Proceedings 1978 British Crop Protection Conference-Weeds

THE CONTROL OF VOLUNTEER POTATOES WITH DIFFERENT HERBICIDES AND THE APPLICATION OF A NON-SELECTIVE HERBICIDE IN SOME CROPS

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Summary In the Netherlands the growth of volunteer potatoes is a serious problem, not only from the point of view of competition with crops but also for phytosanitory reasons. Among the various methods to be considered for its solution in the present study attention was paid to the use of herbicides. Results are presented on herbicides promising for the use in various crops: auxin type herbicides, soil acting and contact herbicides. Of all products glyphosate was most promising. This herbicide offers good perspectives in crops planted at wide row distances when applied with a machine specially constructed for this purpose.

INTRODUCTION

In the Netherlands potato growing covers about 24% of the 700,000 ha in arable production. Modern harvesting methods involve a considerable loss of tubers on the field (Lumkes, 1974), which may result in an intensive volunteer growth in subsequent crops especially after mild winters.

The first exploratory experiments on chemical control of volunteer potatoes in winter wheat crops and stubbles (Lumkes and Sijtsma, 1972; Lumkes, 1974) did not produce satisfactory results. These experiments were carried out in normally established potato crops.

Research was continued with a number of herbicides alone or in combinations, in search for establishing the relation between the stage of development of the crop and the susceptibility of the plants, of the shoots as well as of the tubers. Satisfactory control was obtained with only a restricted number of herbicides in some crops in which they are used selectively. It appeared that glyphosate is a very dependable product. At first sight it can only be used in the stubble because of its little selective characteristics. However, still there are possibilities to use glyphosate for the control of volunteer potatoes in some crops grown at wide row distances, when the specially constructed band sprayer designed by Hardeman is used (CABO, internal report 1974). This paper concerns the chemical control of volunteer potatoes only.

METHODS

The research reported here concerns the study of the effects of several herbicides on planted potatoes of the cultivar Bintje (size 28/45 mm) to simulate volunteer plants. Some herbicides were applied early in spring before or after planting, either to the surface or incorporated after application. In two experiments the potatoes were planted in autumn as well as in spring, while the herbicides were also applied in autumn and/or in spring. In these experiments some other crops were also sown and tested for their competitive action upon sprouting and development of the potatoes. Several products were applied at various lengths of time after emergence of the potatoes, either before tuber formation, during tuber formation, just prior to flowering or after flowering. The potatoes were harvested when the foliage of the plants in the control plots had died off, either naturally or because of Phytophthora infestans infestation. Yields were determined per plot of 6-12 m^2 netto. The tubers were graded for size, weighed per class and counted. They were stored in a cool room and tested later for their germinative capacity.

In one case from each class ten tubers were planted out in the autumn. The soil was covered during the winter, protecting the plants from extreme frost damage, so that the germinative capacity could be assessed in early spring.

In some experimental and practical field plots an experimental band sprayer was used, either manually or mounted on a tractor. This machine is useful for a selective application of glyphosate in between the rows of crops like maize and sugarbeet. The rows were protected against exposure of the herbicide by means of protective hoods of a length of about 60 cm, a height of 6.5 cm and a width of 9 cm. The liquid was applied drop wise from a sprayboom with small holes of 1 mm spaced at 1,5 cm intervals.

RESULTS AND DISCUSSION

Preliminary experiments (Lumkes and Sijtsma, 1972; Lumkes, 1974) gave unsatisfactory results for auxin herbicides and their combinations in winter wheat, applied post-emergence to the volunteer potatoes. The results can probably related to the slow, poor and almost etiolated emergence of the potato plants in a good growing grain crop. Under these circumstances a post-emergence application takes place so late that the crop may shield the volunteer plants almost entirely.

In order to measure in a realistic way the susceptibility of the potato plant at different growth stages a number of herbicides and combinations of herbicides was also tested in a normally grown potato crop.

Auxin type herbicides

It has been shown that the sprouts of a potato plant can hardly be killed by auxin type herbicides and are most resistant to the phenoxyacetic acids (MCPA, 2.4 D). With fenoprop or, to a smaller extent, with the mixture of 2.4-D-dicamba, the potatoes survive, but the yield is often considerably reduced. In application just before or during tuber formation the number of tubers could, however, increase considerably, especially that of the small tubers and at the expense of the larger ones. In addition after application at the indicated stages many tubers showed malformations in the form of cork formation and growth fissures. During storage under controlled conditions the germinative capacity decreased. This decrease was greater in later applications. Reduction in sprouting was increased by letting overwinter the tubers in the soil (table 1).

The effect of auxin type herbicides is greatest after applications under favourable environmental conditions. In the dry summer of 1976 the potatoes were only temporarily inhibited in growth.

Soil acting herbicides

Several soil acting herbicides were tested either after planting or after emergence of the potatoes. The results obtained with the most promising products are indicated in the Tables.

An initially inhibitive effect of ethofumesate on sprouting and shoot development of potatoes growing in a sugarbeet crop could be obtained by applying 1 or 2 kg a.i./ha after planting of the potatoes. After some time the potato plants recovered and the yield and germinative capacity after storage were hardly affected (Table 2).

In practical onion growing good control results are obtained with a 2 or 3 times repeated application of chlorpropham at time intervals of several days. The shoot growth of the potatoes is controlled to such an extent that the onion crop does not suffer anymore from their presence. This result could not be obtained in an actual practical field of potatoes, where still too many tubers were formed, although they were considerably reduced both in number and size (Table 2).

Based upon the good results obtained by Lutman (1974), on fields planted in autumn and spring with potatoes (depth 5-10 cm) chlorpropham, trifluralin and dichlobenil were applied and incorporated in the autumn of 1975 and in spring 1976. It is shown in Table 3 that even the dose of 12 kg of chlorpropham/ha caused only a slight inhibition of sprouting but had no effect on yield and number of tubers. A better effect was obtained with 5 kg of trifluralin/ha, slightly less with 2½ kg in autumn and in particular at planting time of the potatoes in spring. During winter the product had moved into the zone of the tubers and/or in spring, the planting technique used caused the product to penetrate into that soil horizon. With 4 kg dichlobenil/ha a similar reduction in yield and in number of tubers was obtained, while 8 kg/ha applied in autumn resulted in a much lower emergence of potatoes planted in the spring (Table 3). A shift was observed from the larger to the smaller sized tubers. The poor or small effect of the mentioned herbicides can probably be explained by drought in the winter and in spring which may have retarded their penetration from the upper to the deeper soil horizon reaching the buds of the potatoes. Under the more humid conditions of the spring 1975 with 4 and 8 kg of chlorpropham the emergence of a large number of tubers could be prevented, although the production per plant of tubers still emerging was almost normal. These products cannot however be used in practice, because high doses are needed. Moreover, their long persistence in the soil may affect the subsequent crop.

Better results could be obtained with metoxuron or a mixture of atrazine with a mineral oil and/or wetting agent, applied on still very small potato plants (Table 2). An addition of mineral oil to metoxuron occasionally weakened the effect. With both products, however, the results are strongly dependent on weather conditions. Similar to the situation with soil acting herbicides this dependence was particularly evident during the exceptionally dry season of 1976. But even under favourable weather conditions, the degree of control of tuber formation obtained was sometimes disappointing. Similar variable results with a.o. metoxuron were observed by Lutman (1976) and are partly explained by the observation of Lutman (1977) that volunteer plants emerging from small tubers are more susceptible than those coming from larger ones.

It was quite apparent that soil acting herbicides and probably to a greater extent the auxin type herbicides are more effective under the better environmental conditions when applied post-emergence to the volunteer potatoes on a humid soil at a sufficiently high temperature. Perhaps the plants and the weeds in general, are then less hardened off, and tissues of the shoot are more accessible to the herbicide.

Although the mentioned herbicides, the auxin type herbicides included, are sometimes quite effective, the suppressing effect of a more strongly competitive crop is much greater. In the experiments carried out so far, the multiplication factor of planted potatoes in cereals was only 0.75-1.5. Without a crop by all the mentioned herbicides this factor was several times higher. Moreover the tubers formed by plants that suffered from competition had in majority a diameter smaller than 25 mm.

