EFFECT OF PLANT GROWTH REGULATORS ON SEED TUBER YIELD IN POTATOES

Manjula S. Bandara, Karen K. Tanino and Doug R. Waterer
Dept. of Horticulture Science, University of Saskatchewan,
Saskatoon, Saskatchewan, S7N 5A8, Canada.

Abstract

Seed potato growers seek to maximize the number of desirable sized tubers. This study examined how foliar application of plant growth regulators (PGRs) influence total tuber number (TTN) and drop (25 -50 mm) seed tuber number (STN) in Norland (NOR), Russet Burbank (RB) and Shepody (SH) potatoes under field conditions in 1993 and 1994.

In 1993, PGRs, paclobutrazol (PTZ; 300, 450, 600 mg/L), kinetin (KIN; 10 and 20 mg/L), all possible combinations of the above rates of PTZ and KIN and Methyl jasmonate (MJ; 10^{-7}, 10^{-6}, 10^{-5} and 10^{-4} M) were applied to NOR and RB potatoes. In 1994, PTZ (300 mg/L), both KIN rates, and the two lowest rates of MJ were eliminated and KIN 20 mg/L or GA3 250 mg/L were applied to some of the PTZ treatments. The potato cultivar, SH was also included. Plants were treated with the PGRs at two growth stages; NOR (1993), RB (1993 and 1994) SH (1994) were treated when tubers were <10 mm or <20 mm in diameter). NOR potatoes (1994) were treated at stolon initiation (no tubers) or early tuber initiation (<8 mm in diameter).

PTZ increased STN in RB by 29 to 40% and in SH by 57 to 70 % over the controls. However, PTZ had no effect on TTN and STN in NOR in either year. MJ had no effect on STN in NOR (1993), in RB in either year or in SH in 1994. In 1994, the highest rate of MJ increased STN in NOR by 40% over the control. Application of KIN alone, in combination with PTZ or following PTZ treatment and GA3 to PTZ treated plants had no beneficial effect on either TTN or STN of all three cultivars, compare to the PTZ treatments applied alone.

This study suggests that under field conditions PTZ can be used to increase seed tuber production in RB and SH while MJ appears to be effective in NOR potatoes.

Introduction

Potato is conventionally propagated through tubers. Uniformity and varietal purity are maintained by using tubers or other vegetative parts of the potato plant. The ability to consistently produce high quality seed potatoes at low cost is critical for successful potato production.

Tuber size profile is an important quality component of a potato seed lot. A potato seed lot comprised mainly of medium sized tubers is of high value because less sizing is necessary with fewer larger tubers graded out. Potato cultivars grown in North America are cultivated in a manner conducive to the production of many large tubers. However, many farmers prefer drop size (25-50 mm in diameter) potato tubers over large whole tubers or cut tuber pieces and are often ready to pay a premium for that size seed potatoes. Larger tubers increase the weight of potatoes per unit area, which increases both seed and transport costs. Additionally, larger tubers could be better utilized for direct consumption or processing if small tubers are available for seed purposes. Larger tubers are generally unacceptable for seed because when they are cut some seed pieces may not certain a meristem or eye (blind seed pieces) and subsequently plant population may be reduced (Nielson et al., 1989).

When potatoes are grown for seed, cultural practices need to be used in order to maximize the production of seed size tubers and decrease the yield of large tubers. Tuber number is positively correlated with stem number and tuber size at harvest and is inversely proportional to the number of tubers per hill (Bleasdale, 1965; Wurr, 1974; Lynch and Rowberry, 1977; Iritani et al., 1983). However, tuber number may be manipulated by altering stem and tuber number through changes in plant density, seed piece size and physiological age of seed tuber. Higher plants density or larger seed pieces effectively reduce overall tuber size (Iritani et al., 1983). However, increasing seed pieces per acre or seed piece size also increases costs. Plant grown from tubers with advanced physiological age have more stems and smaller tubers than do plants grown from physiologically younger seed (Iritani and Weller, 1987).

