Netherlands Journal of Agricultural Science 37 (1989) 185-196

Influence of gibberellic acid (GA_3) applied to the crop on growth, yield and tuber size distribution of seed potatoes

K. B. A. BODLAENDER & M. VAN DE WAART

Centre for Agrobiological Research (CABO), P.O. Box 14, NL 6700 AA Wageningen, Netherlands

Received 25 November 1988; accepted 14 March 1989

Abstract

Gibberellic acid (GA_3) was sprayed in two dosages, 50 and 100 g a.i. ha^{-1}, on potato crops at several growth stages to modify tuber size distribution in seed potato production. GA_3 applied in early growth phases (till the beginning of tuberization) promoted stem elongation and stolon growth. GA_3 caused an increase in the total number of tubers, causing a shift in tuber size distribution in favour of the smaller sizes. After early application of GA_3, total tuber yields in July decreased or did not change as compared to the untreated plots, but in general the yield of the tuber size most valuable as seed potatoes (28-45 mm) increased, especially when GA_3 was sprayed on the crop in the period of stolon growth until the beginning of tuber initiation. The low GA_3 dosage should be preferred, as the higher dosage infavourably affected tuber shape (long and curved tubers). Some differences in the extent of these effects were observed between cultivars. The GA_3 treatments did not show negative after-effects on growth and yield of the progeny.

Keywords: seed potato production, gibberellic acid, tuber size distribution, *Solanum tuberosum* L.

Introduction

Tuber size distribution is an important characteristic in potato production. In seed production – harvests in the Netherlands mostly in July – the middle sizes (28-45 mm) are most valuable. In late liftings for ware potatoes and processing, large tubers are most desired. Breeders have tried to produce cultivars with large tubers for ware potatoes and processing.

Middle sizes have a higher seed potato value: they produce a larger number of stems associated with a higher tuber yield per kg seed tubers, compared to the larger seed tubers (Reestman & de Wit, 1959). Therefore, it was tried to change the tuber size distribution of these cultivars in liftings for seed potato production in favour of the middle sizes.

Tuber size is influenced by the total tuber yield and by the number of tubers. It was tried to manipulate tuber size distribution in several ways: by storage and pre-sprouting conditions (Haverkort et al., 1989), treatment of seed tubers or the crop with growth regulators, and by cultural methods (plant density, water and nitrogen supply).

The number of tubers per plant can be increased by treating the seed tubers before planting with gibberellic acid, causing a shift of the tuber size distribution towards the smaller sizes (a.o. Holmes & Lang, 1978; Keller & Berces, 1964; Marinus & Bodlaender, 1978; von Meltzer & Moll, 1979; Utheib et al., 1981). In this way, higher yields of the middle tuber sizes were obtained in liftings for seed potato production.

The number of tubers per plant can also be increased by spraying various growth regulators (e.g. daminozide, chlormequat, ethephone, 2,4-D) on the foliage during tuber initiation (Bodlaender & Algra, 1966; Laycock, 1970; Menzel, 1980; Stallknecht, 1983). In some cases, also an increase in yield of the medium-sized tubers at early liftings is reported.

In other experiments, gibberellic acid was sprayed on potato plants. Gibberellic acid temporarily promoted early leaf growth and dry matter production. Okazawa (1959) observed an inhibition of tuberization by spraying gibberellic acid on the foliage. Menzel (1980), who sprayed gibberellic acid on cuttings, found a decrease in number of tubers. No data on tuber sizes are presented by these authors.

In a preliminary experiment, in 1982, gibberellic acid (GA_3) was sprayed on the crop at three growth phases. This experiment showed unexpected results: the application of GA_3 during stolon growth positively affected the yield of the medium-sized tubers at the lifting in July, in contrast to later sprayings. This effect was studied in further experiments and results are reported here.

Materials and methods

Gibberellic acid was sprayed on potato crops in a series of field experiments in the years 1982-1986. The seed tubers were stored in darkness at 4 °C till the beginning of March. Then they were – after 3 to 5 days at 16 to 18 °C in darkness – pre-sprouted in the light (fluorescent tubers) at 10-12 °C till planting after mid-April; in 1984, however, cold-stored seed potatoes were planted. The plant density varied in the experiments. The lower plant density of 40 plants per 10 cm^2 was applied to show the effects of GA_3 on the numbers of tubers more clearly than with higher plant densities.

