5. check, weed-free‡	0.0b	0.0b	0.0b	0.0b	0.0b	0.0b
6. check, weedy[α]	3424.7a	7448.3a	13015.8a	13.5b	805.1a	972.3a
$P_{0.05}$	*	*	*	*	*	*
$P_{0.01}$	**	**	**	**	**	n.s.

[x] refer to Table 1 for treatment details.

[y] fresh weight. Values are totals of weed fresh weights (g) collected at the end of each growing season for four consecutive years. Means within a column followed by the same letter are not significant different according to Duncan = s multiple range test at the P level indicated (P>0.05 or P>0.01).

† 16255-the adjuvant Amigo (Chevron Chemical, Burlington, ON, Canada).

S.O.C.-Superior Oil Concentrate (Zeneca, Grimsby, ON, Canada).

‡ I weed-free checks were hand-weeded as required during the growing season.

[α] check plots were weeded once per year, at the end of the growing season.

ND-data not recorded (not a broadleaf control product)

Table 3. Exp 43-1: Ginseng root weight means (g/root) for three trials

Treatments [x]	Trial 1					Trial 2					Trial 3				
	Year of growth					Year of growth					Year				
	1[&]	2[&]	3[&]	4[&]	4C[4]	1[&]	2[&]	3[&]	4[&]	4C[4]	1[&]	2[&]	3[&]	4[&]	4C[∞]
1. chlorthal dimethyl (3x)	0.26a	1.41	2.33	3.50	4.29	0.16a	0.73	2.87a	5.33a	4.14a	0.20a	1.83	3.15a	2.81	4.35a
2. chlorthal dimethyl (2x)	0.24a	1.41	1.72	3.63	4.18	0.14ab	1.00	2.91a	5.54a	4.27a	0.24a	1.59	3.42a	3.92	4.01a
3. clethodim+16255†(2x)	0.26a	1.45	1.54	3.72	4.17	0.13ab	0.93	3.22a	5.18a	3.99a	0.25a	1.68	3.88a	3.21	3.38ab
4. fluazifop-p-butyl+ S.O.C. # 2x)	0.26a	1.44	2.19	4.57	3.75	0.14ab	0.85	3.20a	4.02a	4.03a	0.24a	1.65	3.22a	5.18	3.77a
5. check, weed-free‡	0.27a	1.38	1.82	4.02	4.10	0.14ab	0.88	3.12a	4.83a	4.26a	0.24a	1.8	3.30a	2.97	3.57a
6. check, weedy [α]	0.13b	1.2	1.86	4.25	4.31	0.11b	0.73	2.08b	3.87b	2.63b	0.11b	1.15	1.30b	2.40	2.34b
$P_{0.05}$	*	n.s.	n.s.	n.s.	n.s.	*	n.s.	*	*	*	*	n.s.	*	n.s.	*
$P_{0.01}$	**	n.s.	n.s.	n.s.	n.s.	**	n.s.	n.s.	n.s.	**	**	n.s.	**	n.s.	n.s.

[x] refer to Table 1 for treatment details.

[∞] commercial dry root weight at the final root harvest.

[&] values in each column for years 1-4 are freeze-dried weights (g/root) for each year of growth. Means within a column followed by the same letter are not significant different according to Duncan = s multiple range test at the P level indicated.

† 16255-the adjuvant Amigo (Chevron Chemical, Burlington, ON, Canada).

S.O.C.-Superior Oil Concentrate (Zeneca, Grimsby, ON, Canada).

‡ weed-free checks were hand-weeded as required during the growing season.

[α] weedy check plots were weeded once per year, at the end of the growing season.

ing season. The weed-free check was kept free of all weeds during the growing season by hand weeding as needed. Where required, the graminicide treatment plots (Exp 43-1) were kept free of all broadleaf weeds, broadleaf treatment plots (Exp 43-2, 43-3) were kept free of grass weeds, and plots for the pre-emergent weed control treatments (Exp 43-1, 43-10) were hand weeded of all weeds immediately prior to each herbicide application. "Weedy check" plots were weeded once at the end of each growing season.

At the end of each of the four growing seasons, ginseng roots were harvested in a 15 cm wide strip across the north end of the each plot. Roots were washed, cut, freeze-dried and weighed. In most trials all remaining roots were dug after the final year (fourth year) of growth, counted, washed and kiln-dried then weighed.

Table 4. Exp 43-1: Ginseng plant and root density means (number/m^2) for three trials

Treatments[x]	Trial 1					Trial 2					Trial 3				
	Year of growth					Year of growth					Year of growth				
	1[&]	2[&]	3[&]	4[&]	4C[∞]	1[&]	2[&]	3[&]	4[&]	4C[∞]	1[&]	2[&]	3[&]	4[&]	4C[∞]
1. chlorthal dimethyl(3x)	135	106	82	55	83	76	102	119	40a	92	70a	145	71a	n/a[z]	36
2. chlorthal dimethyl(2x)	153	101	104	62	104	70	98	104	37a	73	64ab	128	56a	n/a	39
3. clethodim+16255[†](2x)	149	105	91	50	85	68	94	99	37a	77	61ab	139	65a	n/a	45
4. fluazifop-p-butyl+ S.O.C.[#] (2x)	139	108	94	68	115	78	95	110	42a	78	61ab	134	68a	n/a	39
5. check, weed-free[‡]	148	103	92	57	110	90	100	102	39a	72	53b	132	65 a	n/a	34
6. check, weedy[α]	163	116	102	58	109	73	59	79	14b	47	31b	115	36 b	n/a	30
$P_{0.05}$	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s.	*	n.s.	*	n/a	n.s.
$P_{0.01}$	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	**	n.s.	**	n.s.	**	n/a	n.s.