Total dry matter production and distribution to different organs determine tuber yields in potatoes (Love11 and Booth, 1967; Melis and van Staden, 1984). Application of plant growth regulators (PGRs) at tuber initiation can alter photosynthate partitioning in favour of tuber production (Dyson, 1965). The role of PGRs on potato tuberization has been widely studied and reviewed by Vreugdehil and Struik (1989). Gibberellins (Love11 and Booth, 1967; Menzel, 1980; Vreugdehil and Struik, 1989) and ethylene (Vreugdenhil and van Dijk, 1989) have been found to inhibit and cytokinins (Palmer and Smith, 1969; Pelacho and Mingo-Castel, 1991a) to promote, tuberization in several ***in vitro*** systems. Hammes and Nel(l975) suggested that tuberization is controlled by a balance between endogenous gibberellins and tuber forming stimulus. To enhance tuberization, decreasing gibberellins below some minimum within the plant is required. This reduction can be achieved by using anti- gibberellin compounds such as CCC (Dyson, 1965; Gunasena and Harris, 1971; Menzel, 1980), B995 (Boldlaender and Algra, 1966) and recently tetcyclasis and triazole (Langille and Hepler, 1992) have produced promising results.

Paclobutrazol (PTZ) [(2R,3R+2S,3S)- 1-(4-chlorophenyl) 4,4-dimethyl-2-(1,2,4-triazol- 1-yl)-pentan-3-ol] is a triazole compound which inhibits shoot growth in a wide range of species including apple (Greene and Murray, 1983; Steffens et ***al.,*** 1983) and potatoes (Balamani and Pooviah, 1985). PTZ effectively enhanced tuberization in ***in vitro*** potatoes (Harvey et ***al.,*** 1991; Simco, 1991; 1993). Combined treatments of paclobutrazol with kinetin produced a synergistic effect on tuberization (Simco, 1993).

Recent studies attracted the interest among potato physiologists with the isolation of substances from potato leaves that induce tuberization (Koda and Okazawa, 1988) and is related chemical to jasmonic acid (Yoshihara ***et al.***, 1988). Because of the similarity in structure of the substance to jasmonic acid, several studies have been initiated to determine the effect of jasmonic acid on tuberization of potato cultured ***in vitro*** and revealed that jasmonic acid was found to induce tuberization of potato stolons (Pelocho and Ming-Castel, 1991b) cultured ***in vitro.*** Advantages of whole plant treatment include lower cost per tuber and the ability for growers to more easily adopt this technology over tissue culture techniques.

Despite the availability of information on the tuberization of potato plants grown under controlled environment conditions, the field studies using PGRs with the objective of increasing drop size seed potato number per plant are lacking. Therefore the present study was conducted to examine the effect of various PGRs paclobutrazol, kinetin, GA3 and methyl jasmonate on total tuber number and seed tuber number in Norland (NOR), Russet Burbank (RB) and Shepody (SH) potatoes under Saskatchewan growing conditions.

Materials and Methods

A field study was conducted at the Horticulture Science Department potato plots (Sandy Loam Soil, pH=6.5) in Saskatoon for two years, 1993 and 1994. Prior to planting, soil fertility levels was adjusted to meet Saskatchewan Soil Testing Laboratory recommendation for irrigated potatoes. Seeds of the cultivars, NOR (Elite iii in 1993 and 1994), RB (Elite iii in 1993 and 1994) and SH (Elite ii in 1994) were planted at the spacing of 30 cm in row and 1 m between rows on the 18th of May and 26th of May in 1993 and 1994, respectively. In 1993, paclobutrazol (PTZ) (300, 450 and 600 mg/L), kinetin (KIN) (10 and 20 mg/L), all possible combinations of PTZ and KIN and methyl jasmonate (MJ) (10^{-7}, 10^{-6}, 10^{-5} 104 M) were applied to Norland (NOR) and Russet Burbank (RB) potatoes. In 1994, **PTZ (300** mg/L), KIN (10 and **20** mg/L), MJ (10^{-7} and 10^{-6} M) and all PTZ and KIN combinations were eliminated and GA3 250 mg/L and KIN 20 mg/L treatments were applied to some PTZ treatments. In 1994, the cultivar Shepody (SH) was also included to the study. Plants were treated with plant growth regulators (PGRs) at two growth stages; NOR (1993), RB (1993 and 1994) and SH (1994) were treated when tubers <10 mm or <20 mm in diameter. NOR (1994) was treated at stolon initiation (no tubers on the plant) or early tuber initiation (<8 mm in diameter).

The surfactant, Cittowett Plus was added to each chemical solution and water treatment at a rate of 0.12% v/v. All sprayings was carried out using a CO2 powered knapsack sprayer (R and D Sprayers Inc., Opelousus, LA, USA) with one Teejet (SS80015) nozzle operating at 276 kPa pressure applying 112.5 L of solution per ha. Separate containers were used for each chemical during spraying to avoid cross-contamination.

