J. Ginseng Res.
Vol. 26, No. 1, 17-23(2002)

Gibberellin Effects on Inflorescence Development, Bud Dormancy and Root Development in North American Ginseng

L. J. Rolston, J. T. A. Proctor#, R. A. Fletcher* and D. P. Murr
Department of Plant Agriculture, Division of Horticultural Science,
*(*Department of Environmental Biology), University of Guelph, Ontario, Canada, N1G 2W1*
(Received September 18, 2001)

Abstract : Gibberellic acid (GA) was applied to field-grown 3-year-old North American ginseng (*Panax quinquefolius* L.) between 1 and 4 times, before and during bloom in 1999. Applications of both GA_3 and GA_{4+7} four times (x4) to the developing inflorescences increased maximum pedicel length, and seed head diameter and height. Treatment with GA_{4+7} increased mean and total root fresh weight linearly, whereas those treated with GA_3 did not show similar increases. Both GA_3 and GA_{4+7} at 50, 100 and 200 mg L^{-1} (x4) increased the incidence of breaking of dormancy of perennating buds with GA_3 being twice as effective as GA_{4+7}. Both GA_3 and GA_{4+7} treatments resulted in an increased number of new bud initials forming per root, with the number of new initials per root increased two-fold by the GA_3 sprays compared to GA_{4+7}.

Key words : *Panax quinquefolius*, gibberellins, senescence, root weight, perennating bud

INTRODUCTION

Applications of ethephon (as a source of ethylene) required to achieve berry removal in ginseng often resulted in premature chlorophyll loss, development of pigments in the leaves, and abscission (Fiebig, 1999). The reduction of chlorophyll may impair photosynthetic processes, leading to a reduction in carbon fixation by the plant. Therefore, methods for minimizing leaf coloration and injury due to ethephon treatment are necessary.

Symptoms of senescence can be delayed in detached leaves or leaf discs by the application of cytokinins (Richmond and Lang, 1957; Letham, 1967), auxins (Osborne and Hallaway, 1964) or gibberellins (Beevers, 1966). Pigment synthesis occurring within plastids (chlorophyll, carotenoids) and in the vacuole (anthocyananins) are induced by ethylene and arrested by gibberellins and cytokinins (Goldschmidt, 1974, 1980). Fletcher (1969) demonstrated that senescence in bean leaves (*Phaseolus vulgaris*) is retarded by the application of gibberellins. In addition, gibberellins also induce green chloroplast development (Goldschmidt, 1974) and reduce the biosynthesis of carotenoids and anthocyanins (Dostal and Leopold, 1967; Proebsting and Mills, 1969; Abdel-Gawad and Romani, 1974). However, the senescence effect of gibberellins have been reported more widely with fruits than leaves (Noodén and Leopold, 1978). Other common physiological effects of gibberellins in the developing plant include cell elongation and increasing internode length (Davies, 1995; Graebe, 1987).

The objective of this study was to determine the effect of foliar applications of gibberellin on inflorescence and root development in North American ginseng.

MATERIALS AND METHODS

Three-year-old ginseng in an established garden at JCK Farms, North of Burford, Ontario was used to determine the effects of GA on seed head and root development. The plants were grown under wooden lath shade at a height of 1.9 meters, providing approximately 75% shade to the crop in raised soil beds at commercial spacing, and covered with straw mulch.

Sprays were applied with an 8.5 L Hudson backpack sprayer fitted with a Teejet nozzle (80015) at approximately 2 kg cm^{-2} pressure. Approximately 300 mL of solution was applied per meter of row. Plots were sprayed in the morning (about 20°C), on calm days, to the point of

#To whom correspondence should be addressed.
(Tel) 519-824-4120; (Fax) 519-767-0755
(E-mail) jtprocto@uoguelph.ca

run-off. No wetting agents were added to these solutions.