Contact herbicides

Contact herbicides like DNOC, diquat, paraquat, dinoterb and ioxynil have an effect similar to that of hoeing. Above the soil surface the plant is partly or entirely killed, but resprouting takes place rather soon. Glyphosate, however, has quite another effect. This herbicide not only kills the above ground parts, but is also translocated to the subterraneous parts, including the already formed tubers. When applied to small plants, prior to tuber formation sometimes resprouting could occur (Table 4). This phenomenon was not observed after tuber formation, or on "natural" volunteer potatoes. This may be related to the origin of natural volunteer potatoes which is mainly from smaller tubers, and moreover to the fact that a potato tuber left in winter in the soil forms new tubers earlier in the season than a potato tuber planted in spring. In one experiment all the tubers present at the time of application were entirely rotten at harvest time. In other experiments only a small percentage of the tubers survived, and even the survivors were partly damaged by the herbicide. The best effect was obtained under adequate soil moisture conditions at a temperature of about 20 °C. During dry and warm weather the above ground parts die off too rapidly. Perhaps the transport to the subterrane plant parts was too slow. After tuber formation this transport increases so that the effect of herbicide application is better after tuber formation. During storage many of the tubers that were hit by the herbicide initiated cork formation but still many of them were capable of sprouting. However, sprouting strongly decreases after storage in the soil. Advantage can be taken of all these factors in an application of glyphosate in the stubble of cereals.

In a recent experiment it was observed that if 1/3rd or half of the number of stems of mature plants was protected against being contacted by the herbicide the originally covered stems developed symptoms due to glyphosate after about 8 days. After 3 weeks the shielded stems were not or only partly killed. It was important, however, that there was a large number of attacked tubers: white dots, growth fissures like those noticed earlier after fenoprop applications, and occasional rotting.

Although glyphosate cannot be selectively applied in any arable crop there are still possibilities for its use in crops drilled at wide row distances with a machine specially designed to this purpose (Hardeman, 1974). The principle of this machine has been explained before under "methods". The drift hazard does not allow the use of glyphosate in another way. In maize and sugarbeet crops its use resulted in an almost 100% kill of natural potato volunteers and also of those growing in the crop rows.

Based upon the Hardeman-principle, a prototype factory made machine was constructed in 1977 which could be mounted on the back of a tractor. It appeared however that this construction was not optimal. In 1978 we also experimented with this prototype put in front of or underneath the tractor, like a hoeing attachment, to enable the driver to survey the work better. The reason for its placement behind the tractor was to prevent the tractor wheels picking up any spray liquid from the treated plants and taking it to the crop. With the attachment in front of the tractor this effect was never observed. To attain the desired density of volunteer potatoes they were planted in almost all the experiments. It appeared that planted potatoes needed a higher dose of glyphosate than natural volunteer potatoes. For practical purposes the recommendation now could be 1 kg a.i./ha. In 1977 the first experiments with this machine started.

As appears from Table 5 in 1978 we investigated several selective methods of application, for instance, a spraying machine with shields protecting the rows instead of with hoods. This will permit additional, much later treatments. However, this version constructed with spray nozzles, gave more drift as apparent from the increased kill and the frequency of symptoms.

The kill of potato plants between the crop rows was efficient. In the crop rows as indicated in Table 4 the effect was less than in the years before. This is probably due to the abnormal weather conditions before, during and after treatment with a dry, very warm period at the end of May and in early June. Under more favourable conditions the special properties of glyphosate make the treatment adequate when only a part of the plant is hit by the spray liquid. It was noticed that plants that were not killed but only partly hit by the spray liquid were inhibited in growth and showed abnormalities in their tops.

Based upon all the results it is justified to start in practice.

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Table 1

Results on field planted potatoes with fenoprop and 2.4-D/dicamba

Time of appl.	Herbicide and dose in kg a.i./ha		% tubers				Rel. yield				% infected tubers			% germination conditioned storage				% germination over wintering in soil 1975	Tuber size in % < 35 mm ∅			
			1974	1975	1976	1977	1974	1975	1976	1977	1974	1975	1976	1974	1975	1976	1977		1974	1975	1976	1977
I	fenoprop	1,5		130		215		85		70		64			74		24	48		72		83
	fenoprop	1,5	118	79	130	150	65	62	101	71	62	76	33	44	30	31	10	17	65	58	67	72
II	2.4-D/dicamba 1,25/0,6		86				58				55			69					47			
III	fenoprop	1,5	115		114		75		104		30		17	7		29			50		64	
IV	fenoprop	1,5	105	91			100	98			15	5		79	63			36	40	42		
	untreated	-	100= 665	100= 733	100= 1042	100= 918	100= 492 kg	100= 32 kg	100= 36 kg	100= 49 kg	11	8	6	89	95	98	52	77	40	53	59	41

I = before tuber formation
II = early tuber formation
III = early flowering
IV = post flowering

Table 2

Influence of some herbicides on field planted potatoes, variety Bintje. Sandy soil.

Herbicide and dose in kg a.i./ha		Time of application	% tubers				Rel. yield				% infected tubers			% germination					Tuber size in % < 35 mm Ø			
														conditioned storage				over wintering in soil 1975				
			1974	1975	1976	1977	1974	1975	1976	1977	1974	1975	1976	1974	1975	1976	1977		1974	1975	1976	1977
ethofumesate	1	after plant.	105				100				11			90					39			
ethofumesate	2	after plant.	96				87				45			90					41			
dichlobenil	1.8	after plant.	98			82	105			72	13			89			24		36			56
dichlobenil	3.6	after plant.	82				90				18			89					38			
atrazine	1.5	after plant.	44	47	107	67	36	38	118	51	5	3	10	88	94	99	46	89	44	66	57	52
atrazine mineral oil	2.5 5.2	before tuber formation		0	93	20		0	113	12		0	7		0	98	42			0	58	59
atrazine Citowett	1.5 2	before tuber formation			58				77				6			97					53	
atrazine mineral oil bentazon	1.5 2.6 1.4	before tuber formation			50	31			65	26			5			100	48				51	47
metoxuron	3.2	before tuber formation		22	44	9		19	62	7		30	11		86	96	26	80		64	53	56
metoxuron mineral oil	3.2 5.2	before tuber formation		34	50	2		25	68	2		17	5		81	99	40	86		67	51	50
chlorpropham	2.4 3x	before tuber formation			30	48			17	27			39			99	63				80	67
untreated	-	-	100= 665	100= 690	100= 1042	100= 918	100= 492 kg	100= 28 kg	100= 36 kg	100= 49 kg	11	8	6	89	96	98	52	90	40	55	59	41

Table 3

Influence of chlorpropham, trifluralin and dichlobenil, incorporated on planted potatoes, 1975/1976. Clay soil.

Herbicide and dose in kg a.i./ha		Time of application	% emerged plants		Rel. yield		% tubers		Tuber size in % < 35 mm ∅	
			P1	P2	P1	P2	P1	P2	P1	P2
chlorpropham	6	October	100	100	116	94	110	86	48	37
chlorpropham	6	February	98.6	100	103	117	95	102	40	38
chlorpropham	12	October	98.6	100	116	103	114	114	43	50
chlorpropham	12	February	100	98.6	121	102	116	92	45	42
trifluralin	2½	October	100	100	115	82	118	62	51	42
trifluralin	2½	February	94.4	100	105	106	92	98	45	44
trifluralin	5	October	100	97.2	127	64	64	40	49	32
trifluralin	5	February	94.4	97.2	73	106	106	79	49	31
untreated	-	-	100 = 24 kg	100 = 24 kg	100 = 278 kg	100 = 320 kg	100 = 4778	100 = 5664	42	45
dichlobenil	1	October	100 = 24	100 = 24	103	104	103	85	52	53
dichlobenil	1	February	93	100	67	82	76	75	46	54
dichlobenil	2	October	100	99	79	78	74	73	54	54
dichlobenil	2	February	97	100	91	109	85	93	60	57
dichlobenil	4	October	78	68	61	53	44	40	70	69
dichlobenil	4	February	97	100	86	97	101	92	48	52
dichlobenil	8	October	50	32	49	10	28	7	74	67
dichlobenil	8	February	72	54	56	32	59	28	60	64
dichlobenil	8*	October	96	100	79	76	89	74	47	50
dichlobenil	8*	February	100	96	89	78	107	89	50	42
untreated	-	-	97	99	100 = 5704 kg	100 = 5842 kg	100 = 292	100 = 320		

* Not incorporated

P1 = planting date: 28 October 1975

P2 = planting date: 23 February 1976

Date of application: 30 October 1975
24 February 1976

Cultivar: Bintje, 28/35 mm ∅

Table 4

Influence of glyphosate on field planted potatoes, variety Bintje.