Throughout the growing season, standard management practices for seed production were employed. Weed were controlled using appropriate pre- and post-emergent herbicides in conjunction with inter-row tillage. The crop was hilled twice using a rolling cultivator. At the second hilling, 50 kg N/ha was broadcast and incorporated into the hill. Supplemental irrigation was used to maintain soil moisture at optimal levels throughout the growing season. Aphids and Colorado potato beetles were controlled by foliar applications of furadan and Decis. After eliminating boarders 6.0 m (1993) or 4.4 m (1994) long row from each treatment was harvested. After curing at room temperature for about one week, tuber from each treatment were graded into three categories (>25-50 mm, >50-75 mm, and >75 mm) according to their diameters. The effects of treatments on total and seed tuber (25-50 mm) number were evaluated by executing ANOVA in a Randomized Complete Block Design (1993) and Split-plot Design (1994) using pre-planned contrasts as follows:

i. Trend analysis for rates of PGRs, time of application and PGR rate x time of application interactions by considering control as zero levels.

ii. Synergistic effects due to combined application of **PTZ+KIN** over the individual applications of the same compounds (1993). Moreover, the effects of PTZ followed by GA3 or KIN (1994) on TTN and STN were compared with PTZ treatments applied alone.

Results

Irrespective of crop growth stage at application, increasing rates of PTZ, KIN or MJ had no effect on TTN and STN in NOR in 1993 (Table 1). Combined treatments of PTZ+KIN had no beneficial effect on both TTN and STN, over the average of individual applications of the compounds (Table 1). In fact, some treatment combinations (ie. PTZ 450+KIN 10 or 20 mg/L) reduced TTN compared the average of individual treatments (Table 1). In contrast, increasing rates of PTZ resulted in a consistent increase in the TTN and STN in RI3 (Table 1). For example, depending upon the rates, PTZ increased TTN by 18 to 24 % and STN by 29 to 36 % over the controls (Table 1). Increasing rates of KIN and MJ had no effect on TTN and STN in RB (Table 1). In general, combined treatment of PTZ+KIN had no beneficial effect on TTN over the average of the PGRs applied alone (Table 1).

Based on 1993 field results, treatments were revised in 1994 study. In 1994, treatments with PTZ (300mg/L), both rates of KIN (10 and 20 mg/L) applied alone, the two lowest rates of MJ and all PTZ+KIN combinations were eliminated and KIN 20mg/L or GA3 250 mg/L were applied to some of PTZ treatments. The potato cultivar, SH was also included in 1994.

Results indicated that irrespective of the crop growth stage at application, PTZ had no effect on TTN and STN in NOR potatoes (Table 2). Increasing rates of MJ resulted in a linear increase in TTN and STN in NOR (Table 2). Depending upon the rate, MJ increased TTN by 6 to 16% STN by 5 to 40% over the controls (Table 2). On average, KIN and GA3 applied to NOR plants treated with PTZ had no beneficial effect on either TTN or STN compared to those treated with PTZ alone (Table 2).

Increasing rates of PTZ resulted in a linear increase in TTN and STN in RB potatoes in 1994 (Table 2). On average, PTZ increased TTN by 18%, STN by 29 to 39% over the controls (Table 2). Increasing rates of MJ resulted in a linear increase in TTN, but had no effect on STN in RB (Table 2). Treatment with KIN or GA3 following PTZ application had no effect on TTN and STN compared to treatments with PTZ alone (Table 2).

Despite the difference in crop growth stage at application, none of PGRs had significant effect on TTN in SH potatoes (Table 2). Increasing rates of PTZ, however, resulted in a linear increase in STN in SH in 1994 (Table 2). Depending upon rate, PTZ increased STN by 57 to 70% over the control (Table 2). MJ had no effect on STN in SH. On average, treatment with GA3 applied to PTZ treatments reduced TTN and STN compared to treatments with PTZ alone (Table 2).

Summary and Conclusions

Increasing rates of PTZ consistently increased STN of RB and SH potatoes, but had no effect on TTN in SH. MJ increased STN of NOR without having adverse effect on TTN, but had no effect on STN in RB and SH. PTZ had no effect on either TTN or STN in NOR potatoes under field conditions.