Gibberellic acid was applied as GA_3 in two dosages, with 1000 l water per ha.

A survey of the experimental conditions is presented in Table 1. Four experiments were carried out with three spraying dates to determine at which growth stage gibberellic acid should be applied to the crop to obtain the most favourable effect on tuber size distribution for seed potato production; every treated plot was sprayed only once. Data and growth stages for the spraying times in the four years differed (see Table 2). In 1986, GA_3 was sprayed on the foliage of four cultivars at one date only.

The plots were lifted in July at the usual time in seed potato production. In one

Table 1. Survey of experiments with application of gibberellic acid to seed potato crops, 1982-1986.

Experimental data	1982	1983	1984	1985a	1985b	1986
Soil type	sand	sand	clay	clay	clay	clay
Cultivar	Jaerla	Jaerla	Jaerla	Jaerla	Jaerla	see [1]
Seed size (mm)	35-45	35-45	40-50	35-40	35-40	35-45
Plants per 10 m^2	40	40	65	50	50	40
Plot (m^2) (net)	8	7.5	9	6	6	9
Replicates	3	4	4	4	3	4
Planting date	15 April	26 April	19 April	23 April	23 April	22 April
Spraying date	27 May	27 May	1 June	29 May	29 May	28 May
	17 June	3 June	8 June	5 June	5 June	
	6 July	9 June	15 June	19 June	19 June	
GA_3 (a.i.) (g ha^{-1})	50-100	50-100	50-100	50-100	50	50-100
Lifting date	12 July	14 July	23 July	17 July	see [2]	see [1]

[1] Jaerla, Ostara: lifted 4 July; Spunta: lifted 9 July; Alpha: lifted 16 July.
[2] 24 May, 5 June, 15 June, 26 June, 10 July, 17 July.

Table 2. Growth characteristics and growth stages at spraying dates. Experiments 1982-1985. Cultivar Jaerla.

Year	Spraying date	Growth stage[1]	Growth characteristics				
			Stem length (cm)	Stolons (number per plant)	Stolon length (cm)	Tuber initials (number per plant)	Tubers (number per plant)
1982	27 May	B					
	17 June	C	53				
	6 July	D	69				
1983	27 May	A	9-10		1-3		
	3 June	B		10	2-4	<1	
	9 June	C		50	4-5		18
1984	1 June	B	6	13	2-2.5	0.5	–
	8 June	C	17	30	4-5	12	0.7
	15 June	C/D	31	48	4-5	20	17
1985	24 May	A	0-8	14	0-7	–	–
(a and b)	5 June	B	13	25	2-10	4	–
	19 June	C	27	27	2-10	11	0.5

[1] Growth stages at spraying dates: A = first part of stolon growth, B = stolon growth and beginning of tuber initiation, C = tuber initiation, D = tuber growth.

experiment (1985b), a number of liftings were carried out to study the effect of GA_3 on the development of stolons and tubers. At the liftings, weights and number of tubers (>5 mm) were determined. The total yield was graded into the following sizes: 5-13, 13-28, 28-35, 35-45, 45-55 and >55 mm). In some experiments, also the dry matter content of the tubers was determined.

Possible after-effects of GA_3 on growth and tuber yield of the progeny was studied in two experiments (1982/1983 and 1984/1985). Seed tubers (size 35-45 mm) obtained from plants treated with GA_3 and from untreated plants were stored, presprouted and planted in the field in the following spring, in sand and clay soil, respectively. The plant density was 40 plants per 10 m^2. The plots were lifted in August, when the senescence of the foliage had progressed to a large extent.

Results

Effects of spraying date and dosage

Effect of GA_3 on foliage growth and flowering
Soil coverage by the foliage was enhanced (±25 %) by spraying GA_3 on the crop in early growth phases, especially with the higher dosage. This effect will be mainly attributed to the slightly increased stem length (±5 cm). The number of stems (varying between 3 and 4; in 1984 between 4 and 4.4 per plant) was generally not affected by the GA_3 treatments; only in 1984 a small increase, especially by the first application of GA_3, was found. The fresh weights of the leaves at the harvest in July did not show clear effects of the treatments; in two experiments (1984 and 1985) an increase in leaf dry weight, especially after the later GA_3 treatments, was observed.

