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The response of black currant and weeds to glyphosate

Jerzy Lisek

Research Institute of Pomology and Floriculture
Pomologiczna 18, 96-100 Skierniewice, Poland
e-mail: jlisek@insad.pl

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ABSTRACT

In 2001–2003, two formulations of glyphosate containing isopropylamine salt used at the rate of 1.08 and 2.16 kg a. i. ha^{-1}, and ammonium salt at 1.02 and 2.04 kg a. i. ha^{-1}, were assessed with respect to their effectiveness in controlling weeds on black currant plantations in Skierniewice (central Poland), during the dormant period of the bushes. Application of the herbicide in November was completely safe for the shrubs, which did not show any symptoms of damage after the start of vegetation. Glyphosate applied in March caused damage to developing shoots and leaves, but did not reduce fruit yields produced by the black currant bushes. Glyphosate effectively controlled winter hardy weeds, both annual and perennial, eliminating them or reducing their number from March until the first days of May when, no longer controlled by glyphosate, annual weeds began to sprout *en masse* and perennial weeds developed again.

INTRODUCTION

The growing requirements, in accordance with the Directive 91/414/EEC, concerning the safety of chemical plant protection products for man, living organisms and the natural environment, lead to restrictions in the use of herbicides for fruit crops. The withdrawal of some soil herbicides, including simazine and metolachlor, has reduced the number of products applied on black currant plantations and is an encouragement to seek new solutions. Application of herbicides modifies the range of weed species and when there is no rotation it leads to the compensation of the hard-to-control species, thus limiting the biological diversity of plant communities (Lipecki and Szwedo 1988, Wróbel 1999).

Glyphosate is a commonly used herbicide for fruit crops. It undergoes quick biodegradation and controls many different weeds, including perennials (Spring 1993, Lisek 2001). In Poland, glyphosate has not been recommended yet for controlling weeds in black currant. In countries with a temperate marine climate, such as Great Britain and Ireland, application of glyphosate on black currant plantations is carried out during the dormant period of the bushes, most often from December until February (Clay 1972, Stott et al. 1974, Rath 1977).

The aim of the experiments was to assess the effectiveness of glyphosate on black currant plantations following its application in late autumn and early spring, including the herbicide's safety for the bushes and its effect on the development and range of the species in weed communities.

MATERIAL AND METHODS

Four field experiments were carried out in 2001 – 2003, on two fruit-producing plantations of black currant situated in Skierniewice (central Poland). In the first location – Starbacicha, on a plantation of the cultivar 'Ben Lomond' planted in the autumn of 1997, glyphosate was applied on 19 March and 6 November, 2001. On the second plantation – in the Pomological Orchard, consisting of bushes of the cultivar 'Titania' planted in 1992, treatments were carried out on 5 March and 4 November, 2002.

On both plantations, the distance between the bushes was 4 × 0.5 m. Grass was maintained in the alleyways. The experiments were set up on a pseudopodsolic sandy loam soil, using the random block method, in four replications. On the 'Ben Lomond' plantation, prior to the experiment, weeds were controlled by mechanical means (soil rotovator and hoeing) and chemical means (foliar herbicides: diquat, glufosinate-ammonium), and the total plot area was 60 m^2 (40 × 1.5 m), including unweeded, control plots. On the 'Titania' plantation, soil herbicides had been used for a few seasons: simazine and napropamid, and the total plot area was 80 m^2 (40 × 2 m).

In the experiments, the effectiveness of two glyphosate formulations was assessed: one containing isopropylamine salt (Roundup 360 SL), applied at the rate of 1.08 and 2.16 kg a. i. ha^{-1}, and the other containing ammonium salt (Roundup Max 680 SG), used at the rate of 1.02 and 2.04 kg a. i. ha^{-1}.

Treatments were carried out using a plot sprayer, without shields, at a working pressure of 0.2 MPa, water volume of 300 dm^{-3} ha^{-1}, and air temperature not lower than 10ºC. In November herbicides were applied after all leaves fell.