[x] refer to Table 1 for treatment details.
[&] number of ginseng stems per m^2. Means within a column followed by the same letter are not significantly different where % = 0.05, according to Duncan's multiple range test at the P level indicated.
[∞] number of roots at final harvest.
[†] 16255-the adjuvant Amigo (Chevron Chemical, Burlington, ON, Canada).
[#] S.O.C.-Superior Oil Concentrate (Zeneca, Grimsby, ON, Canada).
[‡] weed-free checks were hand-weeded as required during the growing season.
[α] check plots were weeded once per year, at the end of the growing season.
[z] n/a=data not available.

Table 5. Exp 43-1: Ginseng seed weight (g/plot) in years three and four for three trials

Treatments[x]	Trial 1 [&]		Trial 2 [&]		Trial 3 [&]	
	Year of growth		Year of growth		Year of growth	
	3	4	3	4	3	4
1. chlorthal dimethyl (3x)	128.1	155.0	94.5a	111.7	192.7a	19.8
2. chlorthal dimethyl (2x)	120.4	193.1	89.9a	120.1	150.1a	19.3
3. clethodim+16255[†] (2x)	131.0	184.2	80.0a	111.7	171.7a	24.4
4. fluazifop-p-butyl + S.O.C.[#] (2x)	117.5	198.3	95.0a	123.9	171.6a	17.7
5. check, weed-free[‡]	141.0	183.9	75.8a	134.8	174.1a	11.9
6. check, weedy[α]	127.5	215.2	22.4b	60.1	38.5b	10.2
$P_{0.05}$	n.s.	n.s.	*	n.s.	*	n.s.
$P_{0.01}$	n.s.	n.s.	n.s.	n.s.	**	n.s.

[x] refer to Table 1 for treatment details.
[&] fresh weight of seeds per plot. Means within a column followed by the same letter are not significantly different at the P level indicated, according to Duncan's multiple range test.
[†] 16255-the adjuvant Amigo (Chevron Chemical, Burlington, ON, Canada).
[#] S.O.C.-Superior Oil Concentrate (Zeneca, Grimsby, ON, Canada).
[‡] weed-free checks were hand-weeded as required during the growing season.
[α] weedy check plots were weeded once per year, at the end of the growing season.

This value was designated as the commercial dry root weight. Plant density values were determined by counting all visible ginseng plants in the entire plot and were adjusted to a number per m^2 planted area basis. Plant density values for the final year represent all the ginseng roots harvested on number per m^2 planted area basis.

Seeds were harvested in the 3rd and 4th year of each trial by hand picking all ripe berries in each plot, depulping, then recording the fresh weight of surface-dried seed. The values for the 4th year harvest were adjusted upwards to be comparable to the 3rd year on a g/plot basis. Data were analysed using Proc GLM of the Statistical Analysis System (v 6.11; SAS Institute Inc, Cary NC) and Duncan = s multiple range test. Each exper-

iment was repeated at least twice; the repeats are referred to as trials. Experiments were carried out between 1988 and 1995, with subsequent data analysis.

Results

1. Experiment 43-1: clethodim, fluazifop-p-butyl, chlorthal dimethyl

Extremely low grass weed densities occurred in the first trial of this experiment (Table 1) despite the addition of weed seeds, as indicated by the low value for grasses harvested in the weedy check plots (Table 2). At the higher grass weed populations in trials 2 and 3, all herbicide treatments tested in this trial were superior to the weedy checks. Clethodim and fluazifop-p-butyl tended to reduce grass populations more effectively than chlorthal dimethyl. Chlorthal dimethyl, in either three or two split applications in each of the first two years of growth, was very effective in broadleaf weed control in all three trials.

Dry root weight, plant density and seed yield of ginseng were not significantly reduced by herbicide treatment when compared to the weed-free check (Tables 3~5). Generally, where weed populations were high, weedy checks had reduced plant stands, root weights and seed weights, when compared to other treatments. Root number per m^2 at harvest, however, was not affected (Table 4), indicating that mean root size was reduced at high weed pressures. During the eight years these trials were conducted no visible ginseng phytotoxicity due to the herbicide applications was observed.

2. Experiment 43-2: 2,4-D amine

In both trials (Table 6), 2,4-D amine was phytotoxic to ginseng. Levels of weed control achieved were not significant when compared to the weedy checks, however, weed populations may have been too low to demonstrate weed suppression (Table 7). The first herbicide applications (June) caused 80%~90% of the ginseng plants in the 2.24 kg ae/ha plots and approximately 30% of the plants in the 0.28 kg ae/ha plots to bend just below the plant apex to the extent that the apex was pointing towards the ground. The July application (Table 6) of the high rate caused 5% of plants to bend in this way. The August application of the high rate and the July and August applications of the low rate did not result in this response. These effects were not permanent and the ginseng stems reverted to erect growth within a few weeks. In the second year of growth in trial 2, this effect was greatly reduced for the early season/high rate application in both the number of ginseng plants involved and the degree of deformation. The late season and lower rate applications were also proportionately lower in this respect. Leaf edge and tip browning occurred following herbicide application in the second year of growth. The

Table 6. Expt 43-2: Post-crop-emergence herbicide application treatments

Treatments†	Rate kg ae[ß] /ha	Application date	
		Trial 1[χ]	Trial 2[χ]
		1989	1990/91
1. 2,4-D amine/June	2.24	Jn 30	Jy 28/Jn 25
2. 2,4-D amine/July	2.24	Jy 24	Jy 24/Jy 24
3. 2,4-D amine/Aug	2.24	Au 11	Au 24/Au 30
4. 2,4-D amine/June	0.28	Jn 30	Jy 28/Jn 25
5. 2,4-D amine/July	0.28	Jy 24	Jy 24/Jy 24
6. 2,4-D amine/Aug	0.28	Au 11	Au 24/Au 30
7. check, weedy [α]	–**	–	–

† treatments were 2,4-D applied in the month indicated during the seedling year (trial 1) or during the seedling and second years of growth (trial 2). Ginseng was seeded in October 1988 and 1989 for trials 1 and 2, respectively.