Time of appl.	Chemical	Dose in kg a.i./ha	% tubers				Rel. yield				% infected tubers			% germination conditioned storage				% germination over wintering in soil 1975	% rotten tubers 1977	Tuber size in % < 35 mm ∅			
			1974	1975	1976	1977	1974	1975	1976	1977	1974	1975	1976	1974	1975	1976	1977			1974	1975	1976	1977
	glyphosate	1.08	28		7	0.3	31		13	0,1	16		16	70		95	0		100	43		44	67
	glyphosate	1.44		24				19				33			91			[illegible]			71		
I	glyphosate	2.16	37		13	2	33		18	2	11		9	76		99	24		76	44		44	30
	glyphosate	2.88		13				11				17			93			53			75		
	glyphosate	3.24	20				29				7			70						27			
	glyphosate	1.08	43		27	2	24		8	0.4	13		91	80		83	47		53	71		96	
	glyphosate	1.44		0				0				0			0			0			0		
II	glyphosate	2.16	3		13	0	2		3	0	3		93	91		46	0		0	54		95	
	glyphosate	2.88		0				0				0			0			0			0		
	glyphosate	3.24	1				1				0			65						65			
	glyphosate	1.08	42		73	78	18		27	38	92		99	44		62	57		42	75		89	
III	glyphosate	2.16	16			64	5			28	95			32			61		39	81			
	glyphosate	3.24	13				4				90			21						84			
	glyphosate	4.32	7				2				90			33						87			
	glyphosate	0.72	107				90				47			87						41			
IV	glyphosate	1.44	114	107			94				43	27		75	94			5		44	54		
	glyphosate	2.88		98								32			92			5			57		
	glyphosate	4.32	97				84				63			45						41			
	untreated	-	100= 665	100= 773	100= 1042	100= 918	100= 92 kg	100= 263 kg	100= 36 kg	100= 49 kg	11	8	6	89	95	98	52	77	47	40	53	59	41

I = before tuber formation
II = early tuber formation
III = early flowering
IV = post flowering

Table 5

Results of some inter row applications with 1.08 kg a.i./ha glyphosate in maize and sugarbeet with different machines in 1978

Crop	Type of machinery used	% plants of the crop Killed		Damaged		Visual assessment of the crop on 13 June[1]		Planted potatoes in the crop row % killed	% damaged	% not damaged
		+	-	+	-	+	-			
Maize	A = Shield-sprayer rear mounted	22.3	22.1	32.4	23.9	2.4	3.2	5	49	46
	B = Hood-protection dribble bar front mounted	2.2	0.5	10.5	2.4	5.8	7.7	7	49	44
	C = Some manually operated	11.5	4.4	9.8	7.2	5.0	6.8	2	63	35
	D = Some mounted underneath tractor	0.9	4.1	3.6	2.4	7.7	8.2	7	41	52
	Untreated	0	0	0	0	9	9	0	0	100
Sugarbeet	A = Shield-sprayer mounted in front of tractor	13.1	11.9	28.7	30.1	4.3	4.8	8	36	56
	B = Same rear mounted	10.6	8.4	40.1	32.6	3.0	4.8	2	49	49
	C = Hood-protection dribble bar front mounted	10.4	8.9	12.4	2.4	4.8	5.7	9	46	45
	D = Same rear mounted	17.2	15.4	15.0	5.0	3.0	5.0	12	47	41
	E = Same manually operated	27.0	15.9	24.7	14.4	3.3	5.8	24	60	16
	F = Same mounted underneath tractor	11.7	8.4	12.4	5.8	5.0	6.3	7	43	50

[1] 9 = not damaged
1 = killed
\+ = with planted potatoes
\- = without potatoes
Date of application: 31 May 1978

Proceedings 1978 British Crop Protection Conference - Weeds

INFLUENCE OF CROPS ON VOLUNTEER POTATOES

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SUMMARY

When we found that the number of volunteer potatoes in different crops was not always the same, a field experiment was set up to study the influence of different crops on the emergence, growth and reproduction of volunteer potatoes.
In spring eight tubers/m^2 of potatoes, variety Bintje, were planted in perennial ryegrass, winter barley, winter wheat, spring barley, spring wheat, sugar-beet and maize. Crops and potatoes were grown in monoculture.
The emergence of volunteer potatoes in spring is retarded by crops that are sown in autumn and have a high light interception by the end of April. The lower soil temperature seems to be responsible for this retardation.
In the winter cereals and perennial ryegrass, the volunteer potato plants are small, and die often very early. Only one or two small tubers are formed per potato plant. In the spring cereals growth of potato plants is suppressed less than in winter cereals. However, tuber production in spring barley is about the same as that in winter cereals whereas tuber production in spring wheat is twice that in winter cereals. Maize and sugar-beet were completely overgrown by volunteer potatoes, so the yield of the volunteer potatoes was not evidently influenced by these crops. Tuber production was measured on 17 July. It is possible that later in the growing season the production of volunteer potatoes strongly is influenced by harvesting date and regrowth possibilities.

INTRODUCTION

The crop and the crop growing system are very important for the occurrence, development and reproduction of weeds. The damage caused by a weed depends also on the crop and the crop growing system.
The time between sowing date and the date when the ground is completely covered by the crop is very important because in this period most weeds establish. Every crop has its own microclimate and it is unlikely that all weeds are influenced in the same way by differences in light, temperature and humidity. Because micro organisms (diseases) are influenced by the microclimate too, there is an indirect affect.
The harvesting date is important because harvesting almost always means the end of the growth of plants in the harvested crop and by this time weeds must have formed seeds or other reproductive organs (rhizomes, tubers). However, if the harvesting date is very early, some weeds can regrow.
In our trial we regarded volunteer potatoes as a perennial weed whose occurrence, development and reproduction depends on the factors mentioned.

PRESENCE OF VOLUNTEER POTATOES IN DIFFERENT CROPS

In the crop rotation trial "de Schreef", situated in the Flevopolder, the number of volunteer potatoes in the crops has been counted every year since 1971 (Hoekstra en Maenhout 1976). The number of volunteer potatoes in a crop depends partly on the harvesting losses of the previous potato crop and on the intensity of tuber killing by frost during the winter. Thus this number is different almost every year (Lumkes 1977). In some years, numbers of volunteer potatoes above 200,000/ha were found in some crops and numbers above 50,000/ha were counted frequently. The average number of volunteer potatoes in the crops of the crop rotation trial over a period of seven years is shown in Table 1.

Table 1

Number of volunteer potatoes (x 1000)/ha in the crops of the crop rotation trial "de Schreef", average of the years 1971-1977.

(sp=sporadic=less than 510 plants/ha [1]w.wheat since 1975)

Nr.	Previous crop	In 1st crop		In 2nd crop		In 3rd crop		In 4th crop		In 5th crop	
2 A	Potatoes	S.barley	45	Peas	5	W.wheat	2	Flax	1	Grasseed	sp
3 A	Potatoes	W.wheat	14	Flax	3	S.beet	4	S.barley	1	Peas	sp
3 B	Potatoes	S.barley	41	Lucerne	1						
3 C	Potatoes	S.barley	38	Grasseed	7						
4 A	Potatoes	W.wheat	15	S.beet	6	S.barley	2				
4 B	Potatoes	Grasseed	15	S.beet	7	S.barley	1				
5 A	Potatoes	S.beet	52	S.barley	2						
5 B	Potatoes	Grasseed	20	S.beet	7						
6 A	Potatoes	S.beet	62	Peas	3	Oats	2	S.barley[1]	1	Ley	sp
6 B	Potatoes	S.beet	60	Peas	6	S.barley[1]	4	Ley	sp	Ley	sp
6 C	Potatoes	S.beet	61	S.barley	4	Ley	sp	Ley	sp	Ley	sp

The conclusion is that after a potato crop there are less volunteer potatoes in the following crop when this crop is sown in autumn (grass seed, winter wheat) than in spring (spring barley, sugar-beet). The average number of volunteer potatoes per hectare is 16,000 with crops sown in autumn and 50,000 with crops sown in spring. In rotations with a duration of three or four years, there are always many volunteer potatoes on the field.
The very different results of the crop rotation trial "de Schreef" was the reason to set up field trials with simulated volunteer potatoes in different crops to study the influence of the condition of the environment on volunteer potatoes.

FURTHER RESEARCH INTO THE BEHAVIOUR OF VOLUNTEER POTATOES IN DIFFERENT CROPS

1. Method. Volunteer potatoes were simulated by planting potatoes, variety Bintje, in the beginning of March 1978 in (already sown) winter crops and (not sown yet) summer crops. Eight tubers of size 25-28 mm were planted per m^2 in one half of the field so that we could compare crops growing with and without volunteer potatoes. Table 2 shows the crops used in our research and the cultivation system.

