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In Vitro Flower Abscission Induction in North American Ginseng

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Abstract : *In vitro* studies using detached inflorescences with peduncles were conducted to investigate flower abscission agents in North American ginseng (*Panax quinquefolius* L.). Of the nine compounds studied only three, ammonium thiosulphate (ATS), abscisic acid (ABA) and ethephon induced abscission. Anilazine, benzyladenine, carbaryl, gibberellic acid, napthaleneacetic acid and thidiazuron did not induce abscission. ATS dip treatments did not induce abscission but the spray treatments induced 60.5% abscission at 1500 mg · L^{-1} and 33.1% at 3000 mg · L^{-1}. Severe chlorophyll loss occurred on all inflorescences treated with ATS. Both ABA dip treatments and a 250 μmol · L^{-1} spray treatment caused abscission (40%) without adverse effects, and timing of ABA application was important. Because ABA was only significant in the dip treatments, ABA may not be a practical option for field use on ginseng. Ethephon sprays induced more abscission as the season progressed and as the concentration increased. As the dip concentrations of ethephon increased, the abscission rate decreased and the health of the inflorescences declined. The 1500 mg · L^{-1} spray of ethephon gave consistent abscission results over the growing season with little phytotoxicity. Treatment with the competitive ethylene inhibitor 1-methylcyclopropene (1-MCP) suggested that flower abscission was due to the liberation of ethylene from the breakdown of ethephon.

Key words : *Panax quinquefolius,* ethylene, plant growth regulators

INTRODUCTION

Plant growth regulators (PGRs) are widely used and studied as flower removal agents in horticultural crops.[1] Recently, removal of ginseng flowers using PGRs has been proposed as an alternative to expensive manual removal.[2,3] Fiebig *et al.*,[3] showed that ethephon was effective in stimulating flower abscission in ginseng. However, at the higher concentrations of applied ethephon needed to remove flowers, chlorophyll loss and development of red, orange and yellow pigments in the leaves, and sometimes leaf abscission, were observed. Also, as in studies with crops such as olive and cherry[4,5] ethylene-induced ginseng flower abscission has been variable, and dependent on the prevailing environmental and crop conditions. The ginseng inflorescence is displayed both above and within the canopy which could mean a variable response to applied ethephon particularly if ethephon is effective only when applied to the site of action, as in olive.[6]

A prolonged period of anthesis (4 to 6 weeks) is characteristic of ginseng.[2,7,8] Although a series of morphological changes in the flower and the inflorescence take place during anthesis, flower abscission in ginseng during anthesis does not usually occur naturally as it does in other crops such as olive.[9] Initiation of the floral abscission process in ginseng using PGRs would be valuable to growers as it should mimic manual inflorescence removal and increase root yield by 26%.[10]

In an attempt to ensure definitive results, it was necessary to introduce ethephon and other potential abscission-inducing PGRs to the site of action under controlled conditions. Such an approach overcomes the problems of uptake of ethephon and other compounds by foliar treatments of whole plants in the field under variable conditions. A laboratory-scale method was developed by which ginseng flower abscission, induced by stem or spray uptake of PGRs, could be studied. Also, possible relationships between *in vitro* results with those found under field conditions were explored.

MATERIALS AND METHODS

1. 2000 Experiments.

Inflorescences of North American ginseng (*Panax quinquefolius* L.) were collected four times (June 20, 28, July

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17 and August 8) from a 3-year-old commercial garden north of Paris, Ontario. Inflorescences were broken off at the base of the peduncle, placed in jars of deionized water and transported back to the lab. The inflorescences were kept in water over night.

Three compounds, ethephon, gibberellic acid (GA), and 6-benzylamino-purine (BA), each at three concentrations, were tested for their ability to remove flowers from ginseng inflorescences. Two bioassays (sprays and dips) were evaluated. The inflorescences for the first experiment were harvested on June 20 and prepared by measuring the diameter of the peduncle at the base of the inflorescence head and the diameter of the inflorescence head using the MAX-CAL Electronic Digital Calipers (Fowler and NSK, Cole-Parmer, Illinios). The length of the peduncle, after 2-4 cm were cut from the base with a razor blade, was measured with a ruler to ensure that all peduncles were of the same length. For the dip treatments (Table 1) the inflorescences were immediately placed in small plastic vials containing 10 ml of the test solutions ("dip"). For the spray treatments inflorescences were placed in vials that contained 10 ml of deionized water and sprayed with the test solutions to the drip point, using a hand held household sprayer.

The experiment was set up as a randomized complete block design with four blocks and 1 inflorescence per treatment. All treatments were randomized within each block on a table that was continually lit with a Phillips Ceramalux high pressure sodium lamp (400Watts-100Volts) which provided an average of 190 $\mu mol\ s^{-1}\ m^{-1}$ PAR (photosynthetically active radiation) at the inflorescences. A quantum sensor (LI-COR, Lincoln, Nebraska) attached to a Quantum/Radiometer/Photometer (Model LI-189) was used to measure PAR.