Spraying GA_3 on the foliage temporarily caused yellow discolouration of the leaves, this being more pronounced at the high GA_3 dosage. This discolouration disappeared after some time. Flowering was promoted by the application of GA_3; especially with the last two applications (in 1983 and 1985) more abundant flowering was observed than in the untreated plots.

Tuber yield, tuber size distribution and shape of the tubers
Total tuber yield and the yield of the seed potato fraction 28-45 mm at the harvest in July are presented in Table 3. The effect of GA_3 on total tuber yield varied between experiments, spraying times (growth stages) and GA_3 dosages. Total tuber yield was not or hardly influenced by the first application of GA_3 in 1982, 1984 and 1985, but was decreased by this application in 1983. By later applications of GA_3 (not the very late one in 1982), total tuber yield decreased to a variable degree, the negative effect being more pronounced with the 100 g GA_3 treatment. In general, the GA_3 treatments did not or only slightly influence the dry matter content of the tubers at the harvests. However, with the high GA_3 dosage this content decreased at the last two sprayings in 1984 and 1985 (data not shown).

The yield of the seed potato fraction 28-45 mm showed distinct effects of the GA_3 treatments. In the untreated plots, only a relatively small part of the total tuber yield was sized between 28 and 45 mm. In general, the yield of this tuber size increased significantly by GA_3 treatment. This effect was most pronounced when GA_3 was applied during stolon growth till the beginning of tuber initiation (growth stage B, see Table 2, T1 in 1982 and 1984, T2 in 1983 and 1985), the effect being somewhat larger at the high GA_3 dosage. A substantial increase in yield of the 28-45 mm fraction was also obtained with the application of the high GA_3 dosage during

Table 3. Effect of gibberellic acid on total tuber yield and yield of the seed potato fraction 28-45 mm. Experiments 1982-1985. See further Table 1.

Treatment	Growth stage[1]	Tuber yield (kg per 10 m²)		Growth stage	Tuber yield (kg per 10 m²)	
		total	28-45 mm		total	28-45 mm
	1982			*1983*		
Untreated		34.0	4.5		31.1	4.7
GA_3 50 g ha^{-1}	B	35.2	7.1***	A	29.1**	5.5
GA_3 50 g ha^{-1}	C	31.3**	5.5	B	27.8***	11.2***
GA_3 50 g ha^{-1}	D	33.7	4.2	C	30.4	8.7
GA_3 100 g ha^{-1}	B	33.4	8.2***	A	26.0***	8.9***
GA_3 100 g ha^{-1}	C	28.4***	7.9***	B	26.7***	15.0***
GA_3 100 g ha^{-1}	D	32.7	4.4	C	28.6***	13.7***
	1984			*1985a*		
Untreated		39.9	8.6		30.7	8.8
GA_3 50 g ha^{-1}	B	42.0	10.1*	A	30.4	9.5
GA_3 50 g ha^{-1}	C	37.6	8.4	B	26.5***	17.4***
GA_3 50 g ha^{-1}	C/D	37.4	8.2	C	29.6	11.3**
GA_3 100 g ha^{-1}	B	38.5	12.2***	A	29.4	9.1
GA_3 100 g ha^{-1}	C	36.1	13.2***	B	23.7***	18.5***
GA_3 100 g ha^{-1}	C/D	33.0	10.0*	C	23.1***	15.3***

[1] At spraying date, see Table 2.
P(%): comparison with untreated plots; $^{*}P < 0.1$, $^{**}P < 0.05$, $^{***}P < 0.01$.

tuber initiation; at the lower GA_3 dosage, applied at that stage, the yield of this fraction increased to a smaller extent or not at all.

The GA_3 treatments giving a distinct increase in the yield of the size 28-45 mm, caused in nearly all cases a decrease in the yield of the larger tubers (>45 mm). This shift in tuber size distribution is presented in Fig. 1 for plots treated with 50 g GA_3 ha^{-1} in growth stage B. In the 4 years the smaller sizes show the same type of reaction to GA_3. However, in 1982 and 1984 the yield of size 45-55 mm was increased by GA_3, but in 1983 and 1985 it was decreased. This difference may be due to the growth duration and weather and soil conditions in the various experimental years.