The selectivity of the herbicides for black currant plants, following the applications both in March and November, was assessed every month from mid-April until mid-July, using a 9-point logarithmic scale, where 1 means no damage to the cultivated plants, and 9 – their dying out. The fruit crop was picked by hand from 5 bushes growing on each of the experimental plots.

The effectiveness of weed control, expressed as the reduction in the number of the most important weeds, was assessed in the first week of May, and the reduction in the fresh weight of weeds – in the first week of May and before fruit harvest, usually on 15 July. The range of weed species was determined at the same time in May (the number of weeds) and July (% soil coverage).

The results relating to the reduction in the number of weeds and the yields produced by the black currant shrubs were analyzed statistically, separately for the two dates of herbicide application, by using an analysis of variance, with the method of weed control as the only factor. Significance was declared at the level of $p=0.05$. The results of the effectiveness of weed control, presented as percentages, were worked out by means of the Bliss's transformation.

RESULTS

The autumn application of glyphosate was completely safe for the shrubs of both cultivars – 'Ben Lomond' and 'Titania' (Table 1). After the herbicide application in November, there was no visible damage to the shrubs the following year. The application of glyphosate in March, however, caused damage to the shrubs: dying out of some buds and shoots growing out of them, deformation of leaves – lack of obvious flapping, chlorosis between the veins of young leaves and necrosis along their periphery. These symptoms occurred to a small extent in the lower part of the bush, up to a height of 30-40 cm and were most clearly visible in April and May.

Yielding of black currant bushes on the plots where glyphosate had been used was present after all herbicide applications and the scores there were significantly higher than for the control plots (table 1). Significant differences in the yields, dependent on the formulation and dose of glyphosate used to control weeds, were noted only after the March application of the herbicides on the 'Ben Lomond' plantation in 2001. The shrubs growing on the plots sprayed with the ammonium

salt of glyphosate at the higher rate produced significantly better yields than when the lower dose of glyphosate in the form of the isopropylamine salt was used.

The effectiveness of weed control of the two glyphosate formulations was high (tables 2 and 3). Perennial weeds, among them *Achillea millefolium* L., *Epilobium adenocaulon* Haussk., *Rumex* sp., *Sonchus arvensis* L., *Taraxacum officinale* Web. and some of the annual weeds such as *Bromus hordeaceus* L. and *Geranium pusillum* L. were controlled effectively only by the higher doses of glyphosate. Weed species such as *Epilobium adenocaulon* Haussk., *Rumex crispus* L. and *Taraxacum officinale* Web. were more effectively controlled by glyphosate applied in November than in March.

The reduction in the fresh weight of weeds following glyphosate application stayed at a high level, above 80%, until the first ten days of May (table 4). Significant differences in weed reduction were apparent only on the 'Ben Lomond' plantation and depended on the dose of glyphosate and not on its formulation. During the period May to mid-July, the weight of weeds on the plots increased. In July, the differences in weight reduction were statistically significant only on the 'Titania' plantation, where glyphosate applied in March at the higher rate reduced the weight of weeds to a greater extent than after its use at the lower rate.

The average share of different weeds in covering the plantations was assessed in July and is presented in table 5. At the location Starbacicha, the highest percentage of the surface area of the plots sprayed with glyphosate was covered by *Chenopodium album* L. and *Echinochloa crus-galli* (L.) Pal. Beauv., whereas the control plots were predominantly covered by *Taraxacum officinale* Web. and *Geranium pusillum* L. In the Pomological Orchard, the herbicide-sprayed plots were dominated by *Artemisia vulgaris* L., *Equisetum arvense* L., *Chenopodium album* L. and *Echinochloa crus-galli* (L.) Pal. Beauv., whereas the control plots were strongly dominated by *Agropyron repens* (L.) Pal. Beauv. and *Taraxacum officinale* Web.