One day after placement under the sodium lamp each inflorescence was held over a plastic dish and the peduncle was tapped. This was repeated at about the same time each day for 5 days and the number of flowers that abscised was recorded. Open flowers, set fruit and flower buds were all counted as "flowers". Visual observations of any changes in the inflorescences were recorded and deionized water was added after day 3 to prevent the vials from drying out. The diameters of the peduncle and inflorescence head were measured at the end of the experiment.

Table 1. Treatments (Trt) for flower abscission from 3-year-old North American ginseng inflorescences harvested on June 20 and 28, 2000.

Trt	Jun-20	Jun-28
1	Control - sprayed with water	Control - sprayed with water
2	Sprayed with 500 mg · L^{-1} ethephon	Sprayed with 500 mg · L^{-1} ethephon
3	Sprayed with 1500 mg · L^{-1} ethephon	Sprayed with 1500 mg · L^{-1} ethephon
4	Sprayed with 3000 mg · L^{-1} ethephon	Sprayed with 3000 mg · L^{-1} ethephon
5	Control - sprayed with water	Control - dipped in 10 ml of water
6	Dip in 10 ml of 500 mg · L^{-1} ethephon	Dip in 15 ml of 500 mg · L^{-1} ethephon
7	Dip in 10 ml of 1500 mg · L^{-1} ethephon	Dip in 15 ml of 1500 mg · L^{-1} ethephon
8	Dip in 10 ml of 3000 mg · L^{-1} ethephon	Dip in 15 ml of 3000 mg · L^{-1} ethephon
9	Sprayed with 50 mg · L^{-1} GA	Sprayed with 5 mg · L^{-1} NAA
10	Sprayed with 100 mg · L^{-1} GA	Sprayed with 10 mg · L^{-1} NAA
11	Sprayed with 200 mg · L^{-1} GA	Sprayed with 20 mg · L^{-1} NAA
12	Dip in 10 ml of 50 mg · L^{-1} GA	Dip in 15 ml of 5 mg · L^{-1} NAA
13	Dip in 10 ml of 100 mg · L^{-1} GA	Dip in 15 ml of 10 mg · L^{-1} NAA
14	Dip in 10 ml of 200 mg · L^{-1} GA	Dip in 15 ml of 20 mg · L^{-1} NAA
15	Sprayed with 25 mg · L^{-1} BA	Sprayed with 50 mg · L^{-1} thidiazuron
16	Sprayed with 50 mg · L^{-1} BA	Sprayed with 100 mg · L^{-1} thidiazuron
17	Sprayed with 100 mg · L^{-1} BA	Sprayed with 125 mg · L^{-1} thidiazuron
18	Dip in 10 ml of 25 mg · L^{-1} BA	Dip in 15 ml of 50 mg · L^{-1} thidiazuron
19	Dip in 10 ml of 50 mg · L^{-1} BA	Dip in 15 ml of 100 mg · L^{-1} thidiazuron
20	Dip in 10 ml of 100 mg · L^{-1} BA	Dip in 15 ml of 125 mg · L^{-1} thidiazuron

Table 2. Treatments (Trt) for flower abscission from 3-year-old North American ginseng inflorescences harvested on July 17 and August 8, 2000.

Trt	Jul-17	Aug-08
1	Control - sprayed with water	Control - sprayed with water
2	Sprayed with 500 mg · L^{-1} ethephon	Sprayed with 500 mg · L^{-1} ethephon
3	Sprayed with 1500 mg · L^{-1} ethephon	Sprayed with 1500 mg · L^{-1} ethephon
4	Sprayed with 3000 mg · L^{-1} ethephon	Sprayed with 3000 mg · L^{-1} ethephon
5	Control - dipped in 15 ml water	Control - dipped in 15 ml water
6	Dip in 15 ml of 500 mg · L^{-1} ethephon	Dip in 15 ml of 500 mg · L^{-1} ethephon
7	Dip in 15 ml of 1500 mg · L^{-1} ethephon	Dip in 15 ml of 1500 mg · L^{-1} ethephon
8	Dip in 15 ml of 3000 mg · L^{-1} ethephon	Dip in 15 ml of 3000 mg · L^{-1} ethephon
9	Sprayed with 15000 mg · L^{-1} ammonium thiosulphate	Sprayed with 25 mmol · L^{-1} ABA
10	Sprayed with 30000 mg · L^{-1} ammonium thiosulphate	Sprayed with 250 mmol · L^{-1} ABA
11	Dip in 15 ml 15000 mg · L^{-1} ammonium thiosulphate	Dip in 15 ml of 25 mmol · L^{-1} ABA
12	Dip in 15 ml of 30000 mg · L^{-1} ammonium thiosulphate	Dip in 15 ml of 250 mmol · L^{-1} ABA
13	Sprayed with 1000 mg · L^{-1} anilazine	Sprayed with 0.375 g · L^{-1} carbaryl
14	Sprayed with 2000 mg · L^{-1} anilazine	Sprayed with 0.75 g · L^{-1} carbaryl
15	Dip in 15 ml of 1000 mg · L^{-1} anilazine	Dip in 15 ml of 0.375 g · L^{-1} carbaryl
16	Dip in 15 ml of 2000 mg · L^{-1} anilazine	Dip in 15 ml of 0.75 g · L^{-1} carbaryl