Control, hand removal and GA treatment plots were arranged in a section of the established garden using a randomized complete block design (RCBD) with 3 replicates. Spray treatments consisted of 50 to 200 mg L^{-1} pre- and post-bloom GA, applied from 2 sources, GA_3 [Activol, Abbott Laboratories, North Chicago, Ill. (1 tablet=1 g a.i. gibberellic acid 5-10% w/w), alternative name: BERELEX tablets, Composition: Gibberellic Acid and Adipic Acid], and GA_{4+7} [Procone, Abbott Laboratories (4.2 g a.i. per L gibberellins GA_{4+7}, 40% w/w), inert carrier]. Concentrations of GA_3 and GA_{4+7} used, volumes applied, and times of treatment are listed in the Tables. Plots were 3.0 m long and each treated plot was divided in two. One-half of each plot provided plants for seed head sampling throughout the season, the other half was used for seed and root harvest at the end of the season.

At each sampling date, 10 seed heads per treatment with peduncle attached were selected randomly from within the plots. Counts of dormant and broken perennating buds were made at root harvest on September 28 to determine the effect of GA sprays on bud dormancy.

Data analysis was performed using Analysis of Variance using general linear models procedure of SAS (SAS Institute, Cary, N.C.). Treatment means which included growth regulator and hand removal effects were also compared using the Least Significant Difference (LSD) or Duncans Multiple Range Test at $P<0.05$.

RESULTS AND DISCUSSION

1. Root mean/total fresh weight and number

Both mean and total root fresh weight increased linearly as the concentration of GA_{4+7} increased (Table 1). Sprays of 200 mg L^{-1} GA_{4+7} applied 4 times throughout inflorescence development (pre-bloom and bloom) resulted in a 10% increase in mean root fresh weight and a 20% increase in total root fresh weight. Similar increases were

Table 1. Root fresh weight and number in North American ginseng treated with GA or hand removal of inflorescences. Treatments were applied in June 1999, on JCK Farms 3-year-old gardens

Treatment (mg L^{-1})	Root Fresh Weight (g)		Root Number
	Mean	Total	
Control	15.1 bcd[z]	2448 bc	163 ab
Hand Removal	15.5 abcd	2457 bc	161 ab
100 GA_3 pre-bloom (x1) [y]	16.6 abc	2741 abc	167 ab
100 GA_3 bloom (x3)	17.3 a	2805 ab	163 ab
100 GA_{4+7} pre-bloom (x1)	15.9 abcd	2412 c	152 ab
100 GA_{4+7} bloom (x3)	15.9 abcd	2670 abc	169 ab
Control	15.1 bcd	2448 bc	163 ab
50 GA_3 (x4)	16.4 abcd	2528 bc	156 ab
100 GA_3 (x4)	16.7 abc	2655 abc	160 ab
200 GA_3 (x4)	16.9 ab	2471 bc	149 b
Significance [x]			
L	NS	NS	NS
Q	NS	NS	NS
Control	15.1 bcd	2448 bc	163 ab
50 GA_{4+7} (x4)	14.7 d	2527 bc	174 ab
100 GA_{4+7} (x4)	15.0 cd	2526 bc	169 ab
200 GA_{4+7} (x4)	16.6 abc	2936 a	177 a
Significance [x]			
L	*	*	NS
Q	NS	NS	NS

[z]Within columns, means followed by the same letter are not significantly different using LSD ($P\leq 0.05$)
[y]Sprays applied once (x1) on June 7, 3 times (x3) on June 15, 21, 29, or 4 times (x4) on June 7, 15, 21, 29
[x]Grouped GA treatment means (excluding hand removal) analyzed by single-degree-of-freedom contrasts
NS, *, Effect not significant or significant at $P<0.05$ respectively

not seen with GA_3 sprays. Regression analysis showed no effect of either GA_3 or GA_{4+7} on root number.

The largest differences in root fresh weight occurred between the highest application rates of GA and the control (16.9 and 16.6 vs. 15.1 g, Table 1). Few differences were seen with the timing of the GA sprays. Early application of 100 mg L^{-1} GA_3 and GA_{4+7} (1×pre-bloom) resulted in mean and total root fresh weights similar to those of multiple applications of the same concentration (3×bloom). Combination of 100 mg L^{-1} GA_3 and GA_{4+7} pre-bloom and bloom sprays (4×) resulted in mean and total root fresh weights similar to those of pre-bloom sprays alone.