Table 2

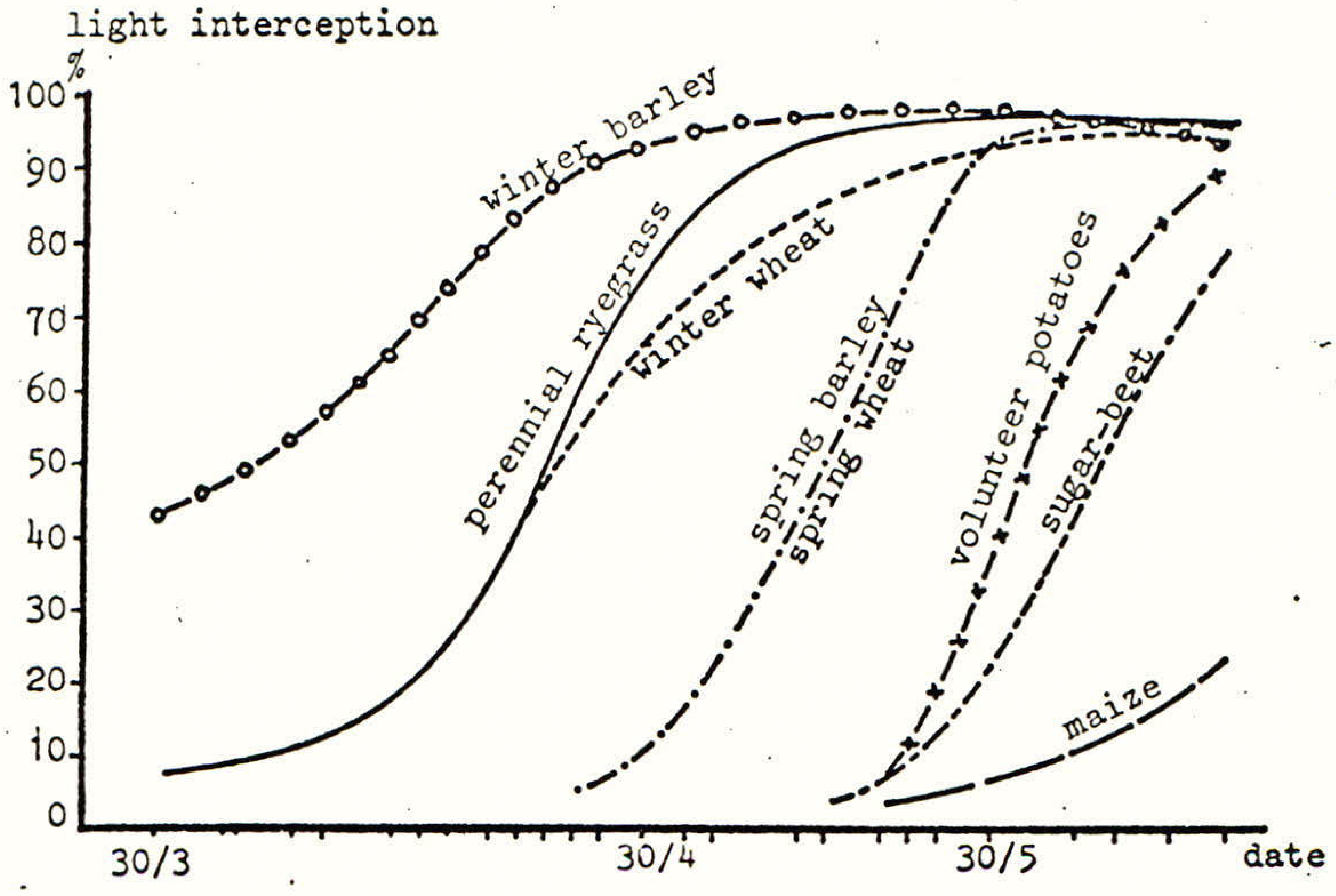
Crops and crop growing systems, 1978.

crop	variety	seed rate/ha	distance between rows	sowing date	kg N/ha
perennial ryegrass	Premo	10 kg	25 cm	27/9/77	100
winter barley	Banteng	110 kg	12.5 cm	27/9/77	80
winter wheat	Lely	140 kg	12.5 cm	25/10/77	120
spring barley	Pirouette	100 kg	12.5 cm	5/4/78	60
spring wheat	Bastion	140 kg	12.5 cm	5/4/78	90
sugar-beet	Monohil	140,000 seeds	50 cm	8/4/78	160
maize	LG 11	110,000 seeds	75 cm	25/4/78	200
only vol.potatoes	Bintje	800,000 tubers	35 cm	7/3/78	140

We measured growth of the crops with and without volunteer potatoes and emergence, growth and reproduction of the volunteer potatoes.

Figure 1.

Light interception at different dates of crops grown without volunteer potatoes and of volunteer potatoes grown without a crop, 1978.



2. Growth of the crops. Because the disposal of light is very important in plant competition, the growth of a crop was measured by its light interception at different times. Figure 1 shows the growth of the crops without volunteer potatoes and of volunteer potatoes growing without a crop.
It is evident that the light interception of crops sown in autumn is nearly hundred percent when sugar-beet, maize and volunteer potatoes still have to start growing. The spring cereals grow faster than the latter group of crops but slower than the autumn-sown crops. Sugar-beet and especially maize grow less quickly than volunteer potatoes.

3. Rapidity of emergence of volunteer potatoes. In spring the rapidity of emergence of volunteer potatoes in the crops is very important because every day emergence is delayed, the competition ability of the crops grows stronger and stronger, so that the volunteer potatoes have more difficulty in growing.
The first potatoes emerged at the beginning of May. Natural volunteer potatoes near our trial emerged at the same time, so in this way the simulated volunteer potatoes were normal.
The number of emerged volunteer potatoes in the different crops was counted on 8 and 16 May. Table 3 shows the percentages of the tubers that had emerged by these dates.

Table 3

Percentages of volunteer potatoes that had emerged by two dates, 1978

crop	8 May	16 May
perennial ryegrass	2	16
winter barley	0	1
winter wheat	2	16
spring barley	6	56
spring wheat	14	69
sugar-beet	18	65
maize	8	63

In the crops sown in autumn the volunteer potatoes emerged more slowly than in spring-sown crops, probably because of the soil temperature. On a sunny day at the beginning of May, the soil temperature 6-7 cm below the surface was measured. Under winter barley it was 12° C, under winter wheat 15° C, and in a field without a crop 18° C. Under spring-sown crops the temperature was almost the same as in the field without a crop. We concluded that the presence of a winter crop delays the heat supply of the soil and therefore the emergence of volunteer potatoes. By the end of May almost all the volunteer potatoes in all the crops had emerged.

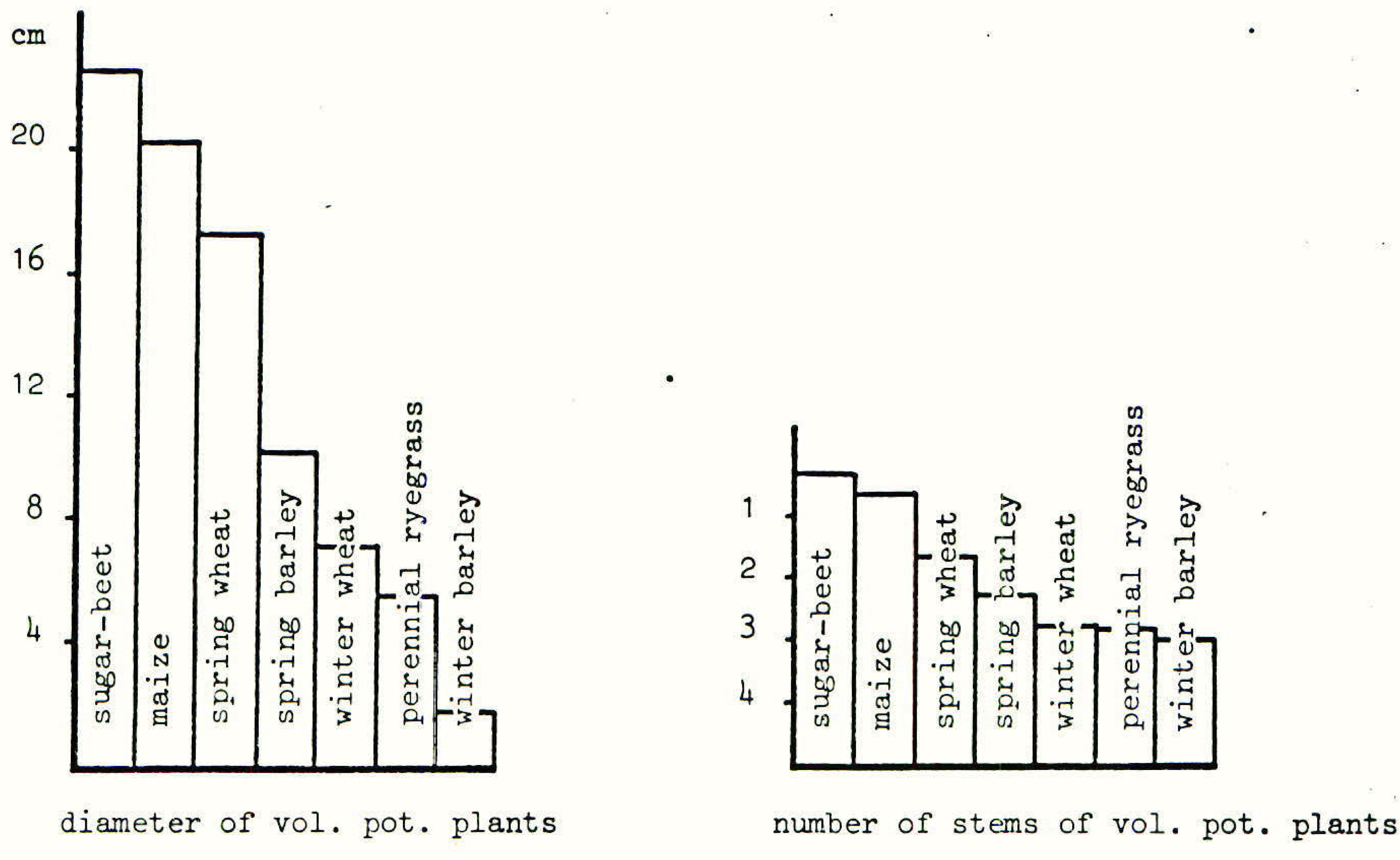
4. Growth, vitality and mortality of volunteer potatoes. Because the environmental conditions of the potatoes were totally different in the various crops, we expected them to react. On 29 May, the diameter of the volunteer potato plants and the number of stems were measured. The results are shown in Figure 2. In crops sown in autumn the volunteer potatoes have a much smaller diameter and fewer stems than in crops sown in spring. There is a resemblance between the growth of the volunteer potatoes and that of the crops (Figure 1). When the crop intercepts more light, the growth of the volunteer potatoes falls of (Figure 2).