DISCUSSION

Glyphosate used without shields along the rows of black currant shrubs needs to be applied onto green weeds during the dormant period of the shrubs, at an air temperature above 0ºC. These requirements are more difficult to meet in Poland than, for example, in England or Ireland, where milder winters allow it to be applied in the period December-February, which is considered much safer for black currant than applications of glyphosate in the second half of October, immediately after leaf fall, or in March (Clay 1972, Stott et al. 1974).

Table 1. Herbicide tolerance and yield of two black currant cultivars after spring or autumn glyphosate treatment, Skierniewice 2001–2003

Treatment	Dose (kg ha^{-1})	'Ben Lomond'				'Titania'			
		Crop selectivity (1-9 scale)*		Yield (kg per bush)		Crop selectivity (1-9 scale)		Yield (kg per bush)	
		2001	2002	2001	2002	2002	2003	2002	2003
		(spring treat.)	(autumn treat.)	(spring treat.)	(autumn treat.)	(spring treat.)	(autumn treat.)	(spring treat.)	(autumn treat.)
Control	-	1.0	1	1.36 a**	1.89 a	1.0	1	1.51 a	1.47 a
Isopropylamine salt	1.08	2.0	1	1.52 b	2.23 b	1.5	1	1.86 b	1.75 b
Isopropylamine salt	2.16	2.5	1	1.62 bc	2.32 b	2.0	1	1.81 b	1.77 b
Ammonium salt	1.02	2.3	1	1.61 bc	2.26 b	1.8	1	1.89 b	1.75 b
Ammonium salt	2.04	2.5	1	1.69 c	2.30 b	2.3	1	1.87 b	1.82 b

* 1 – no damage of black currant plants, 9 – dying of black currant plants

** The averages were compared separately for each apraying date. Means followed by the same letter do not differ at p = 0.05.

Table 2. Weed control efficacy after spring and autumn glyphosate treatment at Starbacicha location, 2001 – 2002

Weed	Average number of weeds on untreated plots in May (N^{o} m^{-2})		Reduction of weed number (%)							
			2001 (spring treatment)				2002 (autumn treatment)			
			Isopropylamine salt		Ammonium salt		Isopropylamine salt		Ammonium salt	
	2001	2002	Dose (kg ha^{-1})							
			1.08	2.16	1.02	2.04	1.08	2.16	1.02	2.04
Geranium pusillum	18	23	66 a	98 b	68 a	99 b	80 a	98 b	82 a	100 b
Lamium purpureum	17	21	75 a	97 b	79 a	100 b	76 a	99 b	73 a	99 b
Matricaria inodora	16	18	85 a	100 b	88 a	100 b	84 a	99 b	84 a	100 b
Poa annua	32	28	99 a	100 a	100 a	100 a	100 b	100 b	99 a	100 b
Senecio vulgaris	24	22	97 a	100 b	99 ab	100 b	100 b	100 b	97 a	100 b
Stellaria media	31	27	99 a	100 a	100 a	100 a	100 b	100 b	98 a	100 b
Achillea millefolium	16	17	64 a	93 b	65 a	94 b	66 a	94 b	68 a	93 b
Agropyron repens	19	16	71 a	100 b	73 a	100 b	75 a	99 b	78 a	99 b
Epilobium adenocaulon	15	14	58 a	83 b	60 a	85 b	65 a	94 b	66 a	97 b
Rumex acetosella	13	16	69 a	97 b	70 a	99 b	66 a	96 b	68 a	97 b
Sonchus arvensis	14	15	71 a	86 b	73 a	88 b	78 a	98 b	79 a	98 b
Taraxacum officinale	23	26	76 a	91 b	79 a	90 b	78 a	97 b	78 a	99 b

Note: see Table 1

Table 3. Weed control efficacy after spring and autumn glyphosate treatment in Pomological Orchard, 2002 – 2003