No significant increase in mean or total root fresh weight was seen with hand removal. Small plots showed no more benefit with hand removal than larger, field-scale trials run in the same season. Proctor *et al.* (1999) stated that ginseng root fresh weights increased 25 to 30 percent by the end of the season as a result of manual inflorescence removal in early July. Therefore, this result further supports the notion that physiological stress due to low rainfall and high temperatures may have been partly responsible for the lack of root yield increase in these field trials.

2.Perennating bud counts

GA applications increased loss of dormancy in perennating buds on harvested roots of ginseng (Fig. 1). Occurrence of premature expanding of perennating buds increased as concentration of both GA_3 and GA_{4+7} increased (Table 2). Dormancy loss was less with GA_{4+7}. Based on an average of one perennating bud per root, GA_3 and GA_{4+7} at 200 mg L^{-1} applied four times (pre-bloom and bloom) resulted in 98% and 48% loss of dormancy (buds broken), respectively. Even the lowest rate of GA_3 at 100 mg L^{-1} applied once at pre-bloom resulted in approximately 46% of buds breaking dormancy. Similar applications of GA_{4+7} resulted in only 11% loss of dormancy. Occurrence of bud dormancy break in control plots was approximately 2%. This rate of bud break falls below the 5-8% rate that can be attributed to fluctuations in Fall temperatures (Anon, 1998). Premature bud development in the Fall has been seen previously in one-year-old gin-

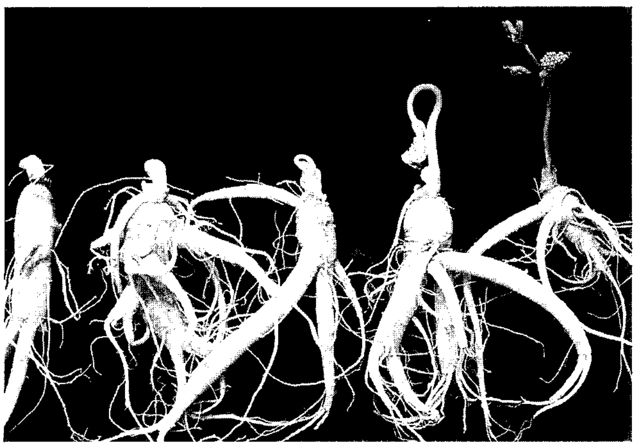

Fig. 1. Range of perennating bud broken dormancy of North American ginseng roots treated with gibberellic acid. The untreated (control) is on the left.

Table 2. Occurrence of broken and new bud initials on harvested roots of North American ginseng treated with GA or hand removal of inflorescences. Treatments were applied in June 1999, on JCK Farms 3-year-old gardens and roots were harvested and observed on September 28, 1999

Treatment ($mg\ L^{-1}$)	Root Perennating Bud Mean Counts		
	Broken	Broken (%)	New Bud Initials/Root
Control	0.02 g[z]	2	0.18 i
Hand Removal	0.02 g	2	0.33 hi
100 GA_3 pre-bloom (x1)[y]	0.46 d	46	1.23 e
100 GA_3 bloom (x3)	0.70 c	70	2.03 c
100 GA_{4+7} pre-bloom (x1)	0.11 fg	11	0.51 h
100 GA_{4+7} bloom (x3)	0.18 f	18	0.72 g
Control	0.02 g	2	0.18 i
50 GA_3 (x4)	0.69 c	69	1.93 c
100 GA_3 (x4)	0.81 b	81	2.48 b
200 GA_3 (x4)	0.98 a	98	2.73 a
Significance [x]			
L	**		**
Q	**		**
Control	0.02 g	2	0.18 i
50 GA_{4+7} (x4)	0.29 e	29	0.93 f
100 GA_{4+7} (x4)	0.41 d	41	1.12 ef
200 GA_{4+7} (x4)	0.48 d	48	1.44 d
Significance [x]			
L	**		**
Q	**		**

[z]Within columns, means followed by the same letter are not significantly different using LSD ($P \leq 0.05$)
[y]Sprays applied once (x1) on June 7, 3 times (x3) on June 15, 21, 29, or 4 times (x4) on June 7, 15, 21, 29
[x]Grouped GA treatment means (not including hand removal) analyzed by single-degree-of-freedom contrasts
**Effect significant at $P \leq 0.01$