Gibberellic acid also influenced the shape of the tubers. Plants that were sprayed with the low dosage during stolon growth produced slightly elongated tubers. When the high dosage of GA_3 was sprayed during tuber initiation, long and curved tubers were observed.

Stolon growth and number of tubers

The influence of the early application of GA_3 on tuber size distribution may be explained by the effects of GA_3 on stolon growth and the number of tubers.

Observations on stolon growth were restricted to two experiments. At harvest in

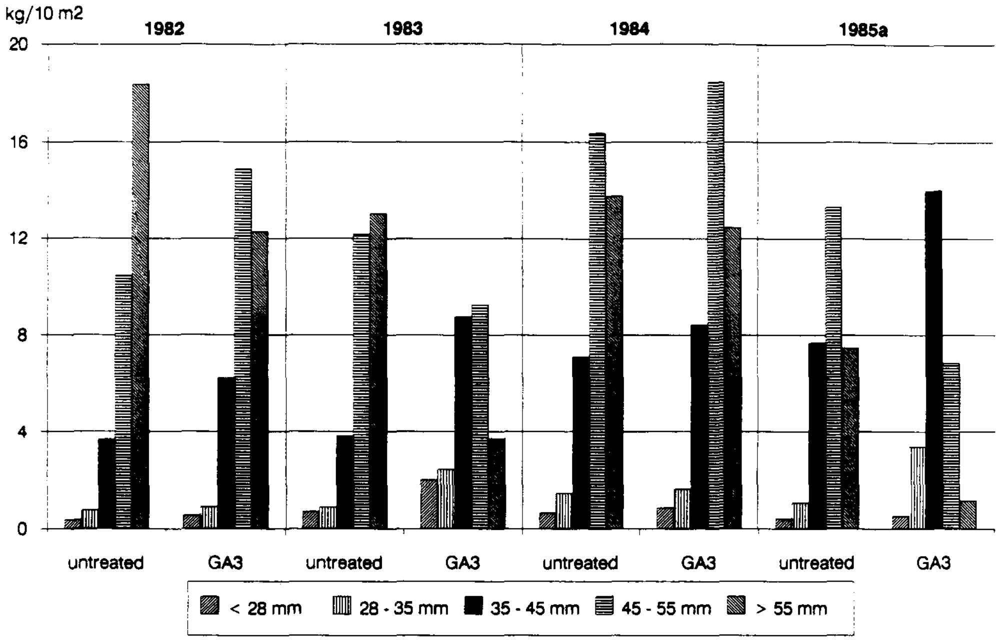

Fig. 1. Effect of gibberellic acid (50 g GA_3 a.i. ha^{-1}), sprayed on the foliage in growth stage B (Table 2) on tuber yield and number of tubers (total and in size 28-45 mm) of seed potato crops. Cultivar Jaerla.

July 1983, untreated plants only had a few short stolons, plants treated with the 50 g GA_3 dosage had more and somewhat longer stolons, and plants treated with the high dosage had many and often long stolons. These effects were most pronounced with the first spraying. In 1985, stolons were studied at several liftings from 24 May till 17 July.

The number of main stolons of the untreated plants increased rapidly till 5 June (from 14 to 25 main stolons per plant) and more gradually afterwards till 17 July (35 main stolons per plant). The number of main stolons of plants treated with the 50 g GA_3 dosage during stolon growth did not increase further after 24 June and finally was somewhat lower (31 to 32 per plant) than the number of stolons of the untreated plants. However, the variation in number of stolons was rather large. Certainly, GA_3 did not increase the total number in this experiment (Table 4). More evident was the effect of GA_3 on the length of the main stolons: the number of main stolons longer than 10 cm was increased distinctly by the first two GA_3 applications. Branching of the stolons, too, was somewhat promoted by these GA_3 treatments. In this experiment the numbers of tuber initials and tubers at earlier liftings in June (not presented here) indicated a slight retardation of tuberization by the GA_3 treatments; however, this effect disappeared soon.