Table 3. Treatments (Trt) in experiment 5 to explore the effects of 1-MCP (1-methylcyclopropene) and ethephon on flower abscission from 3-year-old North American ginseng inflorescences harvested on June 20, 2001.

Trt	Description
1	Control - sprayed with deionized water
2	Control - dipped in 15 mL water
3	Exposed to 600 nL · L^{-1} 1-MCP then sprayed with deionized water
4	Exposed to 600 nL · L^{-1} 1-MCP then dipped in 15 mL deionized water
5	Exposed to 600 nL · L^{-1} 1-MCP then sprayed with 1500 mg · L^{-1} ethephon
6	Exposed to 600 nL · L^{-1} 1-MCP then dipped in 15 mL of 1500 mg · L^{-1} ethephon
7	Sprayed with 1500 mg · L^{-1} ethephon
8	Dipped in 15 mL of 1500 mg · L^{-1} ethephon

The experiment was repeated on three other dates (June 28, July 17 and August 8) using the same ethephon treatments and two new compounds each time. Inflorescences for the second experiment were collected on June 28 and á-naphthalene acetic acid (NAA) and thidiazuron were investigated (Table 1). For the third experiment, investigating ammonium thiosulphate (ATS) and anilazine, inflorescences were collected on July 17 (Table 2). Inflorescences for the final experiment were collected on August 8 and the effects of ethephon, abscisic acid (ABA) and carbaryl were examined (Table 2).

2. 2001 Experiments.

Inflorescences were collected five times (June 20, 26, July 6, 17 and August 1) from a 3-year-old commercial garden north of Paris, Ontario, as in 2000. An additional 20 inflorescences were harvested and the number of bud and florets were counted on each in order to estimate the percent bloom (florets + set fruit) in the field.

In the first experiment (experiment 5) the ethylene blocker, 1-methylcyclopropene (1-MCP), was used to determine if the abscission caused by ethephon was a result of the release of ethylene. Inflorescences were exposed to either water, 1500 mg · L^{-1} ethephon, or combinations of the two and 1-MCP (Table 3). Sixteen inflorescences, harvested on June 20, were exposed to 600 nL · L^{-1} of 1-MCP for 24 hours at 21 ± 2°C in sealed plastic chambers with a volume of 0.2 m^3. The 1-MCP source

was 0.18 g of EthylBloc powder (Floralife, Inc., Walterboro, SC). The inflorescences were placed in small beakers that were covered with parafilm and the inflorescence peduncles were poked through the parafilm. The EthylBloc powder was placed in an Erlenmeyer flask and the flask was placed in the chamber with the inflorescences. The chamber was sealed tightly using duct tape. A hypodermic syringe was used to inject 50 mL of water into the flask containing the EthylBloc. The syringe hole was sealed with duct tape and the flask was gently agitated. After exposure to 1-MCP for 24 hours the inflorescences were divided into 4 groups of 4 and each inflorescence was placed in its own vial. The vials of three of the groups were filled with 20 mL of deionized water and the vials of the fourth group were filled with 20 mL of 1500 mg · L^{-1} ethephon. One of the groups that was placed in water was sprayed to the drip point with deionized water and another group was sprayed, to the drip point, with 1500 mg · L^{-1} ethephon. All measurements and sampling methods followed those outlined above for 2000.

The four remaining experiments conducted in 2001 investigated one concentration of ethephon, 1500 mg · L^{-1}, and two concentrations of ABA, 25 and 250 μmol · L^{-1} (Table 4). These concentrations were tested over the growing season to determine if the effectiveness of the compounds was dependent on the developmental stage of the inflorescences.

Data analyses were carried out using the general linear model procedure of the Statistical Analysis System program package (SAS Institute Inc., Cary, N.C.) at a probability level of 0.05.

Table 4. Treatments (Trt) 2001 to test flower abscission from 3-year-old North American ginseng inflorescences. Inflorescences were harvested on June 26, July 6, July 17 and August 1.