ß 'ae' denotes that the weight of the product is expressed as the acid equivalent weight.

α weedy check plots were weeded once per year, at the end of the growing season.

χ initial mulches used were wheat in trial 1 and oat in trial 2.

** '–' Indicates that no product was applied.

Table 7. Exp 43-2: Total broadleaf weed means (g/plot) for two trials

Treatments[x]	Trial 1	Trial 2
1. 2,4-D amine/June @ 2.24 kg ae[ß] /ha	2.4	108.9
2. 2,4-D amine/July @ 2.24 kg ae/ha	7.5	53.3
3. 2,4-D amine/Aug @ 2.24 kg ae/ha	1.0	31.8
4. 2,4-D amine/June @ 0.28 kg ae/ha	2.4	57.1
5. 2,4-D amine/July @ 0.28 kg ae/ha	3.1	77.2
6. 2,4-D amine/Aug @ 0.28 kg ae/ha	3.8	109.8
7. check, weedy[α]	11.8	26.8
$P_{.05}$	n.s.	n.s.

x refer to Table 6 for treatment details.

ß 'ae' denotes that the weight of the product is expressed as the acid equivalent weight.

& values are totals of broadleaf weed fresh weights (g) collected at the end of each growing season for four consecutive years.

α weedy check plots were weeded once per year, at the end of the growing season.

Table 8. Exp 43-2: Ginseng root dry weight means (g/root) for two trials

Treatment[x]	Trial 1				Trial 2				
	Year of growth				Year of growth				
	1[&]	2[&]	3[&]	4[&]	1[&]	2[&]	3[&]	4[&]	4C[+]
1. 2,4-D amine/June @ 2.24 kg ae[ß] /ha	0.18d	1.08b	3.28	5.29	0.13	0.70b	2.92	5.20	4.3
2. 2,4-D amine/July @ 2.24 kg ae/ha	0.23bc	1.37ab	4.20	5.13	0.13	0.66b	2.83	4.95	3.95
3. 2,4-D amine/Aug @ 2.24 kg ae/ha	0.22c	1.51a	3.61	4.49	0.13	1.00ab	3.64	6.34	4.12
4. 2,4-D amine/June @ 0.28 kg ae/ha	0.26ab	1.60a	3.78	5.56	0.14	1.10a	3.51	6.49	4.03
5. 2,4-D amine/July @ 0.28 kg ae/ha	0.25abc	1.44a	3.93	5.41	0.15	0.93ab	3.06	6.40	4.26
6. 2,4-D amine/Aug @ 0.28 kg ae/ha	0.27a	1.51a	3.91	4.56	0.13	0.90ab	3.35	4.71	4.09
7. check, weedy[α]	0.27a	1.57a	4.13	5.05	0.14	1.17a	3.07	5.26	4.39
$P_{0.05}$	*	*	n.s.	n.s.	n.s.	*	n.s.	n.s.	n.s.
$P_{0.01}$	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

[x] refer to Table 6 for treatment details.
[+] commercial dry root weight (g/root) at the final harvest (trial 2 only).
[&] freeze-dried weights (g/root) from roots collected at the end of each growing season. Means within a column followed by the same letter are not significantly different at the indicated P level, according to Duncan's multiple range test.
[ß] 'ae' denotes that the weight of the product is expressed as the acid equivalent weight.
[α] weedy check plots were weeded once per year, at the end of the growing season.

Table 9. Exp 43-2: Ginseng plant and root density means (number/m^2) for two trials

Treatments[†]	Trial 1				Trial 2				
	Year of growth				Year of growth				
	1[&]	2[&]	3[&]	4[&]	1[&]	2[&]	3[&]	4[&]	4C[+]
1. 2,4-D amine/June @ 2.24 kg ae[ß]/ha	120	115	105	108	99	70 b	120	70	93
2. 2,4-D amine/July @ 2.24 kg ae/ha	140	125	89	104	81	56 b	126	66	108
3. 2,4-D amine/Aug @ 2.24 kg ae/ha	125	119	102	107	87	147 a	141	62	108
4. 2,4-D amine/June @ 0.28 kg ae/ha	153	113	93	113	97	136 a	129	69	125
5. 2,4-D amine/July @ 0.28 kg ae/ha	125	114	97	116	106	135 a	112	57	91
6. 2,4-D amine/Aug @ 0.28 kg ae/ha	142	111	90	114	97	118 a	120	73	113
7. Check, weedy[α]	148	128	106	125	100	119 a	128	65	101
$P_{0.05}$	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s.	n.s.	n.s.
$P_{0.01}$	n.s.	n.s.	n.s.	n.s.	n.s.	**	n.s.	n.s.	n.s.

[†] refer to Table 6 for treatment details.
[&] number of ginseng stems at the end of each growing season. Means within a column followed by the same letter are not significantly different at the indicated P level, according to Duncan's multiple range test.
[+] number of roots per m^2 at final harvest. Data available for trial 2 only.
[ß] 'ae' denotes that the weight of the product is expressed as the acid equivalent weight.
[α] weedy check plots were weeded once per year, at the end of the growing season.

tions and with a reduced herbicide rate. Significant differences in plant density and root weight occurred only in the first two years of growth and were more pronounced with the higher rates. There were no significant differences in the measured crop responses in the third and fourth years of growth (Tables 8~10).

The main broadleaf weeds present throughout each growing season in both trials were thyme-leaved sandwort (*Arenaria serpyllifolia* L. ARISE), common chickweed (*Stellaria media* (L.) Vill. STEME) and dandelion (*Taraxacum officinale* Weber TAROF). Grass weeds were mainly volunteer grains. This weed spectrum was the same for all treated plots and the check plots.