Application of KIN in combination with PTZ or applied to PTZ treatments, and GA3 to PTZ treatments had no beneficial effect on either TTN or STN of all three cultivars, over PTZ treatments applied alone.

In summary, it can be suggested that under field conditions, PTZ can use to increase seed tuber production in RB and in SH while MJ in NOR potatoes.

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Table 1 Effect of foliar applications of plant growth regulators on the numbers of total and seed (25-50 mm in diameter) tubers in Norland, Russet Burbank potatoes under field conditions (1993).

Treatment	Norland		Russet Burbank	
	Total	Seed	Total	Seed
	--------------number of tubers/$6m^2$ -----------------			
Cont.	216	94	175	110
PTZ* 300 mg/L	222	105	213	154
PTZ 450 mg/L	231	107	207	142
PTZ 600 mg/L	221	104	217	150
KIN**.10 mg/L	200	88	180	111
KIN 20 mg/L	232	99	177	94
MJ! 10^{-7} M	227	91	181	109
MJ 10^{-6} M	216	91	193	112
MJ 10^{-5} M	224	92	181	98
MJ 10^{-4} M	255	102	185	103
PTZ300+KIN10	227	97	191	121
PTZ300+KIN20	204	95	203	133
PTZ450+KIN10	189	91	190	120
PTZ450+KIN20	190	93	193	127
PTZ600+KIN10	202	98	199	139
PTZ600+KIN20	213	94	188	140

Statistical Analysis

Time of App.	ns!!	ns	ns	ns
PGR rates	ns	ns	PTZ (L#)	PTZ (L)
Interaction	ns	ns	ns	ns

Synergistic Effects

(PTZ)+(KIN)vs				
(PTZ+KIN)	*	ns	ns	ns

*=Paclobutrazol; **=Kinetin; !=Methyl jasmonate;
!!=nonsignificant at $p=0.05$ level; #= Linear.

Table 2 Effect of plant growth regulators on the number of total and seed (25-50 mm in diameter) tubers in Norland, Russet Burbank and Shepody potatoes.

Treatment	Norland		Russet Burbank		Shepody	
	Total	seed	Total	Seed	Total	Seed
	------------------ Number of tubers/4.4m^2 ______________					
Cont.	146	37.2	110	50.4	98	24.6
PTZ* 450mg/L	147	45.1	130	70.0	112	42.0
PTZ 600mg/L	139	41.1	129	64.8	106	38.6
MJ! 10^{-5} M	155	39.2	131	53.5	102	27.0
MJ 10^{-4} M	167	51.7	121	49.8	102	29.8
PTZ 450 & KIN 20mg/L	149	42.5	131	71.0	122	49.4
PTZ 450 & GA_3 250mg/L	146	46.2	129	69.8	103	32.5
PTZ 600 & KIN 20 mg/L	143	41.7	132	74.8	104	36.9
PTZ 600 & GA_3 250mg/L	129	34.9	121	70.1	89	33.4

Statistical Analysis

PGR rates:						
PTZ	ns	ns	L#	L	ns	L
Time of app.	ns	ns	ns	ns	ns	ns
Interaction	ns	ns	ns	ns	n	ns
MJ	L	L	L	ns	ns	ns
Time of App.	ns	ns	ns	ns	ns	ns
Interaction	ns	ns	ns	ns	ns	ns
PTZ vs						
PTZ & KIN	ns	ns	ns	ns	ns	ns
Time of app.	ns	ns	ns	ns	ns	ns
PTZ vs						
PTZ & GA_3	ns	ns	ns	ns	*	*
Time of app.	ns	ns	ns	ns	ns	ns

*=Paclobutrazol;!= Methyl jasmonate; ns=non-significant at p=0.05 level;#=Linear.

References

Balamani, V and Poovaiah, B.W. 1985. Retardation of shoot growth and promotion of tuber growth of potato plants by paclobutrazol. Am. Potato J. 62: 363-369.

Bleasdale, J.K.A. 1965. Relationships between set characters and yield in main crop potatoes. J. Agric. Sci. (Camb.) 64:361-366.

Bodlaender, K.B. A. and Algra, S. 1966. Influence of the growth retardant B 995 on growth and yield of potatoes. Eur. Potato J. 9:242-258

Dyson, P.W. 1965. Effects of gibberellic acid and 2-chloroethyl-trimethylammonium chloride on potato growth and development. J. Sci. Food Agric. 16: 542-549.