Trt	Description
1	Control - sprayed with deionized water
2	Sprayed with 1500 mg · L^{-1} ethephon
3	Control - dipped in 15 ml of deionized water
4	Dipped in 15 ml of 1500 mg · L^{-1} ethephon
5	Sprayed with 25 μmol · L^{-1} ABA
6	Sprayed with 250 μmol · L^{-1} ABA
7	Dipped in 15 ml of 25 μmol · L^{-1} ABA
8	Dipped in 15 ml of 250 μmol · L^{-1} ABA

RESULTS AND DISCUSSION

2000 Experiments. Among the nine different PGRs (Tables 1 and 2) tested only ammonium thiosulfate, ABA and ethephon (Fig. 1) resulted in abscission. GA and BA (Table 1) resulted in either no abscission, or cumulative abscission of less than 1% (data not shown). The BA results were surprising as BA has been known as a fruitlet thinning agent in numerous apple cultivars.[11-14]

Napthaleneacetic acid (NAA) is a potent thinning agent

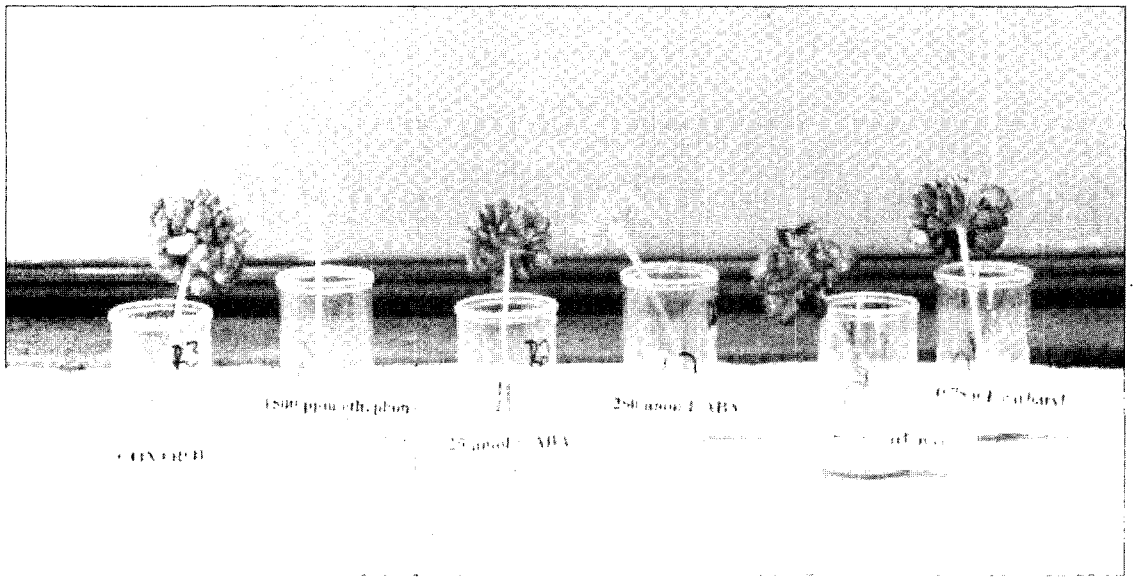

Fig. 1. Response of detached inflorescences with attached pedicles 4 days after being placed in water (control) or five different plant growth regulator solutions. There was no abscission of berries in the controls.

for apples when applied between king bloom opening and when the fruitlets are 12 mm diameter,[15] However, with ginseng there was no abscission from the NAA treatments (Table 1). While the pedicels of the flowers drooped downwards and red streaks were noted on the peduncles, the inflorescences developed normally.

The highest cumulative abscission (2.45%) from thidiazuron was with the 50 mg · L^{-1} spray treatment. Elfving and Cline[11] reported that thidiazuron at 62 and 125 mg · L^{-1} applied 22 days after full bloom thinned 'Empire' apples below the commercially accepted crop levels. Greene[16] however, determined that thidiazuron was capable of thinning 'Empire' apples to an ideal crop level when 5 mg · L^{-1} was applied 18 days after full bloom. In both studies application timing of thidiazuron was crucial in achieving optimum fruit size and yield.

Response of apples to thidiazuron was also cultivar dependent.[16] Since there are no cultivars of North American ginseng and it is genetically diverse[17,18] the use of thidiazuron for flower thinning may be dependent on genetic composition and/or application timing. North American ginseng treated with thidiazuron showed an increase in root biomass and adventitious buds.[19]

Both anilazine spray and dip treatments (Table 2) of 2000 mg · L^{-1} gave cumulative abscission of less than 1%. The dip treatment of 1000 mg · L^{-1} resulted in a cumulative abscission of 18.8% but was not different from the control (3.24%). The inflorescences treated with the 2000 mg · L^{-1} spray and dip all remained green and healthy. Uptake of anilazine at 1000 mg · L^{-1} resulted in various parts of the inflorescences turning red. In some cases the peduncle and pedicels were streaked red and in other cases the margins of the buds and florets turned red. Anilazine did not cause flower drop or severe phytotoxicity when applied to ginseng inflorescences, so further investigation of multiple applications to whole ginseng plants over the flowering period may lead to a reduction in fruit set.