An important thing to know is when and why volunteer potatoes die. Our impression is that volunteer potatoes die earlier when the density of the crop is high (more light interception) because of lack of light and due to disease. The volunteer potatoes in sugar-beet and maize and the volunteer potatoes without a crop were healthy until at least the end of July. In winter barley and perennial ryegrass there were dead plants already at the end of May (when the last plants emerged!). On 17 July about 40% of the volunteer potatoes in perennial ryegrass had died off. In the other cereals, the health of the volunteer potatoes was poor too, but not as poor as in winter barley and perennial ryegrass. When a potato plant obtains more light, it often quickly recovers its health. This can happen by lodging of cereals, by the potato plant growing above the crop and by ripening of crops. Only when all the stems are already dead there is no reaction to better climatic conditions.

The potatoes we used for our experiment were in general much healthier than natural volunteer potatoes because they were selected seed potatoes.

Figure 2.

The average diameter and the average number of stems of volunteer potatoes grown in different crops. Date: 29 May, 1978.



5. The tuber production of volunteer potatoes. The tuber production of volunteer potatoes is important because tubers formed this year cause the volunteer potato problem of the next year. On 17 July potatoes were harvested. The number of tubers produced and the yield is shown in Table 4.

Table 4

Number of tubers and yield of 10 volunteer potato plants grown in different crops. Harvesting date: 17 July 1978.

	number							yield (gr)						
diameter (cm)	<1,3	1,3-2,5	2,5-3,5	3,5-4,5	>4,5	tot	%	<1,3	1,3-2,5	2,5-3,5	3,5-4,5	>4,5	tot	%
perennial ryegr	6	12	0,3			18	17	4	46	7			56	1,5
winter barley	4	12	0,3			16	16	4	72	3			78	2,1
winter wheat	8	17				25	24	5	70				75	2,0
spring barley	9	20	0,3			29	28	7	80	6			92	2,4
spring wheat	11	29	5			44	42	6	120	57			183	4,9
sugar-beet	7	33	34	43	11	127	121	6	179	748	2068	1058	4058	105
maize	3	22	31	36	8	100	95	3	120	688	1873	723	3405	88
only vol. pot.	8	17	29	39	12	105	100	7	83	638	2068	1068	3862	100

Perennial ryegrass and cereals reduce the tuber production of volunteer potatoes until 2% of the yield and until 25% of the number. Mostly about two very small tubers were formed per volunteer potato plant. At the harvesting date the production of spring wheat, however, was about twice that of the other cereals. The production of volunteer potatoes is hardly influenced by sugar-beet and maize. This is understandable because these two crops were completely overgrown by the volunteer potatoes. So if the farmer does not control volunteer potatoes in these crops, he might have a normal potato yield.

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THE POSSIBILITY OF THE CONTROL OF VOLUNTEER POTATOES WITH PARAQUAT IN MAIZE AND GLYPHOSATE IN THE STUBBLE

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Summary To control volunteer potatoes in maize, it appeared that paraquat only reduced the yield of the new formed tubers, but they were healthy and abundant. In planted potatoes treatments of diquat, DNOC and 2,4-D were studied. Except in the case of 2,4-D, the yield was reduced and a shift was observed towards small tubers.
Glyphosate applied as a stubble treatment gave acceptable results.
The number of rotting tubers was high in different years. A mixture of glyphosate and 2,4-D was less effective. Spraying in the stubble with glyphosate seems to be justified, when the potato volunteer plants grow well.

INTRODUCTION

From many points of view volunteer potato plants are troublesome. The modern harvesting techniques leave a great number of tubers behind in the field. (Lumkes, 1974). Partly as a result of the mild winters these last few years, not enough of these tubers rot away.
Chemical control is often inadequate, because the herbicide used is either ineffective against volunteer potatoes or too toxic for the crop (Lumkes and Sijtsma, 1972).
Since in a maize crop spraying with paraquat can still be practiced at an advanged stage of development, it was investigated to what extent such treatment could control volunteer potato plants.
On account of promising perspectives over the past years, a great deal of attention is also given to the chemical control of volunteer plants in the stubble.

METHODS

Field experiments were conducted in three or four replications
1. in maize, to compare different herbicides;
2. in planted potatoes, to determine yield;
3. in the stubble, to evaluate the effects of different dosages and mixtures of herbicides.

The results of the various experiments are shown in the tables. To assess the controlling effect on volunteer potato plants and/or the crop, a scale of 1 - 10 was used; 1 = no effect on volunteers; crop killed, as the case may be, and 10 = all volunteers killed: no symptoms in the crop, as the casy may be.

RESULTS AND DISCUSSION

As the area of maize cut for silage was extended, volunteer potato plants in this crop became a bigger problem. Of the herbicides used with the cultivation of this crop, even atrazine was as a rule inadequate in its controlling effect.
When from own regional research it appeared that paraquat could also be applied selectively in maize in post-emergence treatments, we investigated the use of such treatment in controlling volunteer potato plants.
Using special equipment, the herbicide was applied between the rows without contacting the leaves from the time the maize plants had reached a height of 50 cm. The lower 8 - 10 centimetres of the maize stems were sprayed at the same time, so as to apply the chemical properly also to the tweeds within rows. The results of this investigation are presented in table 1. Only the effect on the aerial parts of the volunteer potatoes was determined.
Further observations showed that already developed tubers had hardly suffered any damage.
In planted potatoes it was studied how the spraying had effected the development of tubers. In stead of paraquat we used diquat and also 2,4-D and DNOC.
Diquat was applied, because this herbicide was assumed to be more effective than paraquat.
The trial plots were sprayed when the potato foliage was about 25 cm tall.
Tubers were harvested at two different times. The results are given in tables 2 and 3. From the tables it appears that the yield was reduced, except for the case when 2,4-D was used. Newly formed tubers however were healthy and abundant showing practically no difference from untreated plots (tables 2 and 3).
Nevertheless, a clear shift towards small sizes was observed and for this reason such treatment can not applied in practice.

An aditional drawback is the late stage at which the control can take place, since from the viewpoint of competition the potato plants have grown too long among the maize crop. Notwithstanding all the precautions taken, the spraying involves a certain risk for the maize, especially so when using improper equipment (table 1). More promise is offered by another technique (machinery fitted with shields) which makes earlier application possible, but which is not described in this paper.

A number of years ago glyphosate was officially approved in the Netherlands for use as a herbicide in the stubble. It provided good results in the control of both monocotyledonous and dicotyledonous weeds, while affecting to a certain extent also volunteer potato plants.
From screening tests (of the Centre for Agrobiological Research in 1974) it appeared that glyphosate damaged not only the aerial plant parts but also the tubers, causing often rotting at a later stage. In 1976 several trials were conducted in heavily volunteer-infested stubble fields (Baart, 1977). The results were good. The number of tubers that had rotted was high, although the smaller specimens showed to be least sensitive. The success was observed clearly in the catchcrop.
In further research glyphosate was tested both at various dosages and in a mixture with the hormone weed killer 2,4-D. The mixture was not only tried as a control of volunteer potato plants. It was also applied to see in how far its effectiveness could be enhanced for weed control in general. Included in these experiments was also amitrol/ammoniumthiocyanate.
The results are presented in the tables 4 and 5.
When evaluating the effects (KB I), glyphosate appeared to score good results, with the smaller tubers being again least sensitive. Adding 2,4-D, its activity was practically cancelled. In maize, however, the differences in control between glyphosate and the other treatments were small, especially as compared to amitrol/ ammoniumthiocyanate.
In WS I, (table 5) four weeks after application, we noticed but a weak reaction in the potato plants. In sugarbeet the mixture glyphosate + 2,4-D is least successful. The experiments were continued in the autumn of 1977. The stolon and tuber formation of the plants was considerably less than in the autumn of 1976.