Greens, D. W. and Murray, J. 1983. Effect of paclobutrazol (PP333) and analogs on growth, fruit quality and storage potential of ‘Delicious’ apples. Proc. Plant Growth Reg. Soc. Am. 10: 207-2 12.

Gunasena, H.P.M. and Harris, P.M. 197 1. The effect of CCC, N and potassium on the growth and yield of two varieties of potatoes. J. Agric. Sci.76: 33-52.

Hammes, P.S. and Nel, P.C. 1975. Control mechanisms in the tuberization process. Potato Res. 18: 262-272.

Harvey, B .M.R., Crothers, S.H. Evans, N. E. and Selby, C. 199 1. The use of growth retardants to improve microtuber formation by potato (***Solanum tuberosum*** L.). Plant Cell Tiss. Org. Cult. 27:59-64.

Iritani, W. M. and Weller, L.D. 1983. The influence of physiological age, stem numbers and fertility on yield and grade of Russet Burbank potatoes. Am. Potato J. 64:291-299.

Iritani., W. M., L. D. Weller and Knowles, N.R. 1983. Relationships between stem number, tuber set and yield of Russet Burbank potatoes. Am. Potato J. 60 :423-43 1.

Koda, Y. and Okazawa, Y. 1988. Detection of potato tuber-inducing activity in potato leaves and old tubers. Plant Cell Physiol. 29:969-974.

Langille, A. R. and Hepler, P.R. 1992. Effect of three anti-gibberellin growth retardants on tuberization of induced and non-induced katahdian potato leaf-bud cuttings. Am. Potato. J. 60: 131-141.

Lynch, D.R. and Rowberry, R.G. 1977. Population studies with Russet Burbank II. The effect of fertilization and plant density on growth, development and yield. Am. Potato J. 54:57-7 1.

Melis, R.J.M. and van Staden, J. 1984. Tuberization and hormones. Z. Pflanzenphysiol. 113: 271-283.

Menzel, C. M. 1980. Tuberization in potato at high temperatures: Response to gibberellin and growth inhibitors. Ann. Bot. 46:259-265.

Nielson, M., W.M Iritani and Weller, L.D. 1989. Potato seed productivity: Factors influencing eye number per seed piece and subsequent performance. Am. Potato J. 66: 15 1 - 160.

Palmer, C. E. and Smith, O.C. 1969. Cytokinines and tuber initiation in the potato *Solanum tuberosum* L. Nature 221: 279-280.

Pelacho, A. M. and Mingo-Castel, A.M. 1991a. Effects of photoperiod on kinetin-induced tuberization of isolated potato stolons cultured in *vitro. Am.* Potato J. 86: 533-541.

Pelacho, A.M. and Mingo-Castel, A.M. 1991b. Jasmonic acid induced tuberization of potato stolons cultured *in vitro.* Plant Physiol. 97: 1252-1255.

Simco, I. 1991. *In vitro* potato tuberization after the treatments with paclobutrazol. Biologia 46:25 l-256.

Simco, I. 1993. Effects of kinetin, paclobutrazol and their interactions on the mocrotuberization of potato stem segments cultured *in vitro* in the light. Plant Growth Reg. 12:23-27.

Steffens, G.L., S.T. Wang, CL. Steffens and Brenner, T. 1983. Influence of paclobutrazol PP333) on apple seedling growth and physiology. Proc. Plant Growth Reg. Soc. Am. 10: 195-206.

Vreugdenhil, D. and Struik, P.C. 1989. An integrated view of the hormonal regulation of tuber formation in potato. Physiol. Plant. 75: 525-53 1.

Vreugdenhil, D. and van Dijk, W. 1989. Effects of ethylene on the tuberization of the potato *(Solonum tuberosum* L.) cuttings. Plant Growth Regul. 8:31-39.

Yoshihara, T., E.A. Omer, H. Shibata, H. Koshino, H. Matsu-Ura, S, Sakamura, Y. Koda, Y. Kikuta and Okazawa, Y. 1988. Chemical studies on the potato tuber-inducing substance. In Symposium papers of the 30th symposium on the chemistry on natural products. Fukuaka, Japan. pp. 158-163.

Wurr, D.C.E. 1974. Some effects of seed size and spacing on the yield and grading of two main crop potato varieties. I Final yield and its relationship to plant population. J. Agric. Sci.(Camb) 82:37-45.