Ammonium thiosulfate (ATS) spray treatments at 15000 mg · L^{-1} and 30000 mg · L^{-1} (Table 2) resulted in cumulative abscission of 60.5% and 33.1% respectively which was below the 75% abscission required to mimic the effect of hand removal.[3] No abscission was caused by the dip treatments. ATS also caused a number of unwanted effects: in the spray treatments the inflorescences turned white and in the dip treatments entire inflorescences, including peduncles, turned completely white but retained their structural integrity. Such a severe loss of chlorophyll may occur in the leaves and would be detrimental to plants resulting in yield losses. ATS acts as a thinning agent in apples by desiccating the stigmas and styles of flowers.[20] Webster and Spencer[21] reported that browning and shriveling of flowers and necrosis of spur leaves occurred after ATS application to 'Royal Gala' and 'Queen Cox' apple trees. The desiccating action of ATS may be the reason for the severe phytotoxic symptoms noted on individual ginseng inflorescences.

Carbaryl (Table 2 and Fig.1) did not cause abscission of ginseng flowers. Cumulative abscission ranged from 3.1%, by the 0.75 g · L^{-1} spray treatment, to about 15% for all three of the other treatments. The inflorescences sprayed with carbaryl remained healthy throughout the experiment. The peduncles of inflorescences exposed to carbaryl as a dip turned a red-brown colour and some of the berries turned black before dropping.

ABA spray treatments achieved 26.2% abscission for the 25 μmol · L^{-1} concentration and 40% for 250 μmol · L^{-1}. The dip treatments resulted in higher cumulative abscission of 47% and 96% for the 25 and 250 μmol · L^{-1} concentrations respectively. ABA use on preclimacteric apple fruit gave varying results based on timing of application and concentration used[22] (see below). It would be worth examining ABA throughout the growing season to determine if the cumulative abscission would increase if ABA were applied at different stages of inflorescence development, and applied more than once.

The 500 mg · L^{-1} spray treatment of ethephon achieved an average cumulative abscission of 14.6% at the beginning of the season (June 20) and rose to 87.9% in the final experiment (August 8) (Figs. 2 and 3 respectively). Abscission with 1500 mg · L^{-1} increased similarly from 74.8% to 98.1% and the 3000 mg · L^{-1} increased from 88% to 100%. The dip treatment at 500 mg · L^{-1} was more effective then the other two concentrations but the 1500 mg · L^{-1} produced similar results to its corresponding spray treatment. The 500 mg · L^{-1} dip treatments started at 90.1% abscission and increased to 100% while the 3000 mg · L^{-1} dips treatments started at 29.6% and increased to 96%.

The abscission effect of ethephon on ginseng inflorescences was similar to leaf abscission in olives[23] but markedly different from olive fruit abscission.[24] Ethephon concentration, length of exposure, and tissue type are all possible reasons for differences observed between ethephon use in ginseng and in other plants.

The dip treatments of ethephon resulted in a loss of chlorophyll at the base of the peduncles leaving them a beige color. Also, 3000 mg · L^{-1} as a dip treatment

affected the vascular system of the peduncles and inflorescences as the heads of the inflorescences dried up regardless of the degree of abscission. Ethephon spray treatments did not produce any adverse effects. The only noticeable change in the inflorescences was that the bracts and the pedicels turned red.

Ethephon spray at 1500 mg · L^{-1} produced the most consistent results throughout the growing season, obtaining greater than 74% abscission in all experiments, and did not result in adverse effects as seen in the dip treatment. Treatments were analyzed to determine if time, therefore inflorescence development, was a significant factor in the efficacy of ethephon (Table 5). Dip treatments of 1500 mg · L^{-1} and 3000 mg · L^{-1} were significantly different between experiment 1, started on June 20, and experiment 2, started on June 28. The dip treatment of 3000 mg · L^{-1} was also different between experiments 1 and 3 (July 17) as well as the spray treatment of 500 mg · L^{-1}. Only two treatments were not significant when experiments 1 and 4 (August 8) were compared, the 3000 mg · L^{-1} spray treatment and 500 mg · L^{-1} dip treatment. The 3000 mg · L^{-1} spray treatment did not vary throughout the season as it was high enough to consistently cause between 87 and 100% abscission. The 500 mg · L^{-1} dip treatment also did not vary over the four experiments, resulting in 93 to 100% abscission, because it was low enough to elicit a response to ethephon without resulting in severe phytotoxic symptoms. From this time comparison it can be concluded that the timing of ethephon sprays was important to achieve optimum abscission.

Table 5. Results from Tukey's pairwise comparisons to determine the effect of time on ethephon treatments over the 2000 growing season.