3. Experiment 43-3: MCPA-sodium

MCPA-sodium appears to be a useful product for weed control (Table 11). Broadleaf weed populations were suppressed (Table 12) and adverse agronomic effects on the crop appeared to be limited (Tables

Table 10. Exp 43-2 : Ginseng seed weight means (g/plot) for two trials

Treatments†	Trial 1		Trial 2	
	Year of growth		Year of growth	
	3	4∞	3	4∞
1. 2,4-D amine/June @ 2.24 kg aeß/ha	86	130	88	208
2. 2,4-D amine/July @ 2.24 kg ae/ha	88	135	92	206
3. 2,4-D amine/Aug @ 2.24 kg ae/ha	98	123	128	173
4. 2,4-D amine/June @ 0.28 kg ae/ha	87	132	112	216
5. 2,4-D amine/July @ 0.28 kg ae/ha	102	122	148	181
6. 2,4-D amine/Aug @ 0.28 kg ae/ha	88	118	101	217
7. Check, weedy α	74	118	145	206
$P_{.05}$	n.s.	n.s.	n.s.	n.s.

† refer to Table 6 for treatment details.
∞ seed weight results for 4th year were adjusted to 3rd year areas
ß 'ae' denotes that the weight of the product is expressed as the acid equivalent weight.
α weedy check plots were weeded once per year, at the end of the growing season.

Table 11. Exp 43-3: Post-crop-emergence herbicide application treatments

Treatments	Rate kg aeß/ha	Application date Trial 1χ 1991/92	Trial 2χ 1992/93
1. MCPA-sodium†	0.15	Jy 25/Jy 16	Jy 16/Jn 24
2. MCPA-sodium	0.30	Jy 25/Jy 16	Jy 16/Jn 24
3. MCPA-sodium	0.45	Jy 25/Jy 16	Jy 16/Jn 24
4. check, weed-free‡	–**	–	–
5. check, weedyα	–	–	–

z products were applied at the dates indicated during the seedling year and second year of plant growth. For a given treatment, either 2 or 3 applications were made per year. Ginseng normally emerges through the mulch layer during May and June. Trial 1 was seeded in October 1990; trial 2 in October 1991.
ß 'ae' denotes that the weight of the product is expressed as the acid equivalent.
‡ weed-free checks were hand-weeded as required during the growing season.
α weedy check plots were weeded once per year, at the end of the growing season.
* mulches used were wheat, oat, and barley straws in trials 1, 2, and 3, respectively.
** '–' indicates that no product was applied.

13~15). Ginseng plant germination and emergence was poor in the spring of 1992 and lower than expected. Early season estimations of plant densities in the second year of trial 2 indicated an increase of seed germination

Table 12. Exp 43-3: Total broadleaf weed means (g/plot) for two trials

Treatments §	Trial 1∞	Trial 2∞
1. MCPA-sodium @ 0.15 kg aeß/ha	631 b	54
2. MCPA-sodium @ 0.30 kg ae/ha	521 b	25
3. MCPA-sodium @ 0.45 kg ae/ha	749 b	270
5. check, weedy α	3248 a	888
$P_{.05}$	*	n.s.
$P_{.01}$	**	n.s.

§ refer to Table 11 for treatment details. Weed-free checks are deleted from statistical analyses.
ß 'ae' denotes that the weight of the product is expressed as the acid equivalent.
α check plots were weeded once per year, at the end of the growing season.
∞ values are 4 yr fresh weight totals (g)/plot. Means within a column followed by the same letter are not significantly different at the indicated P level, using Duncan's multiple range test.

over the first year (Table 14). At the end of the second year of growth (1993), the ginseng plant population generally consisted of approximately 40% two year old plants and 60% one year old plants. The 1993 plant density results represent the total plant stand, and are a summation of separate counts of one and two year old plants distinguished by leaf number per plant. This categorization indicated an approximate ratio of 60% younger plants and 40% older plants. Checks during the second to fourth growing seasons indicated that this ratio was maintained. Categorization, by counting bud scars, of root age at final harvest was not considered feasible for small plots and no commercial root counts or weights were done for trial 2. No visible ginseng phytotoxic effects were observed in any growth year of either trial. The principle broadleaf weeds present throughout each growing season were common chickweed, dandelion, lamb=s quarters (*Chenopodium album* L. CHEAL), and wild buckwheat (*Polygonnum convolvulus* L.). Other, less prominent weeds included jimsonweed (*Datura stramonium* L. DATST), ragweed (*Ambrosia artemisifolia* L. AMBEL) and lady = s thumb (*Polygonum persicaria* L. POLPE). This weed spectrum was the same for all treated plots and the check plots and similar for both trials.

4. Experiment 43-10: oryzalin, ethalfluralin

A limited amount of phytotoxicity was observed in ginseng following application of oryzalin and ethalfluralin (Table 16). Symptoms that occurred in the second

Table 13. Exp 43-3: Ginseng root dry weight means (g/root) for two trials.