The total number of tubers (Table 5) was increased to some extent by the GA_3 treatments in growth stage B. The effect was most pronounced in 1983. In 1983 and

Table 4. Effect of gibberellic acid on number of main stolons, lateral stolons and tubers. Experiment 1985b, lifting date 17 July. See further Tables 1 and 2.

Treatment	Growth stage[1]	Number per 10 m²					
		main stolons[2]			lateral stolons[2]	tubers	
		total	<2 cm	>10 cm		total	28-45 mm
Untreated		1759	478	7	126	488	189
GA_3 50 g ha^{-1}	A	1556	293	45	191	481	176
GA_3 50 g ha^{-1}	B	1573	588	90	245	629**	354***
GA_3 50 g ha^{-1}	C	1638	293	17	97	597*	263

[1] At spraying date, see Table 2.
[2] No statistical data available.
P(%): comparison with untreated plots; $^*P < 0.1$, $^{**}P < 0.05$, $^{***}P < 0.01$.

Table 5. Effects of gibberellic acid on total number of tubers and number of tubers in the size 28-45 mm. Experiments 1982-1985. See further Table 1.

Treatment	Growth stage[1]	Number of tubers per 10 m²		Growth stage	Number of tubers per 10 m²	
		total	28-45 mm		total	28-45 mm
	1982			*1983*		
Untreated		332	101		459	109
GA_3 50 g ha^{-1}	B	406***	141***	A	380**	100
GA_3 50 g ha^{-1}	C	353	125*	B	646***	220***
GA_3 50 g ha^{-1}	D	339	97	C	519*	166***
GA_3 100 g ha^{-1}	B	399**	158***	A	393*	159***
GA_3 100 g ha^{-1}	C	381*	181***	B	673***	262***
GA_3 100 g ha^{-1}	D	314	96	C	731***	270***
	1984			*1985a*		
Untreated		523	195		428	195
GA_3 50 g ha^{-1}	B	565*	213	A	423	190
GA_3 50 g ha^{-1}	C	427***	173*	B	450	321***
GA_3 50 g ha^{-1}	C/D	427***	167**	C	470	233*
GA_3 100 g ha^{-1}	B	568**	246**	A	382	173
GA_3 100 g ha^{-1}	C	443***	242**	B	486*	353***
GA_3 100 g ha^{-1}	C/D	435***	209*	C	685***	364***

[1] At spraying date, see Table 2.
P(%): comparison with untreated plots; $^*P < 0.1$, $^{**}P < 0.05$, $^{***}P < 0.01$.

1985, also the latest sprayings (in growth stage C) led to an increase in the total number of tubers. In most cases, the high GA_3 dosage increased the number of tubers to a somewhat greater extent than the low dosage did. Spraying GA_3 at a very early or a late growth stage gave in some cases a decrease in the total number of tubers (1983 and 1985a, respectively).

The number of tubers in the size 28-45 mm grade (Table 5) was affected more distinctly. In most cases, the number of tubers of size 28-45 mm was increased by the GA_3 treatments, especially in growth stage B; only in 1984 the effect of the low GA_3 dosage was small.

The average weight per tuber in each tuber size was increased by the GA_3 treatments (varying between 0 and 40 %), especially in the 28-35 mm fraction, due to the elongation of the tubers in the GA_3 plots.

After-effect of GA_3 in the progeny

Seed tubers obtained from treated and untreated plants in the experiments of 1982 and 1984 were planted in the field in the spring of 1983 and 1985, respectively. The plants grown from these tubers did not show clear differences in emergence and foliage growth related to the treatments of the year before. In 1983 the plants from spraying date T2 (low dosage) in 1982 had a somewhat smaller number of stems per plant than the progeny of the untreated plants, the progeny of spraying date T3 (high dosage) a somewhat larger number ($P < 0.05$).

In general, the progeny of the treated plots (especially T1, which had in the previous year the highest yield of tubers in the size 28-45 mm) had a somewhat larger total tuber yield than the progeny of plots that were not treated in the year before; also the yield of large tubers (>45 mm, ware potatoes) was higher for the progeny of treated plants (Table 6). In general, the differences were not significant. The results in the August liftings were certainly not unfavourable for seed tubers from plants sprayed with GA_3 in the year before.

Table 6. After-effect of gibberellic acid. Tuber yield of the progeny of untreated and treated plants. Experiments 1982/1983 and 1984/1985. Cultivar Jaerla, 40 plants per 10 m^2.