This is probably due to the better weather conditions in 1977, which resulted in a long vegetation period and consequently better developed tubers.
Tubers therefore showed less re-growth. The frosty weather in the beginning of 1978 destroyed many of the potato tubers that had stayed behind in the soil and in most of the experiments no differences could thus be established.
For only one experiment WS II in beet in 1978 the following differences were observed:
Untreated: 8 volunteer plants per 40 m^2
Glyphosate + 2,4-D treatment: 3 volunteer plants per 40 m^2. There were no volunteer plants in the other objects.
From the experiments it is evident that spraying in the stubble is justified when the volunteer plants grow well. In some cases it may be better to cut the stubble at a higher level than normally so as to cause less damage to the plants and make it possible for them to take up sufficient amounts of herbicide.

Resume Dans la lutte contre les repousses de pommes de terre en culture de mais il est apparu que le paraquat ne fait que réduire le rendement des tuberculus nouvellement formés; toutefois ceux-ci sont sains et nombreux.
En pommes de terre plantées des traitements au diquat, au DNOC et au 2,4-D ont été étudiés.
Sauf dans le cas du 2,4-D, on a observé pour ces produits une baisse de rendement avec formation de tubercules en moyenne plus petits.
Le glyphosate appliqué sur chaumes a donné des résultats acceptables.
Certaines années on a observé on a observé un nombre élevé de tubercules atteints de pourriture.
Le mélange de glyphosate et de 2,4-D fut moins efficace.

En conclusion, il parait justifié d'effectuer sur chaumes une pulvérisation au glyphosate lorsque les plantes issues de repousses de pommes de terre sont en pleine croissance.

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Table 1

Within row and between row control of volunteer potatoes in maize

Herbicide	kg a.m./ha	Appl. time	Control July Exp. I	Control July II	Crop ass. July Exp. I	Crop ass. July II
atrazine + 11 E oil	1 + 5.6	post-em. 4 leaf	6	5	9	9
terbutryne + 11 E oil	1.5 + 2.58	post-em. ± 50 cm	6	6	8	9
paraquat	0.6	post-em. ± 50 cm	6	8	7	5

I Exp: Zuid-Limburg = Löss clay
organic matter = 1.8%
silt + 28%

II Exp: Noord-Limburg = Sandy soil
organic matter + 3.8%

Table 2

Control of potatoes (planted) by post-emergence (20 cm tall) treatment with herbicides

Herbicide	kg a.m./ha	Crop ass.	Yield of tubers at two different times 20 July (15m²) Calibration 35 mm	35/45 mm	45+ mm
Untreated		8.5	14.73 kg = 100	29.45 kg = 100	5.85 kg = 100
2,4-D	1.25	5	21.43 " = 146	30.00 " = 100	3.85 " = 66
diquat	0.60	3	14.78 " = 100	5.08 " = 17	1.05 " = 18
DNOC	4.80	6	15.77 " = 101	19.81 " = 67	2.75 " = 47
			1 September (15 m²) 35 mm	35/45 mm	55+ mm
Untreated		8.5	5.12 kg = 100	59.48 kg = 100	42.70 kg = 100
2,4-D	1.25	5	6.47 " = 126	69.03 " = 116	31.70 " = 74
diquat	0.60	3	4.74 " = 93	47.28 " = 79	27.45 " = 64
DNOC	4.80	6	5.32 " = 103	58.93 " = 99	34.24 " = 80

Exp. Flevo: Marine clay - silt 40% organic matter 2%

Table 3

Control of planted potatoes

Herbicide	Kg a.m. ha	Appl. time	Yield kg	Number of tubers	Calibrations % 25	25/35	35+ mm	Germination %
diquat	0.8	1	13.49	436	68	82	89	87
diquat	0.8	2	14.71	463	65	80	79	85
diquat	0.8	3	13.65	417	69	73	77	83
untreated			27.96	491	80	79	90	91

1 = first tubers 0-15 mm
2 = one week later
3 = tubers to 0-30-40 mm

Exp: IBS 1561
Marine clay; silt:38%
organic matter: 2%

Tabel 4

KB I Stubble treatment against volunteer potatoes Evaluation at 25 October 1976 (2 x 6 plants) 8 July 1977

Herbicide	kg a.m./ha	time appl.	number of tubers	number of rotting tubers	% rotting tubers	score in maize
amitrol/ ammoniumthiocyanaat	8	22 September	23	10	43	6.6
glyphosate	1.44	22 September	19	13	68	7.3
glyphosate	2.16	22 September	21	16	76	7.8
glyphosate + 2,4-D	1.44 + 2	22 September	30	2	7	6.3

5-6 pl/m^2 cultivar: Ostarte

10 = no potato plants

Exp: Drenthe: Sandy soil
organic matter = 6%

Table 5

WS I   Stubble treatment against volunteer potatoes

Herbicide	kg a.m./ha	time of appl.	Control	Score in sugarbeet
			25 October '76	26 July '77
amitrol/ ammoniumthiocyanate	8	22 September	6	7
glyphosate	1.44	22 September	6	8
glyphosate	2.16	22 September	6	8
glyphosate + 2,4-D	1.44 + 2	22 September	5	6

Exp: Westmaas: Maryne clay
silt 39%
organic matter 2.5%

Proceedings 1978 British Crop Protection Conference - Weeds

EFFECTS OF CROP AND WEED MANAGEMENT ON FIELD POPULATIONS OF VOLUNTEER POTATO

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Summary Counts of volunteer potato plants in June 1975 reflected differences in cereal cropping and herbicide practices in previous years. Choice of cereal crop in 1972/73 had more effect than choice of crop in 1973/74, but, in general, winter wheat reduced potato populations more than did spring barley. In particular, two successive crops of winter wheat reduced survival into 1975 by 73% compared with the potato population found on plots given two successive crops of spring barley. The effect was still evident in June 1976. Where no herbicide treatments were applied in the cereal crops, considerably fewer potato plants were recorded in 1975 than when the cereals had been treated with MCPA or a dichlorprop/ioxynil/bromoxynil mixture. This was attributed to the increased competition suffered by potato plants on unweeded plots. Soil management treatments in 1975 and 1976 involving rotary cultivation for a part or all of the spring, summer and autumn gave better control than regular applications of paraquat alone. The results are discussed in relation to ways of improving the control of volunteer potatoes by crop rotation and weed control technique.

INTRODUCTION

Volunteer potatoes have become a major weed problem in arable rotations in recent years. Considerable research effort has been directed to improving potato harvesting techniques, modifying post-harvest tillage and evaluating chemical methods of control (Lumkes, 1974; Lutman, 1974a, 1974b). The biology of survival of volunteer potatoes has been examined over a period of years at Invergowrie (Perombelon, 1975) and their persistence recorded in fields given different subsequent cropping patterns. Results suggested that they could survive in large numbers where several years of cereal cropping followed the potato crop, but that numbers fell sharply when soft fruit or vegetable crops were included in the rotation. There is however little published information from experiments in which crop rotation and weed control systems have been compared directly for their effects on the survival of volunteer potatoes. In this context, a rotational experiment on changes in seed populations of annual weeds has incidentally yielded useful preliminary information.

MATERIALS AND METHODS

The experiment was carried out at Invergowrie on a sandy loam soil. A potato crop was grown in 1971, followed by spring barley (cv Golden Promise) in 1972. The cereal stubble was ploughed in mid October and a seedbed prepared. Sixteen experimental plots were marked out, each 21 m x 10 m. Half of these were sown with winter wheat, cv Maris Nimrod on 27 October, 1972 at a sowing rate of 180 kg/ha. In early March 1973 the remaining plots were lightly cultivated and spring barley cv Golden Promise was sown at 200 kg/ha on 8 March. The barley was combine harvested on 15 August and the wheat on 23 August. The whole experimental area was rotary cultivated on 3 September and ploughed on 30 October. Winter wheat was drilled on half the plots on 21 November, 1973 and spring barley on the remainder on 2 April, 1974. Plots were selected to give factorial combinations as shown below. Cultivars and sowing rates were as before. The barley was combine harvested on 20 August and the wheat on 9 September. Cereal yields were not recorded in either year.