Treatment §	Trial 1					Trial 2				
	Year of growth					Year of growth				
	1&	2&	3&	4&	4C+	1&	2&	3&	4&	4C+
1. MCPA-sodium @ 0.15 kg ae^{ß}/ha	0.30	2.00	3.48	3.02	4.24	0.33	1.25bc	2.40	2.40	n/a
2. MCPA-sodium @ 0.30 kg ae/ha	0.30	1.75	2.93	4.08	4.45	0.35	1.40ab	2.70	3.35	n/a
3. MCPA-sodium @ 0.45 kg ae/ha	0.30	2.00	3.40	4.76	4.00	0.35	1.50a	2.53	3.22	n/a
4. check, weed-free ‡	0.30	2.00	3.35	3.02	5.27	0.38	1.28bc	1.87	3.47	n/a
5. check, weedy^{α}	0.28	1.75	3.55	3.78	5.43	0.30	1.18c	2.53	3.34	n/a
$P_{.05}$	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s.	n.s.	n/a
$P_{.01}$	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n/a

§ refer to Table 11 for treatment details.
ß 'ae' denotes that the weight of the product is expressed as the acid equivalent.
& values present in each column for years 1-4 are freeze-dried weights (g/root) for each year of growth. Means within a column followed by the same letter are not significantly different at the indicated P level, using Duncan's multiple range test
+ commercial dry root weight (g/root) at the final harvest.
‡ weed-free checks were hand-weeded as required during the growing season.
α weedy check plots were weeded once per year, at the end of the growing season.

Table 14. Exp 43-3: Ginseng plant and root density means (number/m^2) for two trials.

Treatments §	Trial 1					Trial 2				
	Year of growth					Year of growth				
	1&	2&	3&	4&	4C+	1&	2&	3&	4&	4C+
1. MCPA-sodium @0.15 kg ae^{ß}/ha	83	145	66	n/a	29	67	75 ab	n/a	n/a	n/a
2. MCPA-sodium @0.30 kg ae/ha	92	151	71	n/a	39	67	85 a	n/a	n/a	n/a
3. MCPA-sodium @0.45 kg ae/ha	90	156	72	n/a	39	71	88 a	n/a	n/a	n/a
4. check, weed-free‡	90	142	66	n/a	40	68	72 ab	n/a	n/a	n/a
5. check, weedy^{α}	82	151	65	n/a	36	57	57 b	n/a	n/a	n/a
$P_{.05}$	n.s.	n.s.	n.s.	n/a	n.s.	n.s.	*	n/a	n/a	n/a
$P_{.01}$	n.s.	n.s.	n.s.	n/a	n.s.	n.s.	n.s.	n/a	n/a	n/a

§ refer to Table 11 for treatment details.
& number of ginseng stems. Means within a column followed by the same letter are not significantly different at the indicated P level, using Duncan's multiple range test.
+ number of roots per m^2 at final harvest.
‡ weed-free checks were hand-weeded as required during the growing season.
ß 'ae' denotes that the weight of the product is expressed as the acid equivalent.
α check plots were weeded once per year, at the end of the growing season

year of growth of trial 1 consisted of stunting, leaf deformation and leaf yellowing in the ginseng shoots. Severity of phytotoxic responses appeared to be related to application rate for both herbicides and was much more pronounced with ethalfluralin treatments than with oryzalin. Symptoms were first noticeable in 1989 approximately 30 days after treatment application. These effects did not persist beyond the second growing season in trial 1. Ginseng dry root weight reductions were found after the second year of growth in trial 1 and only for the ethalfluralin treatments (Table 18). Significant differences were also apparent for ginseng densities in year two and three and for seed yields in year three of trial 1 only (Tables 19, 20). These differences show a tendency to be related to herbicide rate. Significant levels of broadleaf weed control occurred only in trial 2 (Table 17). Grass weed control was not achieved although there was a trend to higher populations in weedy checks. Grass populations were low throughout these trials.

The main broadleaf weeds present throughout each growing season in both trials were ragweed, pigweed (*Amaranthus reflexus* L.), wild buckwheat, thyme-leaved

Table 15. Exp 43-3: Ginseng seed weight means (g/plot) for two trials

Treatments §	Trial 1		Trial 2	
	Year		Year	
	3∞	4∞	3∞	4∞
1. MCPA-sodium @ 0.15 kg aeß/ha	210c	40	117	10
2. MCPA-sodium @ 0.30 kg ae/ha	269a	46	113	12
3. MCPA-sodium @ 0.45 kg ae/ha	247ab	40	124	10
4. check, weed-free‡	233bc	43	101	16
5. check, weedyα	225bc	40	79	12
$P_{.05}$	*	n.s.	n.s.	n.s.
$P_{.01}$	n.s.	n.s.	n.s.	n.s.

§ refer to Table 11 for treatment details.

∞ means within a column followed by the same letter are not significantly different at the indicated P level, using Duncan's multiple range test. Seed weight results for 4th year were adjusted to 3rd year areas.

‡ weed-free checks were hand-weeded as required during the growing season.

ß 'ae' denotes that the weight of the product is expressed as the acid equivalent.

α plots were weeded once per year, at the end of the growing season.

Table 16. Exp 43-10: Pre-crop-emergence herbicide application treatments.

Treatment §	Rate (kg a.i./ha)	Application date	
		Trial 1y	Trial 2y
		1988/89	1990/91
1. oryzalin+water χ	0.75	Ap 20/Ap 20	Ap 24/Ap 15
2. oryzalin+water	1.00	Ap 20/Ap 20	Ap 24/Ap 15
3. oryzalin+water	2.00	Ap 20/Ap 20	Ap 24/Ap 15
4. ethalfluralin+water	0.75	Ap 20/Ap 20	Ap 24/Ap 15
5. ethalfluralin+water	1.00	Ap 20/Ap 20	Ap 24/Ap 15
6. ethalfluralin+water	1.50	Ap 20/Ap 20	Ap 24/Ap 15
7. check, weed-free ‡	–**	–	–
8. check, weedyα	–	–	–

§ refer to Table 11 for treatment details.

χ application of product was followed by application of additional water, equivalent to 6.4 mm of precipitation. Treatments were applied prior to crop emergence through mulch layer. Ginseng normally emerges in May and June. Trials 1 and 2 were seeded in October 1988 and October 1989, respectively.

y initial mulches used were wheat straw in trial 1 and oat straw in trial 2.

‡ weed-free checks were hand-weeded as required during the growing season.

α weedy check plots were weeded once per year, at the end of the growing season.