Treatment previous year	Growth stage[1]	Yield of progeny (kg per 10 m^2)		Growth stage	Yield of progeny (kg per 10 m^2)	
		total	>45 mm		total	>45 mm
	1983[2]			*1985*[2]		
Untreated		41.4	36.7		56.3	52.4
GA_3 50 g ha^{-1}	B	44.6	40.3	B	61.6	57.3
GA_3 50 g ha^{-1}	C	42.0	38.0	C	58.9	56.0
GA_3 50 g ha^{-1}	D	42.7	38.0	C(D)	58.5	55.9
GA_3 100 g ha^{-1}	B	45.3*	40.8*	B	59.2	55.6
GA_3 100 g ha^{-1}	C	41.9	38.1	C	65.6**	61.8***
GA_3 100 g ha^{-1}	D	43.8	39.1	C(D)	60.1	56.5

[1] At spraying dates previous year, see Table 2.
[2] Lifting dates 12 August and 30 August, respectively.
P(%): comparison with untreated plots; *$P < 0.1$, **$P < 0.05$, ***$P < 0.01$.

Experiments with various cultivars

In some experiments, gibberellic acid was also sprayed on the foliage of other cultivars than Jaerla. Only the results of the field experiment in 1986 are presented.

Effect on foliage growth

In this experiment, GA_3 was sprayed on the foliage of the cultivars Jaerla, Ostara, Spunta and Alpha on 28 May. It was aimed to spray in the stage of stolon growth though the cultivars differed somewhat in development at that date. Stem length of three cultivars was then ca 8 cm; the plants of cv. Alpha were ca 3 cm shorter. Stolon growth of Ostara and Spunta was most advanced; Alpha was yet in the first part of stolon growth, number and length of the stolons being still rather small. Ostara had already formed the first tuber initiations at the spraying date. GA_3 enhanced stem elongation of all four cultivars; three weeks after spraying the treated plants were 4-11 cm longer than the untreated ones; Ostara and Spunta showed the largest increase in length by GA_3. Two weeks later the differences in stem length between treated and untreated plants had become small or had disappeared completely. The number of stems per plant was not or hardly influenced by the GA_3 treatment, varying between 2.7 and 2.9 for Jaerla and between 3.2 and 3.5 for the other cultivars. As in the experiments in 1982-1985, the GA_3 applications to the crop caused a temporary discolouration of the leaves, which disappeared after a few weeks. GA_3 also stimulated flowering, especially with the cultivar Spunta.

Effect on tuber yield, tuber size and number of tubers

Total tuber yield (Table 7) was in most cases decreased by GA_3, especially at the

Table 7. Effect of gibberellic acid on tuber yield and number of tubers (total and in size 28-45 mm) of 4 cultivars. Experiment 1986. See further Table 1.

Cultivar	Treatment	Growth stage[1]	Yield (kg per 10 m^2)		Number per 10 m^2	
			total	28-45 mm	total	28-45 mm
Jaerla	untreated		26.6	4.8	325	100
	GA_3 50 g ha^{-1}	B	24.0***	15.1***	550***	298***
	GA_3 100 g ha^{-1}	B	22.9***	15.9***	632***	343***
Ostara	untreated		22.7	9.5	397	214
	GA_3 50 g ha^{-1}	B/C	22.4	10.3	358	204
	GA_3 100 g ha^{-1}	B/C	21.6	14.0***	459**	302***
Spunta	untreated		26.0	12.0	453	243
	GA_3 50 g ha^{-1}	B/C	22.6***	17.6***	603***	329***
	GA_3 100 g ha^{-1}	B/C	21.9***	17.0***	626***	343***
Alpha	untreated		19.0	10.3	427	266
	GA_3 50 g ha^{-1}	A	17.6*	12.8***	440	322***
	GA_3 100 g ha^{-1}	A	15.6***	10.8	388	270

[1] Growth stages at spraying date 28 May: A = first part of stolon growth, B = stolon growth and beginning of tuber initiation, C = tuber initiation.
$P(\%)$: comparison with untreated plots; $*P < 0.1$, $**P < 0.05$, $***P < 0.01$.

high dosage. The yield of the seed tuber fraction 28-45 mm was significantly increased, especially in the cultivars Jaerla and Spunta. However, the other two cultivars were affected only by one dosage in this respect (Ostara by the high and Alpha by the low GA_3 dosage). The increase in yield of tuber size 28-45 mm by GA_3 was in most cases accompanied by a decrease in yield of the larger tuber sizes. The rather small effect on Alpha may be explained by the early growth stage of this cultivar at the spraying date; Ostara, on the other hand, had already started tuber initiation and was therefore not in the appropriate growth phase for application of GA_3.