In spring 1973 cereal plots were split for three herbicide treatments designed to vary the amount of seed returned to the soil by annual weed species. Sub-plot size was 7 m x 10 m. In spring 1974 these treatments were applied again to the same sub-plots. During 1973 and 1974, therefore, the experimental design comprised the following treatments, laid out in a split-plot randomised block with four replicates.

Crop sequence (Main plots) 1972-73 / 1973-74	Herbicide treatment (Sub-plots)	kg/a.i./ha
Winter wheat/winter wheat	None	-
Spring barley/winter wheat	MCPA	0.70
Winter wheat/spring barley	*Dichlorprop/ioxynil/	
Spring barley/spring barley	bromoxynil mixture	0.77 total

Herbicide treatments were applied to both crops on 2 May in 1973 and 30 May in 1974. Application was made using a Drake and Fletcher knapsack sprayer in a water volume of 380 l/ha.

The weed infestation on untreated plots in 1973 was much greater in barley than in wheat plots. Treatment with MCPA gave fair control and the dichlorprop/ioxynil/bromoxynil mixture excellent control of weeds. In 1974 a similar situation applied, but the percentage ground cover by weeds in August on all plots was about twice that recorded in August 1973. While the presence of small numbers of volunteer potatoes in the cereal crops was noted, no records were taken in either year.

After the 1974 cereal harvest, the whole experimental area was rotary cultivated on 23 October and ploughed to 25 cm depth on 6 December. On 21 March, 1975 a seedbed was prepared. The original plots were marked out again and then further sub-divided to include four soil management regimes to represent early and late season options for weed control in horticultural crops. No crop was in fact planted and the site was kept fallow during 1975 and 1976. Plot size at this level was 10 sq. m (1.8 m x 5.5 m). Discards of 0.4 m were left between plots and they were arranged so that a 0.76 m discard was allowed from the boundaries of the original herbicide treatment sub-

*As OXYTRIL P

plots to avoid edge effects. Soil management regimes in 1975 and 1976 were as follows:-

Early/late	Treatment sequence
Cult./cult.	Plots rotary cultivated to 10 - 15 cm depth every six weeks during spring, summer and autumn.
Para./cult.	Plots sprayed with paraquat every six weeks until July; rotary cultivation substituted thereafter.
Cult./para.	Plots rotary cultivated every six weeks until July; paraquat substituted thereafter.
Para./para.	Plots sprayed with paraquat every six weeks during spring, summer and autumn.

All operations were carried out by tractor-mounted equipment, as near as possible to the six week target date. Paraquat was applied at 1.1 or 2.2 kg a.i./ha depending on the density of weeds present. In 1976 the treatments were repeated on the same plots, commencing on 11 March, but no ploughing or seedbed preparation was carried out over the winter. Numbers of volunteer potato plants with above-ground shoots were recorded just prior to every soil management operation during 1975 and 1976. The data was transformed ($\sqrt{x + 0.375}$) for statistical analysis.

RESULTS

The first soil management treatments were carried out on 1 May, 1975. There were no potato shoots above ground at that time, but they appeared towards the end of the month and were counted on 10 June. The choice of crop in 1972/73 produced no significant difference in numbers of volunteer potato plants in June 1975, but plots carrying wheat in 1973/74 had significantly fewer than those with barley (Table 1). Herbicide treatment in the wheat crops had little effect on potato numbers in June 1975, whereas in barley crops plots receiving no herbicide in either year had fewer potato plants than those given herbicides, particularly those treated with MCPA (Table 2). There were no differences attributable to the soil management treatments applied prior to the emergence of the potatoes (Table 3). The second soil management treatments were applied on 13 June, 1975 and further counts were made on 24 July. Rotary cultivation in May and June resulted in significantly higher numbers of potato plants with shoots present in July than were recorded following applications of paraquat (Table 3). Effects of earlier crop rotation were not significant (Table 1) but differences in herbicide treatment in barley crops were still evident, both MCPA and dichlorprop/ioxynil/bromoxynil resulting in significantly higher numbers of potato plants in July 1975 than were recorded on untreated plots (Table 2). Herbicide treatments in wheat crops again showed no effects.

The third soil management treatments on 24 July involved the changeover from 'early' to 'late' season options andwere followed by counts of potato plants with above-ground shoots on 2 September. There were no significant effects of cereal cropping pattern (Table 1), but where barley crops had been treated with dichlorprop/ioxynil/ bromoxynil in 1973 or 1974, numbers of potato plants were significantly greater than on those given no herbicide (Table 2). Differences

Table 1

Effects of crop rotation treatments on no. of volunteer potato plants at various dates

Treatment 1972-73/1973-74	1975						1976					
	10 June		24 July		2 Sept.		3 June		16 July		23 August	
	a	b	a	b	a	b	a	b	a	b	a	b
Wheat/wheat	1240	(1.27)	1153	(1.24)	286	(0.81)	185	(0.75)	44	(0.65)	241	(0.79)
Barley/wheat	2230	(1.61)	2009	(1.54)	520	(0.95)	312	(0.83)	112	(0.70)	223	(0.77)
Wheat/barley	4593	(2.23)*	2227	(1.61)	587	(0.98)	311	(0.83)	215	(0.77)	296	(0.82)
Barley/barley	4553	(2.22)*	2427	(1.67)	651	(1.01)	509	(0.94)*	200	(0.76)	286	(0.81)
S.E.D. mean		(0.347)		(0.309)		(0.110)		(0.079)		(0.058)		(0.059)
1972 - 73 crop	NS		NS		NS		NS		NS		NS	
1973 - 74 crop	+		NS		NS		NS		NS		NS	
Interaction	NS		NS		NS		NS		NS		NS	

Table 3

Effects of soil management treatments on no. of volunteer potato plants at various dates

Treatment 1975-76 Early/late	1975						1976					
	10 June		24 July		2 Sept.		3 June		16 July		23 August	
	a	b	a	b	a	b	a	b	a	b	a	b
Cult./cult.	2653	(1.74)	2080	(1.57)	70	(0.67)	267	(0.80)	48	(0.65)	70	(0.67)
Para./cult.	2992	(1.84)	1690	(1.44)	1065	(1.20)***	284	(0.81)	179	(0.74)	200	(0.76)
Cult./para.	2865	(1.80)	2404	(1.67)	44	(0.65)	218	(0.77)	54	(0.66)	494	(0.93)***
Para./para.	3463	(1.96)	1574	(1.40)	1160	(1.24)***	550	(0.96)*	301	(0.82)**	317	(0.83)**
S.E.D. mean		(0.143)		(0.117)		(0.089)		(0.075)		(0.052)		(0.066)
Early Cult. or Para.	NS		+		+++		NS		+++		NS	
Late Cult. or Para.	NR		NR		NS		NS		NS		+++	
Interaction	NR		NR		NS		NS		NS		+	

*, **, *** Significantly different from W/w or C/c at the 5%, 1% or 0.1% level. NR - Not relevant.
+, +++ Difference significant at the 5% or 0.1% level. NS - Not significant.
a - No. plants/ha; b - No. plants/plot $(\sqrt{x + 0.375})$

Table 2

Effects of cereal herbicide treatments on no. of volunteer potato plants

Date of count	Cereal crop	None a	None b	MCPA a	MCPA b	DIB a	DIB b	S.E.D. mean	
10 June 1975	1972-73								
	W. wheat	2539	(1.71)	3327	(1.92)	2246	(1.62)	(0.192)	(1)
	S. barley	2224	(1.61)	4373	(2.18)**	3467	(1.96)		
	1973-74								
	W. wheat	1696	(1.44)	1713	(1.45)	1710	(1.44)	(0.291)	(2)
	S. barley	3159	(1.88)	6690	(2.66)***	4187	(2.14)		
	Herbicide mean	2377	(1.66)	3832	(2.05)	2829	(1.79)	(0.136)	(3)
24 July 1975	1972-73								
	W. wheat	1532	(1.38)	1624	(1.41)	1809	(1.48)	(0.149)	(1)
	S. barley	1354	(1.32)	2712	(1.76)**	2705	(1.76)**		
	1973-74								
	W. wheat	1299	(1.29)	1619	(1.41)	1768	(1.46)	(0.250)	(2)
	S. barley	1591	(1.40)	2719	(1.76)*	2751	(1.77)*		
	Herbicide mean	1442	(1.35)	2140	(1.59)*	2236	(1.62)*	(0.105)	(3)
2 Sept. 1975	1972-73								
	W. wheat	516	(0.94)	361	(0.86)	415	(0.89)	(0.119)	(1)
	S. barley	307	(0.83)	678	(1.03)	804	(1.09)*		
	1973-74								
	W. wheat	509	(0.94)	283	(0.81)	412	(0.89)	(0.125)	(2)
	S. barley	314	(0.83)	774	(1.07)	809	(1.09)*		
	Herbicide mean	408	(0.89)	512	(0.94)	601	(0.99)	(0.084)	(3)
3 June 1976	1972-73								
	W. wheat	44	(0.65)	556	(0.97)**	191	(0.75)	(0.106)	(1)
	S. barley	148	(0.72)	591	(0.98)*	524	(0.95)*		
	1973-74								
	W. wheat	107	(0.69)	430	(0.90)	226	(0.78)	(0.103)	(2)
	S. barley	82	(0.68)	728	(1.05)**	481	(0.93)*		
	Herbicide mean	94	(0.69)	574	(0.97)***	348	(0.85)*	(0.075)	(3)

