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Seed potato (*Solanum tuberosum* L.) yield and tuber number increase after foliar applications of cytokinins and gibberellic acid under field and glasshouse conditions

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Abstract

The purpose of these experiments is to determine the effects of foliar applications of benzylaminopurine (BAP) and gibberellic acid (GA) on tuber number production of seed potatoes. In field experiments conducted during 1989/90 cv. Mailén was used and BAP, 50 $mg \cdot l^{-1}$ was foliarly applied at (1) tuber initiation, 36 days after emergence (DAE); (2) 54 DAE; and, (3) 64 DAE. Under glasshouse conditions, in 1991/92 cv. Spunta was used and BAP 50 $mg \cdot l^{-1}$ + GA 50 $mg \cdot l^{-1}$ were applied 30 and 37 days after planting/transplanting. In 1992 cv. Huinkul, Kennebec and Spunta were used and BAP 50 $mg \cdot l^{-1}$ + GA 50 $mg \cdot l^{-1}$ and "Biozyme" (Techic SA), a commercial product with auxin (IAA, 32.2 $mg \cdot l^{-1}$), gibberellic acid (GA_3, 32.2 $mg \cdot l^{-1}$) and cytokinins (zeatin, 83.2 $mg \cdot l^{-1}$) at 5 $ml \cdot l^{-1}$ were applied. In cv. Mailén, a higher tuber number in the seed fraction (<80 g) was found when BAP was applied at each of the three crop stages, while applications 54 and 62 DAE also increased tuber number in the 80–400 g fraction. As a result of BAP applications, tuber yield was also significantly increased. In the glasshouse experiments, cv. Spunta showed a significant increase in minituber production in 3 out of 4 cases, either if the mother plant came from *in vitro* generated plantlets or minitubers, or if GA+BAP or Biozyme was applied. It can be concluded that the use of these PGRs under both field and glasshouse conditions in cvs. Mailén and Spunta can result in increased tuber number in the seed fraction.

1. Introduction

The maintenance of a potato production system is heavily dependent on an adequate and continuous supply of high quality seed tubers. During the last 10–15 years, in Argentina and in others Latin American countries, the production of healthy seed, free from virus, fungus and bacterial diseases has been greatly improved [5]. Better diagnostic techniques, such as the ELISA test, adoption of "in vitro" production of plantlets and production of basic seed in aphid-proof glasshouses and isolated areas are the main reasons for this improvement [4].

An important aspect of field multiplication is to produce whole tubers, instead of "cut seed pieces". For this reason a high stem density in seed crops is used, in order to enhance tuber competition and obtain a higher tuber number with small size [1]. However, in Argentina, tuber size is still an important problem in seed production. The most important cultivar, Spunta, tends to produce large tubers, and the growers, in many cases, do not adjust stem densities to seed production. Hence, it is important to develop alternative methods to increase tuber number in seed crops. Moreover, as the initial steps in the production of basic seed begin with *in vitro* plantlets, that produce few tubers per plant, the number of "minitubers" produced under glasshouse conditions is also reduced. This is an important economic factor, when it is realized that in Argentina a minituber costs USd 0.50.

These reasons have led several authors to study the effect of different plant growth regulators (PGR) on tuber number and size [2, 8, 12]. As gibberellic acid (GA) enhances stolon growth, thus promoting forma-

tion of potential tuber sites and cytokinins (benzylaminopurine -BAP- or benzyladenine -BA-) promote cell division and differentiation, it is possible that the use of these PGRs either under glasshouse or field conditions would increase actual tuber number. To examine this, several experiments were carried out with different cultivars, generated from *in vitro* plantlets, minitubers, or seed tubers.

2. Materials and methods

2.1 *Field experiments*

Certified seed potatoes (*Solanum tuberosum* L.) size 50–60 mm, of the medium-early cv. Mailén INTA were planted on 4th October 1989 in the La Plata area (SL 34° 54′) in a randomized block design, in plots of 1 row, 6.25 m length, with 4 replications of the following treatments: foliarly applied BAP, 50 mg·l^{-1} at (1) tuber initiation, 36 days after 100 % emergence (DAE); (2) 54 DAE and (3) 64 DAE. Applications were done with an ultra low volume machine with a water volume equivalent to 35 l·ha^{-1}. The same volume was used in the glasshouse experiments and in all cases the control treatment was sprayed with water.