The numbers of tubers (total and in the size 28-45 mm) generally increased by the GA_3 treatments (Table 7). This increase varied for cultivars and GA_3 dosages.

Discussion

Gibberellic acid (GA_3), sprayed on the foliage of potatoes in early growth phases, temporarily stimulated stem elongation and increased stolon length and branching of the stolons and slightly retarded tuber initiation. At a later growth stage, however, the number of tubers per plant was increased by the early GA_3 treatments.

At liftings in July for seed potato production, total tuber yield was often decreased. At these liftings the yield of tubers in the 28-45 mm – most valuable as seed potatoes – was often increased substantially by the GA_3 application, especially when GA_3 was sprayed in the period of stolon growth till the beginning of tuber initiation (growth stage B). The higher GA_3 dosage was also effective in this respect, when sprayed somewhat later, in the period of tuber initiation. The best result for seed potato production was obtained by spraying the low GA_3 dosage during stolon growth (growth stage B), because the high dosage or later applications caused deformations of the tubers or were less effective for seed potato yield.

Most experiments were carried out with cv. Jaerla. Also in other cultivars, GA_3 treatments affected tuber size distribution by increasing the yield of the seed potato fraction (28-45 mm) at liftings in July. In our experiment of 1986, cv. Ostara was less susceptible than the other cultivars.

The effect of GA_3 on tuber size distribution and yield of the middle sizes 28-45 mm in liftings for seed potato production was determined to a large extent by the effect on the number of tubers. The increase in total number of tubers by the early GA_3 applications caused a shift in tuber size distribution in favour of the smaller sizes, and in consequence, the number of tubers in the size 28-45 mm was increased. Tubers produced by treated plants were longer than those from untreated plants. Therefore the average weight per tuber of a certain size, for instance 35-45 mm, was larger in the treated than in the untreated plots. The large effect of GA_3 on the yield of tuber size 28-45 mm can in general be explained for about 75 % by the larger number of tubers and for about 25 % by the higher average weight per tuber in the treated plots.

The effect of GA_3 sprayed during stolon growth on the number of tubers was probably due to the increase in number of growing points (sites) on the elongated and more branched stolons; in the experiment of 1983 also the number of main stolons was increased by GA_3. Perhaps GA_3 also stimulated more growing sites to grow out into tubers; this suggestion is supported by the effect of the high GA_3 dosage applied during tuber initiation. Booth (1963) also observed elongation of stolons by application of gibberellic acid to the base of stems of potato plants 20 cm high. Our experiment with several liftings revealed that the number of stolons continued to increase also after the start of tuber initiation, especially in the untreated plants. Lis-Kaczynska & Listowski (1977) found that early formed stolons are longer and more branched than the later formed ones and they formed more lateral tubers. This observation can be related to the effects of early applied GA_3 on stolon growth and number of tubers.

Other applications of growth regulators at various growth stages influenced the number of tubers in a different way than gibberellic acid, sprayed on the foliage during stolon growth till the beginning of tuberization. Daminozide (B9 or B995) sprayed on the foliage during tuber initiation, inhibited the elongation of stems temporarily, leading to a change in dry matter distribution: lower stem weight, higher tuber weight; these effects also caused an increase in number of tubers per plant (Bodlaender & Algra, 1966), total tuber yield and yield of tubers in the size 28-45 mm were often increased in early liftings. Stallknecht (1983) mentioned an increase in number of tubers by 2,4-D. These growth regulators have some marked disadvantages (daminozide: high price, 2,4-D: malformations of foliage).