Treatment	June 20 vs. June 28	June 20 vs. July 17	June 20 vs. August 8
Control spray			*
500 mg · L^{-1} spray		*	*
1500 mg · L^{-1} spray			*
3000 mg · L^{-1} spray			
Control dip			*
500 mg · L^{-1} dip			
1500 mg · L^{-1} dip	*		*
3000 mg · L^{-1} dip	*	*	*

*Treatment significant, when compared over time using Tukey's test, at $P \leq 0.05$.

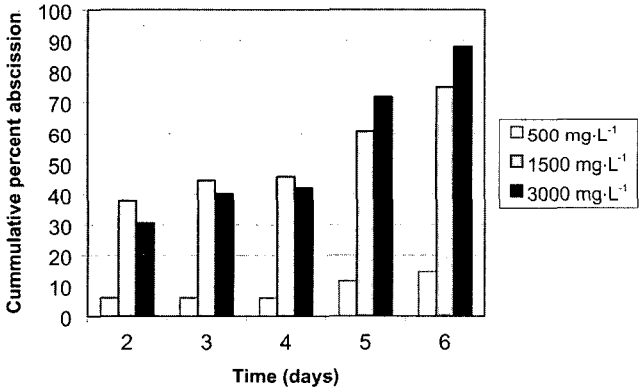

Fig. 2. Cumulative percent berry abscission in a spray bioassay of ethephon, at three concentrations, 500, 1500 and 3000 mg · L^{-1}, started on June 20, 2000. There was zero abscission from the control therefore it was not included. Mean standard error ± 3.53.

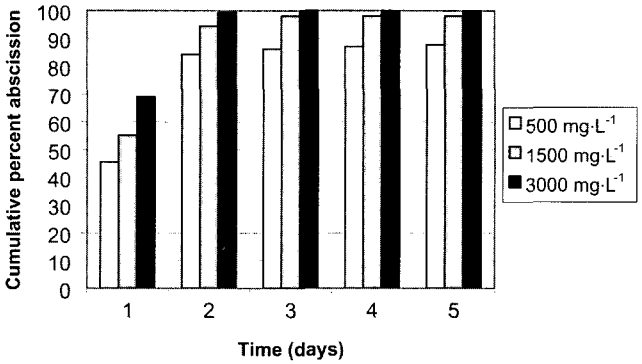

Fig. 3. Cumulative percent berry abscission in spray bioassay of ethephon, at three concentrations, 500, 1500 and 3000 mg·L^{-1}, started on August 8, 2000. There was only 7% abscission in the case of the control therefore it was not included. Mean standard error ± 7.55.

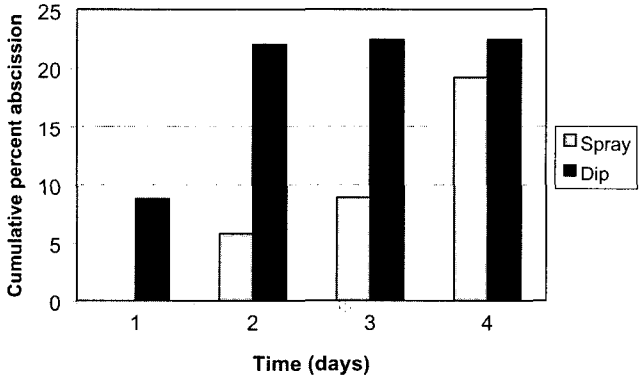

Fig. 4. Cumulative percent berry abscission from spray and dip treatments of ethephon, at 1500 mg · L^{-1}, started on June 20, 2001. There was less than zero abscission from the spray and dip controls therefore they were not included. Mean standard error ± 8.68.

2001 Experiments. Experiments in 2001 were conducted to explore the effectiveness of 1500 mg · L^{-1} ethephon and all four ABA treatments over the course of the growing season. However, the first goal was to ensure that the abscission observed by ethephon was in fact due to the role of ethylene. The only two treatments causing any abscission were the ethephon treatments alone. The spray and dip treatments of 1500 mg · L^{-1} ethephon caused cumulative drops of 19.2% and 22.5% respectively (Fig. 4), and the dip treatment was significantly different from the control. No abscission occurred from the inflorescences treated with 600 nL · L^{-1} of 1-MCP for 24 hours followed by either a spray or dip treatment of 1500 mg · L^{-1} ethephon.

Significant difference between the ethephon treatments and the 1-MCP plus ethephon treatments indicates that 1-MCP successfully blocked ethylene action in the inflorescences. The blocking of ethylene by 1-MCP resulted in the reduction of ethylene-induced disorders of carrot[25], the delay of apple[26] and avacodo[27] ripening, and the decrease in ethylene-induced superficial scald of apple.[28] The above results confirm that the abscission observed in both 2000 and 2001 from ethephon treated inflorescences were a result of the release of ethylene from the breakdown of ethephon.