** '–' Indicates that no product was applied.

sandwort, common chickweed and dandelion. The principle grass weeds present were volunteer oats (*Avena sativa* L.) and wheat (*Triticum aestivum* L.), green foxtail (*Setaria viridis* L. Beauv.), and quackgrass (*Agropyron repens* (L.) Beauv.). This weed spectrum was the same for all treated plots and the check plots.

5. Experiment 43-10A: diquat, glyphosate, 2,4-D amine

The non-selective herbicides used in post-crop-senescence applications (Table 21) appear to have potential for phytotoxicity. Visual observations in the first year of growth for both trials indicated normal growth patterns for ginseng, however, abnormal ginseng growth occurred in diquat and glyphosate plots in trial 1 in the spring of 1990 as ginseng emerged for the third growth season. Symptoms were initially a leaf yellowing and

Table 17. Exp 43-10: Total grass and broadleaf weed means (g/plot) for two trials

Treatments §	Rate (kg a.i./ha)	Grass weeds (g/plot)		Broadleaf weeds (g/plot)	
		Trial 1	Trial 2	Trial 1	Trial 2χ
1. oryzalin+water	0.75	32.0	127.0	118.3	97.9b
2. oryzalin+water	1.00	30.7	925.0	89.3	77.0b
3. oryzalin+water	2.00	16.9	143.7	73.2	35.7b
4. ethalfluralin+water	0.75	47.2	106.4	138	535.4b
5. ethalfluralin+water	1.00	46.1	116.3	82.8	215.4b
6. ethalfluralin+water	1.50	46.3	64.0	63.9	213.0b
7. check, weedy	–	129.6	353.2	161.8	4161.8a
	$P_{.05}$	n.s.	n.s.	n.s.	*
	$P_{.01}$	n.s.	n.s.	n.s.	**

§ refer to Table 16 for treatment details.

χ within a column followed by the same letter are not significantly different at the indicated P level, using Duncan=s multiple range test.

Table 18. Exp 43-10: Ginseng root dry weight means (g/root) for two trials.

Treatment §	Rate (kg a.i./ha)	Trial 1					Trial 2				
		Year of growth					Year of growth				
		1&	2&	3&	4&	4C+	1&	2&	3&	4&	4C+
1. oryzalin+water	0.75	n/a	1.33a	3.77	4.00	n/a	0.17	1.12	2.23	6.28	4.02
2. oryzalin+water	1.00	n/a	1.38a	4.02	4.98	n/a	0.18	1.13	2.84	5.69	4.21
3. oryzalin+water	2.00	n/a	1.45a	4.06	5.98	n/a	0.16	1.05	2.94	5.25	3.59
4. ethalfluralin+water	0.75	n/a	1.32ab	3.23	5.08	n/a	0.18	0.88	2.38	4.78	3.59
5. ethalfluralin+water	1.00	n/a	1.20ab	3.42	4.57	n/a	0.15	0.86	2.43	5.82	3.99
6. ethalfluralin+water	1.50	n/a	1.04b	3.42	5.03	n/a	0.16	0.97	2.84	5.04	3.83
7. check, weed-free	–	n/a	1.41a	3.22	4.66	n/a	0.16	1.03	2.93	6.20	3.85
8. check, weedy	–	n/a	1.40a	3.04	5.59	n/a	0.14	0.96	2.41	4.59	3.45
	$P_{.05}$	n/a	*	n.s.	n.s.	n/a	n.s.	n.s.	n.s.	n.s.	n.s.
	$P_{.01}$	n/a	**	n.s.	n.s.	n/a	n.s.	n.s.	n.s.	n.s.	n.s.

§ refer to Table 16 for treatment details.

& values present in each column for years 1-4 are freeze-dried weights (g/root) for each year of growth. Means within a column followed by the same letter are not significantly different at the indicated P level, using Duncan's multiple range test. Data for year 1 and 4C of trial 1 are not available (n/a).

+ commercial dry root weight (g/root)at the final harvest.

Table 19. Exp 43-10: Ginseng plant and root density means (number /m^2) for two trials

Treatments	Rate (kg a.i./ha)	Trial 1				Trial 2				
		Year of growth				Year of growth				
		1&	2&	3&	4&	1&	2&	3&	4&	4C+
1. oryzalin+water	0.75	89	67ab	87abc	43	89	120	81	60	90
2. oryzalin+water	1.00	116	55ab	68bc	43	97	127	87	62	87
3. oryzalin+water	2.00	94	48b	65c	30	100	123	78	61	105
4. ethalfluralin+water	0.75	105	56ab	82abc	35	101	132	90	60	109
5. ethalfluralin+water	1.00	118	64ab	86abc	40	88	110	81	59	84
6. ethalfluralin+water	1.50	88	51b	72bc	36	98	137	94	58	91
7. check, weed-free	–	111	78a	89ab	48	95	124	89	57	89
8. check, weedy	–	118	79a	95a	51	89	97	64	52	66
	$P_{.05}$	n.s.	*	*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	$P_{.01}$	n.s.	**	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

§ refer to Table 16 for treatment details.

& number of ginseng stems. Means within a column followed by the same letter are not significantly different at the indicated P level, using Duncan's multiple range test.

+ number of roots per m^2 at final harvest. Data available for trial 2 only.

undercurl, followed by dessication and death, and were observed throughout the third and fourth growing seasons. These symptoms were not observed in the 2,4-D, weed-free or weedy check plots nor did they occur in any treatments in trial 2 except for the infrequent occurrence of chlorotic plants observed in the diquat and glyphosate - treated plots in the last two growing years. As a result, there was a reduction in ginseng stand and root weight in the first trial only (Tables 23, 24). Seed yields were not affected (data not shown). In the spring of 1994, a phytophthora root rot infestation in trial 2 severely reduced the ginseng stand across all treatments. Generally the weed population was low for both trials (Table 22). At the higher weed populations in trial 2, all herbicide treatments were superior to the weedy checks (Table 22). Chickweed, dandelion and lamb=s quarters were the principal broadleaf weeds present in the first year of both trials, before herbicide applications were made. Grasses consisted mainly of volunteer winter wheat and, to a lesser extent, foxtail.