During crop growth, stem number·m^{-2} was determined according to Wiersema [15]. Harvest was carried out during February 1990 and for each replication, tuber yield and number was determined for the following size: (a) <80 g; (b) 80–400 g and (c) greater than 400 g.

2.2 *Glasshouse experiments*

During 1991/92 several experiments were carried out in an aphid-proof glasshouse in Santa Clara del Mar (SL 38°). The glasshouses have an aphid-proof mesh 1.30 m high and the roof was made of polyethylene (Agropol 150 UV). Inside the glasshouses, plots of 40 m^2 for each cultivar were used. In each year, each cultivar and treatment were replicated three times. The soil was chemically sterilized one week prior to transplanting or planting of *in vitro* cuttings or minitubers size 25–35 mm, respectively. Within brackets after each cultivar name, is shown its origin: (iv) *in vitro*; (mt) minitubers.

2.2.1 *Experiments in 1991/92*

In 1991/92, cv. Spunta *in vitro* propagated (iv) was used and BAP 50 mg·l^{-1} + GA 50 mg·l^{-1} were applied 30 and 37 days after planting/transplanting. Planting/transplanting was carried out between 22th October and 1st November 1991 and harvest during the 3rd and 4th week of February 1992. Only tuber number·m^{-2} was recorded. All plots were managed in a similar way.

2.2.2 *Experiments in 1992*

Cultivars Huinkul minitubers (mt); Kennebec (mt), Spunta (iv) and Spunta (mt) were used. Planting/transplanting was carried out between 16th and 25th March 1992. BAP + GA at the same concentration as 1991/92 and "Biozyme" (Techic SA), a commercial product wich contains auxin (IAA, 32.2 mg·l^{-1}), gibberellic acid (GA_3, 32.2 mg·l^{-1}) and cytokinins (zeatin, 83.2 mg·l^{-1}) at 5 ml·l^{-1} was applied. Harvest was carried out between June-July 1992; only tuber number·m^{-2} was recorded.

3. Results and discussion

3.1 *Field experiments*

Several authors have used GA to increase tuber number in seed crops but no data on the effects of cytokinins on tuber number are available. In this experiment with cv. Mailén INTA, foliarly applied BAP at different crop stages did not modify stem number·m^{-2}. However, the total number of tubers was significantly increased by all treatments (Table 1). A higher tuber number was found when BAP application was carried out 54 DAE (end of tuber initiation and start of tuber growth). Bodlaender and van de Waart [2] showed that the effect of GA on tuber number was mainly due to an increase in the length and branching of the main stolons which increased the number of tuber sites. Probably, BAP caused a similar effect, because cytokinins are known to stimulate tuber initiation [10, 11, 13, 14]. This conclusion is not in agreement with data presented by Humphries [6] who found that foliarly applied GA significantly increased tuber number either if applied alone or in combination with cytokinins, while no effects of cytokinins alone were found. However, Lang and Langille [7], found that cytokinin absorption and translocation only occurred when an important sink, such as a growing tuber is present, as is the case with the application 54 DAE.

Table 1. Effects of BAP applied at different crop stages on stem number, tuber number and tuber yield under field conditions. Cv. Mailén INTA, 1989/90

Treatment	Stem number · m^{-2}	Tuber number · m^{-2}		
		<80 g	80–400 g	Total number
Control	27 a[2]	29 c	5 b	34 c
(1) 34 DAE[1]	26 a	53 ab	6 b	59 b
(2) 54 DAE	28 a	60 a	13 a	73 a
(3) 62 DAE	24 a	46 b	12 a	58 b
Treatment		Tuber yield (kg · m^{-2})		
		<80 g	80–400 g	Total yield
Control		1.93 b	0.81 b	2.74 b
(1) 34 DAE		2.92 a	1.05 b	3.97 a
(2) 54 DAE		2.25 ab	1.63 a	3.89 a
(3) 62 DAE		2.09 b	1.17 ab	3.27 ab

[1] DAE: Days after emergence.
[2] Within columns, averages followed by the same letters do not differ between them ($P < 0.05$).