Four more experiments were conducted in 2001 and they all examined the same eight treatments (Table 4) to determine the efficacy of ethephon and ABA over the course of the growing season. The results from these four experiments are summarized in Table 6. At the beginning of these experiments (June 26) the percent bloom in the garden was about 48%. The first experiment resulted in a cumulative abscission of 20.3% from the 1500 mg · L^{-1} ethephon spray and 9.5% from the dip (Expt. 6). As the inflorescences used in the dip treatment all died and dried up, the head diameter and peduncle diameter decreased significantly compared to the controls. Only the 20.3% abscission from the ethephon spray and the 34.9% from

Table 6. Cumulative percent flower abscission from 3-year-old North American ginseng inflorescences in experiments 6, 7, 8 and 9 conducted in 2001.

	Experiment Number			
Treatment	6	7	8	9
Control-spray	0.0	0.0	1.7	18.2
1500 mg · L^{-1} ethephon spray	20.3z	100.0z	89.6z	81.1z
Control-dip	0.4	0.4	0.9	3.2
1500 mg · L^{-1} ethephon dip	9.5	90.6z	100.0z	100.0z
25 μmol · L^{-1} ABA spray	0.0	0.0	2.6	3.8
250 μmol · L^{-1} ABA spray	0.3	0.0	0.4	4.2
25 μmol · L^{-1} ABA dip	1.6	17.3z	41.1z	35.2z
250 μmol · L^{-1} ABA dip	34.9z	82.7z	96.5z	58.9z

[z]Means within columns are significantly different from the control using standard t-test at $P \leq 0.05$.

Table 7. Results from Tukey's pairwise comparisons to determine the effect of time on ethephon and ABA treatments over the 2001 growing season.

Treatment	June 26 vs. July 6	June 26 vs. July 17	June 26 vs. August 1
Control spray			*
1500 mg · L^{-1} ethephon spray	*	*	*
Control dip			
1500 mg · L^{-1} ethephon spray	*	*	*
25 μmol · L^{-1} ABA spray			
250 μmol · L^{-1} ABA spray			
25 μmol · L^{-1} ABA dip	*		*
250 μmol · L^{-1} ABA dip	*		

*Treatment significant, when compared over time using Tukey's test. at $P \leq 0.05$.

the 250 μmol · L^{-1} ABA dip treatment were different from the controls.

In the experiment 7 completed on July 6 both ethephon treatments and the two ABA dip treatment were significant. The ethephon spray increased to 100% and the dip treatment achieved 90.6% cumulative abscission. The ABA dip treatments achieved 17.3% and 82.7% for the 25 μmol · L^{-1} and the 250 μmol · L^{-1} treatments respectively. The remaining two experiments (8 and 9) conducted in 2001 had similar results and the head diameter of the four significant treatments also showed a decrease.

The timing of ethephon application was significant (Table 7). It showed that the later ethephon was applied to the inflorescences the more effective it was in causing abscission. From a grower's perspective early abscission is better because more of the plant's resources go into root development instead of seed development. If ethephon is applied when the inflorescences are at least 30% in bloom, optimum abscission (75%) can be achieved.[10)]

Timing of both ABA dip treatments was significant when harvest dates of June 26 and July 6 were compared. The 25 μmol · L^{-1} ABA dip treatment was also significant between June 26 and August 1 (Table 7). Between June 26 and July 6 the abscission caused by the 25 μmol · L^{-1} ABA dip treatment increased from 1.6% to 17.3%. The cumulative abscission caused by the ABA dip treatments decreased between July 17 and August 1 (Table 6) thus indicating that the timing of ABA treatments is important. From a practical stand point, dip treatments are not feasible in the field but were completed in the lab to examine the effects caused by the uptake of the compounds. ABA was not a viable option for flower removal in ginseng as the spray treatments did not cause significant levels of abscission.