Weed	Average number of weeds on untreated plots in May (N^o m^{-2})		Reduction of weed number (%)							
			2002 (spring treatment)				2003 (autumn treatment)			
			Isopropylamine salt		Ammonium salt		Isopropylamine salt		Ammonium salt	
	2002	2003	Dose (kg ha^{-1})							
			1.08	2.16	1.02	2.04	1.08	2.16	1.02	2.04
Bromus hordeaceus	24	31	64 a	96 b	63 a	95 a	71 a	97 b	69 a	97 b
Galium aparine	18	23	100 a	100 a	99 a	100 a	100 a	100 a	99 a	100 a
Agropyron repens	63	52	81 a	99 b	84 a	100 b	84 a	100 b	86 a	99 a
Rumex crispus	14	10	46 a	73 b	48 a	81 c	51 a	84 b	56 a	87 b
Taraxacum officinale	26	29	49 a	79 b	49 a	81 b	56 a	94 b	65 a	96 b

Note: see Table 1

Table 4. Reduction of weed vigour after spring or autumn glyphosate treatment, Skierniewice 2001 – 2003

Treatment	Dose (kg ha^{-1})	Reduction of fresh weight of weeds (%)							
		Starbacicha ('Ben Lomond')				Pomological Orchard ('Titania')			
		2001 (spring treatment)		2002 (autumn treatment)		2002 (spring treatment)		2003 (autumn treatment)	
		May	July	May	July	May	July	May	July
Control	-	0 (0.89)	0 (1.56)	0 (0.71)	0 (1.48)	0 (0.95)	0 (1.72)	0 (0.82)	0 (1.66)
Isopropylamine salt	1.08	81 a	9 a	83 ab	8 a	81 a	51 a	83 a	52 a
Isopropylamine salt	2.16	89 b	14 a	87 ab	12 a	88 b	63 b	86 a	62 a
Ammonium salt	1.02	82 a	10 a	81 a	9 a	85 ab	54 a	84 a	53 a
Ammonium salt	2.04	86 ab	15 a	88 b	11 a	90 b	64 b	88 a	63 a

Note: see Table 1. The fresh weight of weeds (kg m^{-2}) on untreated plots in the brackets is shown

Table 5. Frequency of weed species within black currant plantation at fruit harvest, Skierniewice 2001–2003

Species	% of plot area covered by weeds				
	Untreated control	Isopropylamine salt		Ammonium salt	
		Dose (kg ha^{-1})			
		1.08	2.16	1.02	2.04
	Starbacicha location (average for 2001 – 2002)				
Chenopodium album	8	22	28	27	31
Echinochloa crus-galli	6	18	23	22	24
Geranium pusillum	9	5	3	4	3
Lamium purpureum	7	6	5	6	5
Matricaria inodora	5	1	1	1	1
Poa annua	6	5	6	5	6
Senecio vulgaris	3	2	2	1	1
Stellaria media	7	6	6	7	6
Achillea millefolium	4	3	2	2	2
Agropyron repens	8	5	2	5	1
Epilobium adenocaulon	3	3	3	2	2
Rumex acetosella	7	6	4	5	4
Sonchus arvensis	8	6	3	4	3
Taraxacum officinale	14	5	4	4	3
Others	5	7	8	5	6
	Pomological Orchard (average for 2002 – 2003)				
Bromus hordeaceus	8	4	2	3	2
Chenopodium album	4	16	19	13	15
Conyza canadensis	2	3	4	3	3
Echinochloa crus-galli	2	11	13	10	12
Galium aparine	5	1	1	1	1
Agropyron repens	34	6	1	5	1
Artemisia vulgaris	7	22	26	24	30
Equisetum arvense	6	19	22	21	23
Rumex crispus	7	3	2	3	2
Taraxacum officinale	22	9	5	11	4
Others	3	6	5	6	7