Table 20. Exp 43-10: Ginseng seed weight means (g/plot) for two trials.

Treatments §	Rate (kga.i./ha)	Trial 1 Year of growth		Trial 2 Year of growth	
		3∞	4 ∞	3∞	4∞
1. oryzalin+water	0.75	99.7a	66.8	108.9	160.5
2. oryzalin+water	1.00	82.5abc	61.2	128.3	158.8
3. oryzalin+water	2.00	72.3bc	67.2	127.1	149.2
4. ethalfluralin+water	0.75	17.9abc	57.2	121.4	141.8
5. ethalfluralin+water	1.00	37.1bc	64.4	114.2	161.6
6. ethalfluralin+water	1.50	61.8c	64.8	123.4	156.3
7. check, weed-free	–	87.2ab	61.8	121.0	150.6
8. check, weedy	–	98.7a	72.1	65.9	119.6
	$P_{.05}$	*	n.s.	n.s.	n.s.
	$P_{.01}$	n.s.	n.s.	n.s.	n.s.

§ refer to Table 16 for treatment details.

∞ means within a column followed by the same letter are not significantly different at the indicated P level, using Duncan's multiple range test. Seed weight results for 4th year were adjusted to 3rd year areas for trial 2.

Table 22. Exp 43-10a: Total broadleaf and grass weed means (g/plot) over 3 years in two trials

Treatments §	Broadleaf weeds (g/plot)		Grass weeds (g/plot)	
	Trial 1x	Trial 2x	Trial 1x	Trial 2x
1. diquat+Agral 90†	155.3a	176.6b	150.2a	44.4ab
2. glyphosate+Frigate#	98.5a	362.4b	81.5b	34.3b
3. 2,4-D amine	36.1ab	272.9b	–z	–
5. check, weedyα	101.5a	1087.4a	35.8b	114.1a
$P_{.05}$	*	*	*	*
$P_{.01}$	**	**	**	n.s.

§ refer to Table 21 for treatment details.

x means within a column followed by the same letter are not significantly different at the indicated P level, using Duncan=s multiple range test.

† H non-ionic surfactant (Zeneca, Grimsby, ON, Canada)

cationic surfactant (ISK Biosciences, London, ON, Canada)

‡ weed-free checks were hand-weeded as required during each growing season.

α check plots were weeded once per year, at the end of the growing season.

z '–' grass weed data not collected.

Discussion

Use of pre-plant fumigants is a useful practice in ginseng production[2]. Broadcast fumigation of sites prior to seeding is sufficient to greatly reduce weed populations that normally arise from seeds buried in soil. In addition, the use of a mulch to conserve moisture, prevent frost damage and protect beds from erosion would also be expected to reduce weed populations arising from the soil seed bank. However, the straw mulches that are commonly used in the commercial production of ginseng are the likely source of most weeds observed in the crop. Different sources of straw can result in a widely variable spectrum of weeds, particularly in the case of broadleaf weeds. The majority of grass weeds in these trials were the volunteer grasses of the grain crop

Table 21. Exp 43-10A: Post-crop-senescence herbicide application treatments

Treatments	Rate (kg a.i./ha)	Application date Trial 1χ	Trial 2χ
		1988/89	1991/92
1. diquat+Agral 90†	0.55+0.1%†	Oc 27/Oc 13	Oc 17/Oc 23
2. glyphosate+Frigate#	0.90+0.5%#	Oc 27/Oc 13	Oc 17/Oc 23
3. 2,4-D amine	1.12ß	Oc 27/Oc 13	Oc 17/Oc 23
4. check, weed-free‡	–**	–	–
5. check, weedy α	–	–	–

† non-ionic surfactant Agral 90 (Zeneca, Grimsby, ON, Canada)was applied at 0.45 *l*/ha (0.1% (v/v) of water volume of 450 *l*/ha).

cationic surfactant Frigate (ISK Biosciences, London, ON, Canada) was applied at 2.25 *l*/ha (0.5%(v/v) of water volume of 450 *l*/ha).

‡ weed-free checks were hand-weeded as required during each growing season.

α weedy check plots were weeded once per year, at the end of the growing season.

χ initial mulches used were wheat, oat, and barley straws in trials 1, 2, and 3, respectively. Herbicide applications were made post-crop-senescence (October) during the first two years of ginseng growth. Trial 1 was seeded in November 1987; trial 2 in October 1990.

ß 'ae' denotes that the weight of the product is expressed as the acid equivalent.

** '–' Indicates that no product was applied.

Table 23. Exp 43-10a: Ginseng root weight means (g/root) for two trials

Treatments §	Trial 1			Trial 2			
	Year			Year			
	2&	3&	4&	2&	3&	4&	4C∞
1. diquat+Agral 90†	1.3	4.5a	7.3	2.0	3.0	2.5	3.8
2. glyphosate+Frigate#	1.4	4.2ab	5.7	2.1	3.7	2.8	3.1
3. 2,4-D amine	1.4	2.9c	5.1	1.9	3.8	2.9	3.3
4. check, weed-free‡	1.4	3.2ab	5.0	2.0	2.8	1.8	3.2
5. check, weedy$^{\alpha}$	1.3	3.2ab	6.0	2.1	3.4	3.3	3.3
$P_{.05}$	n.s.	*	n.s.	n.s.	n.s.	n.s.	n.s.
$P_{.01}$	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

§ refer to Table 21 for treatment details.
∞ commercial dry root weight at the final root harvest (data available for trial 2 only).
& values in each column for years 2-4 are present freeze-dried weights (g/root) for each year of growth. Means within a column followed by the same letter are not significantly different at the indicated P level, using Duncan's multiple range test.
† non-ionic surfactant (Zeneca, Grimsby, ON, Canada)
# cationic surfactant (ISK Biosciences, London, ON, Canada)
‡ weed-free checks were hand-weeded as required during each growing season.
$^{\alpha}$ weedy check plots were weeded once per year, at the end of the growing season.