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REFERENCES

1. Nickell, L.G. : Plant growth regulators-Agricultural uses. Springer-Verlag, Berlin, Heidelberg, Germany (1982).
2. Fiebig, A.E., Proctor, J.T.A., Posluszny, U. and Murr, D.P. : The North American ginseng inflorescence: development, floret abscission zone, and the effect of ethylene. *Can. J. Bot.* **79**, 1048-1056 (2001).
3. Fiebig, A.E., Proctor, J.T.A., Murr, D.P. and Reeleder, R.D. : Flower abscission-induction in North American ginseng with ethephon. *HortScience.* **40**, In Press.
4. Klein, I., Epstein, E., Lavee, S. and Ben-Tal, Y. : Environmental factors affecting ethephon in olive (*Olea europeae* L.). *Scientia Hort.* **9**, 21-30 (1978).
5. Olien, W.C. and Bukovac, M.J. : The effect of temperature on rate of ethylene evolution from ethephon and ethephon-treated leaves of sour cherry. *J. Amer. Soc. Hort. Sci.* **103**, 199-202 (1978).
6. Epstein, E., Klein, I. and Lavee, S. : The fate of 1, 2, ^{14}C-(chloroethyl)phosphonic acid (ethephon) in olive (*Olea europeae*). *Physiol. Plant.* **39**, 33-37 (1977).
7. Proctor, J.T.A., Dorais, M., Bleiholder, H., Willis, A., Hack, H. and Meier, V. : Phenological growth stages of North American ginseng (*Panax quinquefolius*). *Ann. Appl. Biol.* **143**, 311-317 (2003).
8. Schluter, C. and Punja, Z.K. : Floral biology and seed production in cultivated North American ginseng (*Panax quinquefolius*). *J. Amer. Soc. Hort. Sci.* **125**, 567-575 (2000).
9. Weis, K.G., Webster, B.D., Goren, R. and Martin, G.C. : Inflorescence abscission in olive: anatomy and histochemistry in response to ethylene and ethephon. *Bot. Gaz.* **152**, 51-58 (1991).
10. Proctor, J.T.A., Percival, D. and Louttit, D. : Inflorescence removal affects root yield of American ginseng. *HortScience.* **34**, 82-84 (1999).
11. Elfving, D.C. and Cline, R.A. : Cytokinin and ethephon affect crop load, shoot growth, and nutrient concentration of 'Empire' apple trees. *HortScience.* **28**, 1011-1014 (1993).
12. Bound, S.A., Jones, K.M., Koen, T.B. and Oakford, M.J. : The thinning effect of benzyladinine on red 'Fuji' apple trees. *J. Hort. Sci.* **66**, 789-794 (1991).
13. Greene, D.W., Autio, W.R. and Miller, P. : Thinning activity of benzyladenine on several apple cultivars. *J. Amer. Soc. Hort. Sci.* **115**, 394-400 (1990).
14. Greene, D.W. and Autio, W.R. : Evaluation of benzyladenine as a chemical thinner on 'McIntosh' apples. *J. Amer. Soc. Hort. Sci.* **119**, 253-257 (1989).
15. Bukovac, M.J. : Plant hormone research: a continuing challenge. *HortScience* **23**, 808-810 (1988).
16. Greene, D.W. : Thidiazuron effects on fruit set, fruit quality, and return bloom of apples. *HortScience.* **30**, 1238-1240 (1995).
17. Boehm, C.L., Harrison, H.C., Jung, G. and Nienluis, J. : Organization of American and Asian ginseng germplasm using randomly amplified polymorphic DNA (RAD) markers. *J. Amer. Soc. Hort. Sci.* **124**, 252-256 (1999).
18. Proctor, J.T.A. and Bailey, W.G. : Ginseng: industry, botany, and culture. *Hort. Rev.* **9**, 188-236 (1987).
19. Proctor, J.T.A., Slimmon, T. and Saxena, P. : Modulation of

root growth and organogenesis in thidiazuron treated ginseng. *Plant Growth Regul.* **20**, 201-208 (1996).
20. Williams, M.W., Bound, S.A., Hughes, J. and Tustin, S. : Endothall: a blossom thinner for apples. *HortTechnology.* **5**, 257-259 (1995).
21. Webster, A.D. and Spencer, J.E. : New strategies for the chemical thinning of apple (*Malus domestica* Borkh.) cultivars Queen Cox and Royal Gala. *J. Hort. Sci. Biotech.* **74**, 337-346 (1999).
22. Masia, A., Ventura, M. Gemma, H. and Sansavini, S. : Effect of some plant growth regulator treatments on apple fruit ripening. *Plant Growth Regul.* **25**, 127-134 (1998).
23. Lavee, S. and Martin, G.C. : *In vitro* studies on ethephon-induced abscission in olive. I. The effect of application period and concentration on uptake, ethylene evolution, and leaf abscission. *J. Amer. Soc. Hort. Sci.* **106**, 14-18 (1981a).
24. Lavee, S. and Martin, G.C. : *In vitro* studies on ethephon-induced abscission in olive. II. The relation between ethylene evolution and abscission of various organs. *J. Amer. Soc. Hort. Sci.* **106**, 19-26 (1981b).
25. Fan, X. and Mattheis, J.P. : Impact of 1-methylcyclopropene and methyl jasmonate on apple volatile production. *J. Agric. Food Chem.* **47**, 2847-2853 (1999).
26. Fan, X., Blankenship, S. and Mattheis, J.P. : MCP inhibits apple fruit ripening. *J. Amer. Soc. Hort. Sci.* **124**, 690-695 (1999).
27. Feng, X., Apelbaum, A., Sisler, E.C. and Goren, R. : Control of ethylene responses in avocado fruit with 1-methylcyclopropene. *Postharvest Biol. Technol.* **20**, 143-150 (2000).
28. Rupasinghe, H.P.V., Murr, D.P., Paliyath, G. and Skog, L. : Inhibitor effect of 1-MCP on ripening and superficial scald development in 'McIntosh' and 'Delicious' apples. *J. Hort. Sci. Biotech.* **75**, 271-276 (2000).