The results of the present work have shown that the intensity of phytotoxicity symptoms was related to the time of herbicide application, the cultivar and the age of the shrubs. Spraying with glyphosate in November was completely safe for the bushes and during the following vegetative season no symptoms of phytotoxicity were observed. Application of the herbicide in March, when buds were developing, resulted in damage to the cultivated plants, but did not cause a reduction in fruit yield to the extent observed when bushes were considerably damaged as a result of glyphosate application at the end of February and beginning of March (Rath 1977). It needs to be recognized that the reason why the bushes of ‘Titania’ had lower susceptibility to becoming damaged by glyphosate is the late start of its vegetative period and a smaller number of young shoots compared with the bushes

of ‘Ben Lomond’. Older shrubs of ‘Titania’ were taller and branched out less than the younger shrubs of ‘Ben Lomond’, the consequence of which was such that in the zone of herbicide application there were fewer buds, which must be regarded as the most important places of glyphosate entry into the plants.

The benefits resulting from the total elimination of or considerable reduction in the competing weeds from March until the beginning of May compensated for the phytotoxicity observed after the March treatment with the herbicides. In spite of the strong growth of weeds in May, June and July, the yields from bushes on the plots where glyphosate was applied in November or March were significantly higher than from the plots where there was no weed control during that time. The experiments confirmed good effectiveness of glyphosate, including the benefits, already described in the literature, of applying glyphosate in late autumn (Lisek 2001). Glyphosate changed the range of weed species growing in the period May-June. It reduced the number and development of winter hardy and sensitive weed species such as *Senecio vulgaris* L., *Stellaria media* (L.) Vill., *Agropyron repens* (L.) Pal. Beauv., *Taraxacum officinale* Web. Their place was taken by weeds sprouting in the spring, mainly *Chenopodium album* L. and *Echinochloa crus-galli* (L.) Pal. Beauv., and perennial weeds – *Equisetum arvense* L. and *Artemisia vulgaris* L., which at the time of herbicide application did not form green plants carrying out photosynthesis. It should be expected that the systematic use of glyphosate will control the biological diversity of weed communities and compensate for hard-to-eliminate species, as is the case in orchards (Lipecki and Szwedo 1988, Wróbel 1999). The quick development of weeds from the beginning of May was an indication of a shortlived herbicide activity in the soil, thus confirming its low harmfulness to the natural environment.

CONCLUSIONS

1. The isopropylamine and ammonium salts of glyphosate used at a rate of 1.02-2.16 kg ha^{-1} are effective in controlling winter-hardy weeds on black currant plantations during the dormant period of the bushes.
2. It is safer for black currant bushes to apply glyphosate in November than in March.
3. The soil activity of glyphosate applied in November or March is shortlived and from the beginning of May annual and perennial weeds, not controlled by glyphosate, start to grow on plantations.

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PLONOWANIE PORZECZKI CZARNEJ I ZACHWASZCZENIE PLANTACJI PO ZASTOSOWANIU GLIFOSATU

Streszczenie: W latach 2001–2003, w Skierniewicach (centralna Polska) na plantacjach porzeczki czarnej, w okresie spoczynku krzewów, oceniano efektywność zwalczania chwastów przy użyciu dwóch formulacji glifosatu, zawierających sól izopropyloaminową w dawkach 1,08 i 2,16 kg s. a. ha^{-1} oraz sól amonową (1,02 i 2,04 kg s. a. ha^{-1}). Aplikacja w listopadzie była w pełni bezpieczna dla krzewów, które nie wykazywały objawów uszkodzeń po ruszeniu wegetacji. Glifosat stosowany w marcu, powodował uszkodzenia rozwijających się pędów i liści, ale nie redukował plonowania porzeczek. Glifosat zwalczał zimotrwałe chwasty jednoroczne i wieloletnie, eliminując lub ograniczając zachwaszczenie od marca do pierwszych dni maja, kiedy rozpoczynały się masowe wschody chwastów jednorocznych oraz rozwój chwastów wieloletnich, nie zwalczanych przez glifosat.

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