Table 2. Effects of GA+BAP and Biozyme applied to different cultivars upon minituber number · m^{-2} under glasshouse conditions, 1991/92 and 1992

Year 1991/92	Control	(number · m^{-2})	BAP+GA
cv. Spunta (iv)[1]	70	*	91
Year 1992	Control	(number · m^{-2})	BAP+GA
cv. Spunta (mt)[2]	106		98
	Control	(number · m^{-2})	Biozyme
cv. Huinkul (mt)	75		78
cv. Kennebec (mt)	62		64
cv. Spunta (mt)	65	*	101
cv. Spunta (iv)	54	*	68

[1] (iv), in vitro plantlets;
[2] (mt) minitubers. (*) Significant differences between treatments ($P < 0.05$).

Foliarly applied BAP 34 DAE significantly increased tuber number in the fraction <80 g, while applications on 54 and 62 DAE also increased tuber number in the fraction 80–400 g. These results are similat to those of Struik *et al.* [12] who found that GA, applied at a high dose to the soil, near the time of tuber initiation, increased the yields in the smaller classes (0–40 g) while later application stimulated the production of very large tubers. The foliar treatment with BAP used in this field experiment required a lower dose and is advantageous because of practical and economic aspects. Although the seed fraction was improved by all treatments, the best results were obtained when applications were carried out 34 and 54 DAE.

The effects on tuber number were also reflected in tuber yield, possibly as a consequence of a great sink capacity in the treated plants, in accordance to Moorby [9] who showed assimilate production and translocation depends on the presence and growth rate of the tubers. BAP applications 34 and 54 DAE significantly increased tuber yield compared to the control treatment. Applications at 62 DAE, although producing a higher yield, did not differ from the control. Several reports have presented controversial effects of the application of GA and cytokinins on tuber yield. Bodlaender and Van de Waart [2] found no effect of GA on tuber yield during three years, but in one year, GA application reduced yield. The effect was greater at the higher GA dose. In the present experiment, the use of BAP increased total tuber yield, while Dwelle and Hurley [3] did not find a measurable response in cv. Russet Burbank when a commercial seaweed extract containing natural cytokinins was foliarly applied, whereas in cv. Lehmi Russet a positive response was found in one of seven years.

3.2 *Glasshouse experiments*

Potatoes are produced in aphid-proof glasshouses in order to multiply them under optimal and disease-free conditions. However, when *in vitro* plantlets are used, they normally produce one or a few tubers per stem. An increase in the number of tubers can be achieved if the mini-tubers obtained from these plantlets are used again. Hence in this experiment, only the number of minitubers produced in all different fractions were determined. Important differences between cultivars were recorded. For example cv. Spunta showed a significant increase in minituber production, either if the mother plant came from *in vitro* plantlets or minitubers or if BAP + GA or Biozyme was applied, in 3 out of 4 cases (Table 2).

Minituber number in cvs. Huinkul and Kennebec did not differ between treatments. It is possible that the level of endogenous cytokinins in these cultivars was higher than in cv. Spunta, hence no response was found when additional cytokinin was applied. In cv. Spunta minituber production was increased by 26 and

30% when the mother plant came from *in vitro* and by 55% when it came from minitubers.

Several reports have shown that GA application normally produced abnormal tuber growth, resulting in malformed kidney-shaped tubers [2, 12]. In these experiments, a similar effect was found only under glasshouse conditions, during the summer season of 1991/92. Possibly the high temperatures in the glasshouse enhanced the effect of GA, because during the winter season no tuber malformations were observed. From these results it can be concluded that the use of both BAP and BAP + GA under field and glasshouse conditions in cvs. Mailén and Spunta may result in increased tuber number in the seed fraction.

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