*, **, *** Significantly different from None at the 5%, 1% or 0.1% level. DIB - Dichlorprop/ioxynil/bromoxynil mixture.

a - No. plants/ha; b - No. plants/plot ($\sqrt{x + 0.375}$)

(1) for horizontal comparisons and
(2) for other comparisons, within each year;
(3) for comparison of pooled herbicide means.

between untreated plots and those given MCPA were not significant on this occasion. Despite the July changeover, soil management regimes showed their effects on numbers of potato plants solely in terms of the 'early' season options. Reversal of the effects noted in July had occurred, with 'early' rotary cultivation resulting in very much fewer plants present in early September than 'early' applications of paraquat. 'Late' season weed management treatments were carried out on 5 September and 17 October, but no further emergence of potato shoots occurred in 1975.

In 1976 'early' season treatments were applied on 11 March and 22 April. The first opportunity to assess the cumulative effects of these soil management regimes on survival of potato tubers over the winter occurred on 3 June, 1976. Results showed that plots which had received only paraquat during 1975 and early 1976 had significantly more survivors in June 1976 than those which had been given rotary cultivation at some time during that period. There were, however, no effects of 'early' or 'late' season options (Table 3). Choice of cereal crop in 1973 - 74 was no longer significant, but two years of winter wheat still showed significantly lower numbers of potato plants than two years of spring barley (Table 1). Effects of cereal herbicide treatments were still present and on this occasion showed some evidence of occurring in wheat as well as in barley plots (Table 2). The overall reduction in numbers of volunteer potato plants on the experimental site between June 1975 and June 1976 was 89%. Soil management treatments were applied on 3 June and again on 20 July, when the changeover was made from 'early' to 'late' options. Numbers of volunteer potato plants at counts taken on 16 July and 23 August showed no significant differences due to any aspect of previous crop rotation or cereal herbicide treatments. However, July records showed a major response to 'early' soil management options, rotary cultivation being much more effective in reducing the numbers than paraquat (Table 3). In August, by contrast, the major effect was of 'late' soil management options, rotary cultivation again showing the lowest number of potato plants. The interaction was also significant. Numbers in late August were higher on all plots than at the mid July count. No further emergence of potato plants occurred after rotary cultivation or paraquat application on 27 August. The experiment was terminated in December 1976.

DISCUSSION

Choice of cereal crop in 1973 - 74 had much more influence on numbers of volunteer potato plants recorded in June 1975 than did choice of crop in 1972 - 73, although in both cases, the tendency was for winter wheat to result in lower numbers than spring barley. The sowing of two successive crops of winter wheat resulted in 73% fewer potato plants in 1975 than were recorded where two crops of spring barley had been grown. Soil management treatments after June 1975 obscured differences due to previous cropping, but in June 1976, counts of the first emergence of volunteer potatoes still showed 64% fewer plants on wheat/wheat as compared with barley/barley plots. Differences between counts taken later in 1976 were not significant.

Effects of choice of crop on survival of volunteer potatoes may be associated with the timing of seedbed and harvesting operations on potatoes (Lumkes, 1974). In this experiment the only difference in land preparation for the two crops was the additional light seedbed cultivation carried out prior to sowing the spring barley. All plots were ploughed and prepared in autumn for sowing winter wheat, and the barley plots were left undisturbed until early spring. Dates of crop harvest were fairly close and stubble cultivations were identical. It is therefore thought that the main effects of cropping patterns were due to the differing competitive abilities of the two crops. Winter wheat produced a dense leaf canopy much earlier in spring than did spring barley and the latter crop was considerably shorter-stemmed. Lutman (1974a) planted potato tubers in the autumn and assessed their survival over the winter and the following growing season on plots kept fallow, sown with winter wheat or sown with spring barley. He found that the crops reduced survival and delayed sprout emergence by the planted tubers very considerably in comparison with the fallow but could find no difference between the effects of the two cereal crops. However, he did not continue the experiment beyond cereal harvest. Work reported by Carson (1961) showed that during the winter the presence of a winter wheat crop buffered the soil against extremes of temperature, thus protecting the potato tubers. Lumkes (1974) reported that fewer volunteer potato plants occurred in the next year when potatoes were followed by winter wheat than when sugar beet was the next crop. Perombelon (1975), however, suggested that the introduction of more open crops such as raspberry and vegetables into the rotation were likely to bring about a greater reduction in tuber survival than would occur with cereal monoculture. There are obviously limitations on the cropping sequences available to farmers following potato crops. However, the effects of crop rotation as a means of reducing the volunteer potato problem should be more thoroughly examined.

Herbicide treatments in following crops may also affect volunteer potato survival. In this experiment, cereal plots unweeded in 1973 and 1974 had significantly fewer potato plants at various dates in 1975 and 1976 than those given herbicide treatments in both years. This is presumably a reflection of the more intense competition with potato plants which resulted from the presence of both weeds and crop than would have occurred where the weeds had been treated by herbicide. The barley crops were weedier than the wheat crops in both years and it was in the barley that the major effects of weed removal by herbicides on subsequent potato populations were recorded. Although the dichlorprop/ioxynil/bromoxynil mixture gave more effective weed control than did MCPA in both years, highest numbers of potato plants were recorded in June 1975 and June 1976 on plots originally treated with MCPA. However, counts later in 1975 showed similar numbers on both sets of plots in July and by September barley plots treated with dichlorprop/ioxynil/bromoxynil were the only ones with significantly more potato plants than untreated plots. Reasons for these differences are not clear. Both cereal herbicides were applied on the same dates in each crop, so that the stage of development of the volunteer potato plant should have been identical for a particular crop. It is possible that the herbicide mixture affected treated potato vegetation in such a way as to delay sprout emergence in the following year, whereas MCPA did not have this effect. In general, attempts to control volunteer potatoes in the cereal crop have not been very successful, since the presence of the crop delayed potato sprouting and shoot production was not sufficiently advanced by the normal time of herbicide application for optimum uptake (Lumkes, 1974). Delaying herbicide treatment increased the risk of injury to the crop. Several cereal herbicides did nevertheless check the growth of the potato plants in Dutch experiments and decreased the percentage of their tubers which sprouted the following spring. Farmers are unlikely to appreciate suggestions that allowing cereal crops to go unweeded will help to reduce populations of volunteer potatoes. The timing and nature of competition by the weeds may have been critical. However, if the effect of the weeds was simply to increase the overall level of competition with the potato plants in the cereal crop, there may be a case for considering raising the level of competition by increasing the sowing rate and hence population density of the crop itself.

The soil management regimes compared in 1975 and 1976 were representative of those which could have been practised in the more widely spaced horticultural crops, although the paraquat treatments, representing non-cultivation, would have been supplemented by appropriate residual herbicides. The rotary cultivation treatments must have disturbed many of the parent tubers at each date, whereas paraquat only affected the potato plant when foliage was present at the date of treatment. It was therefore not unexpected that rotary cultivation resulted in fewer potato plants surviving in June 1976. It was, however, interesting that timing or frequency of cultivation was of little importance and that the only significant difference was between some cultivation during spring, summer and autumn or none. Paraquat applied to the first flush of potato shoots in June 1975 reduced recovery growth more than was achieved with rotary cultivation, but further treatment in July reversed the position. Cultivation in June 1976 reduced subsequent regrowth more than did paraquat; the same happened following cultivation in July regardless of earlier weed management treatments.

Despite the varying response of the volunteer plants to soil management regimes during the summer of 1975 and any possible effects of subsequent autumn and early spring treatments, the numbers of plants which emerged in May 1976, although many fewer, showed carry-over effects of cereal cropping and herbicide treatments similar to those recorded one year earlier. A considerable amount of research has gone into cultivation systems for use during autumn and winter to expose tubers to frost (Lumkes, 1974). A better understanding is also needed of the effects of different forms and timing of soil cultivation in row crops in killing volunteer plants or at least reducing their production of daughter tubers during late spring and summer. This would allow weed control programmes to be modified, where possible, to achieve maximum effect on the volunteer potato problem.

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