Treatment of seed tubers with gibberellic acid before planting generally caused an increase in the number of stems and therefore in the number of tubers per plant, leading to a higher yield of tubers in the middle sizes; this treatment often caused a distinct decrease in total tuber yield (Marinus & Bodlaender, 1978). However, application of GA_3 to the seed tubers is laborious or – when sprayed on the seed tubers during mechanically planting – showed sometimes elongated thin stems and heavy discolouration of the leaves.

Some practical aspects of spraying gibberellic acid on seed potato crops must be taken into account. When GA_3 is sprayed on the foliage during stolon growth, the plants are still rather small and the largest part of the sprayed GA_3 will not be applied to the plants. Therefore the amount of GA_3 used per ha can be decreased considerably by spraying only the rows. The temporary discolouration of the leaves – with the low GA_3-dosage applied during stolon growth – will not be a real hindrance for selection on virus diseases. The GA_3 treatments did not show any negative after-effect on growth and yields of the progeny in the next year.

In untreated seed potato crops at liftings in July, the most valuable fraction of 28-45 mm often is only a relatively small part of the total tuber yield, especially in cultivars with coarse grading. An increase of that part by treatments with growth regulators or elsewise is wanted because of the decrease in price per kg with increasing size (from 28-35 mm upwards). Calculations with the yields of the various sizes showed that early application of GA_3 to seed potato crops can give a substantial increase in financial return to the grower, even with a certain decrease in total tuber yield.

References

Bodlaender, K. B. A. & S. Algra, 1966. Influence of the growth retardant B995 on growth and yield of potatoes. *European Potato Journal* 9: 242-258.

Booth, A., 1963. The role of growth substances in the development of stolons. In: J. D. Ivins & F. L. Milthorpe (Eds), The growth of the potato. Proceedings of the Tenth Easter School in Agricultural Science, Butterworths, London, p. 99-113.

Haverkort, A. J., M. van de Waart & K. B. A. Bodlaender, 1989. Effect of pre-planting temperature and light treatments of seed tubers on potato yield and tuber size distribution. *Potato Research* (in press).

Holmes, J. C. & R. W. Lang, 1978. Manipulating tuber number in the potato crop. Abstracts 7th Triennial Meeting EAPR (Warsaw), p. 53.

Keller, E. R. & S. Berces, 1964. Über die Auswirkungen der Behandlung vorgekeimter Kartoffelknollen mit Gibberellinsäure. *Schweizerische landwirtschaftliche Forschung* 4: 59-66.

Laycock, D., 1970. Modification of potato tuber size by N-dimethylamino succinamic acid. *Potato Research* 14: 234-236.

Lis-Kaczynska, B. & A. Listowski, 1977. The pattern of stolon growth, onset of bulking, and time-span of stolonization and tuberization by cv. Pierwiosnek, an early potato variety. *Acta Agrobotanica* 30: 51-69.

Marinus, J. & K. B. A. Bodlaender, 1978. Growth and yield of seed potatoes after application of gibberellic acid to the tubers before planting. *Netherlands Journal of Agricultural Science* 26: 354-365.

Meltzer, H. von & A. Moll, 1979. Der Einflusz von Gibberellin und anderen Wachstumsfördernden Substanzen auf die Ertragsbildung der Kartoffel. *Archiv für Acker- und Pflanzenbau und Bodenkunde, Berlin* 23: 21-28.

Menzel, C. M., 1980. Tuberization in potato at high temperatures: responses to gibberellin and growth inhibitors. *Annals of Botany* 46: 259-265.

Okazawa, Y., 1959. Studies on the occurrence of natural gibberellin and its effects on the tuber formation of potato plants. *Proceedings Crop Science Society Japan* 28: 129.

Reestman, A. J. & C. T. de Wit, 1959. Yield and size distribution of potatoes as influenced by seed rate. *Netherlands Journal of Agricultural Science* 7: 257-268.

Stallknecht, G. F., 1983. Application of plant growth regultors to potatoes, production and research. In: L. G. Nickell (Ed.), Plant growth regulating chemicals, Vol 2, p. 161-178. CRC Press, Boca Raton, Florida.

Utheib, N. A., M. F. Abbas & A. S. Al-Sammara, 1981. The effect of some growth regulators and thiourea on dormancy and subsequent growth of the potato in Basrah. *Journal of the Indian Potato Association* 8: 134-141.