Table 24. Exp 43-10a: Ginseng plant and root density means (#/m^2) for two trials

Treatments §	Trial 1				Trial 2				
	Year of growth				Year of growth				
	1&	2&	3&	4&	1&	2&	3&	4&	4C∞
1. diquat+Agral 90†	n/a	100	34b	26b	112	121	90	n/a	31
2. glyphosate+Frigate#	n/a	86	47b	42ab	96	128	90	n/a	35
3. 2,4-D amine	n/a	99	108a	70a	100	127	72	n/a	25
4. check, weed-free‡	n/a	79	92a	62ab	96	128	73	n/a	25
5. check, weedy$^{\alpha}$	n/a	94	99a	79a	100	132	88	n/a	35
$P_{.05}$	n/a	n.s.	*	*	n.s.	n.s.	n.s	n/a	n.s.
$P_{.01}$	n/a	n.s.	**	n.s.	n.s.	n.s.	n.s	n/a	n.s.

§ refer to Table 21 for treatment details
∞ number of roots at final harvest (data available for trial 2 only).
& number of ginseng stems. Means within a column followed by the same letter are not significantly different at the indicated P level, using Duncan's multiple range test. Data are not available (n/a) for year 1 of trial 1 and year 4 of trial 2.
† non-ionic surfactant (Zeneca, Grimsby, ON, Canada)
# cationic surfactant (ISK Biosciences, London, ON, Canada)
‡ weed-free checks were hand-weeded as required during each growing season.
$^{\alpha}$ weedy check plots were weeded once per year, at the end of the growing season.

used as the mulch, usually oats. Although some trials were inoculated with viable weed seeds, these seem to have contributed little to the overall weed population. Poor weed control in the grain crops used as a source of straw thus appears to be largely responsible for the weeds present in most ginseng crops. 2,4-D amine and other formulations of 2,4-D and related phenoxy herbicides are often used in common field grain crops such as wheat, oats, rye (*Secale cereale* L.) and barley (*Hordeum vulgare* L.) and are the principal herbicides used for broadleaf weed control in those crops. Two of the most common weeds present in these trials (thyme-leaved sandwort and chickweed) are not susceptible to 2,4-D alone. It is quite probable, therefore, that straw will contain weed seeds selected for 2,4-D resistance. The use of this herbicide for broadleaf weed control in ginseng, given cultural practices now used, thus may not be beneficial in regions where such resistance is common. When used for post-crop-senescence weed control, however, 2,4-D, diquat, and glyphosate did reduce weed populations in some trials. However, the risk of phytotoxicity in

some seasons mitigates against their use in ginseng cultivation. A related phenoxy herbicide, MCPA-sodium, was found to be useful in these studies for broadleaf weed control. The usefulness of a given herbicide product in ginseng production may in part depend on the extent of its use in the grain crops used as the source of mulch; extensive use in grains crops may select for resistance in weed populations. These products may not then be useful in ginseng production. Crop phytotoxic effects vary from year to year and likely from region to region.

The use of straw or other mulches that are relatively free of both weed and cereal grain seeds should greatly reduce the need for herbicides. Mulches that degrade more slowly than cereal straw mulches and thus provide a more constant coverage of soil would be advantageous. Agronomic data from the weedy check plots showed that ginseng growth can be adversely affected at high weed populations, however, ginseng yields were not always reduced in the presence of moderate or even high weed populations. More information on the interactions between weed and ginseng populations is required.

Chlorthal dimethyl, fluazifop-p-butyl, MCPA-sodium and clethodim showed no detrimental effects on ginseng growth in any of the trials reported here. Additional studies with these products appear to be warranted as lower frequencies of applications than used here may be useful at more moderate weed populations. Chlorthal dimethyl has been associated with suppression of certain species of *Phytophthora*.[2] In these trials, metalaxyl applications generally reduced incidence of phytophthora root rot and likely masked any such con- tributions of this product to disease control.

The data show that 2,4-D amine, when used during the growing season, can cause phytotoxic effects to the crop in the year that it is used. The severity of the phytotoxic response appears to be related to the rate used and the timing of the application. However, crop damage appears to be confined to the season in which the applications are made and does not persist into subsequent growing seasons. Similarly, caution should be used with respect to the use of diquat, glyphosate, ethalfluralin, and oryzalin. Phytotoxicity was observed in some trials with these products also and, in the case of glyphosate, severe symptoms appeared as long as one year after application. The variable amounts of phytotoxicity to ginseng observed in different trials suggest that there are interactions with temperature or moisture that control this effect.

In these experiments, ginseng stand density counts become less accurate in terms of representing the actual number of roots present as the crop aged. This appears to be due to factors such as the production of multiple stems by a single root and root dormancy. Although most ginseng roots give rise to a single stem each year, occasionally two or more stems are produced. In addition, roots may not produce a stem in some years, due to dormancy or bud destruction. Ginseng stands generally declined over time. Fluctuation in seed production varied considerably from year to year and trial to trial. This is likely an effect of temperature and moisture conditions during flowering and seed formation.

These trials have shown that effective products for weed control in ginseng are available. Further studies are required to determine optimum application rates for a variety of weed populations, to assess herbicide residue levels in root at harvest, and to determine the yield tolerances of ginseng with respect to weed populations.

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