Fig. 2. Formation of new bud initials (e.g. arrow) on the rhizome of North American ginseng due to gibvberellic acid treatment.

seng plants, and causes redistribution of root reserves to the developing shoot, which would otherwise be used for the next years growth. This loss of dormancy of the perennating bud is considered detrimental for the survival of this perennial crop through the winter months (Anon, 1998). In addition, a higher occurrence of broken perennating buds due to GA_3 treatment, with a subsequent loss of stored nutrients in the root, may be responsible for lack of root fresh weight increases comparable to those seen in GA_{4+7} treatments. A trend towards linear gain in root fresh weight due to multiple applications of GA_3 was not significant.

GA applications increased the occurrence of new bud initials on harvested roots of ginseng (Table 2, Fig. 2). New bud initial number increased as the concentration of both GA_3 and GA_{4+7} increased. Occurrence of new initials is strongly related to the occurrence of bud break as the number of broken buds showed a positive correlation with the development of new bud initials. A stronger correlation between bud break and new bud initials was found for concentrations of 0 to 200 mg L^{-1} GA_3 (r=0.93) than for GA_{4+7} (r=0.44). Loss of dormancy of the perennating bud due to GA sprays stimulates the development of a new bud initial and in some cases, multiple new initials to replace the broken bud. Although the occurrence of multiple-stemmed plants in *Panax ginseng* C.A. Meyer is less than 4%, ginseng plants can develop several adventitious buds through artificial damage to the perennating bud. Application of 100 to 400 mg L^{-1} B9 once per month for 4 months resulted in the development of 2 to 4 adventitious buds (Hong *et al.*, 1995). An increased number of stems per plant has the potential to increase leaf area, and may increase root weight gain. Choi *et al.* (1984) obtained a 50% increase in root yield from multi-stem plants compared to those with single stems. However, it is unknown if the adventitious buds developed through the GA treatments would develop to the point where they could survive the winter and germinate the following spring to form a multi-stemmed ginseng plant. Therefore, premature break of bud dormancy in the ginseng plant has the potential to be very detrimental to the development of the plant.

Table 3. Seed head height (seed intact and seed removed) of North American ginseng treated with GA. Measured on July 29, 1999

Treatment (mg L^{-1})	Mean Seed Head Height (mm)	
	Seed Intact	Seed Removed
Control	17.2 e [z]	12.3 d
100 GA_3 pre-bloom (x1) [y]	28.8 bc	22.2 bc
100 GA_3 bloom (x3)	27.0 bcd	21.3 bc
100 GA_{4+7} pre-bloom (x1)	23.0 d	18.5 c
100 GA_{4+7} bloom (x3)	25.7 cd	18.7 c
Control	17.2 e	12.3 d
50 GA_3 (x4)	28.5 bc	21.7 bc
100 GA_3 (x4)	35.2 a	28.5 a
200 GA_3 (x4)	31.0 ab	24.0 b
Significance [x]		
L	**	**
Q	**	**
Control	17.2 e	12.3 d
50 GA_{4+7} (x4)	25.7 cd	18.8 c
100 GA_{4+7} (x4)	28.2 bc	24.8 ab
200 GA_{4+7} (x4)	30.5 b	23.8 b
Significance [x]		
L	**	**
Q	**	**

[z]Within columns, means followed by the same letter are not significantly different using LSD ($P \leq 0.05$)
[y]Sprays applied once (x1) on June 7, 3 times (x3) on June 15, 21, 29, or 4 times (x4) on June 7, 15, 21, 29
[x]Grouped GA treatment means analyzed by single-degree-of-freedom contrasts
** Effect significant at $P \leq 0.01$

3. Seed head measurements

By July 29, one month after the last GA sprays, maximum ginseng seed head height increased as concentrations of both GA_3 and GA_{4+7} increased (Table 3). A similar relationship was seen when comparing seed heads with seeds intact or removed. GA_3 sprays loosen clusters of 'Thompson Seedless' grape through inflorescence expansion (Mosesian and Nelson, 1968). Pérez and Gomez, (1998) used GA_3 treatments applied to 'Thompson Seedless' grapes 2 weeks before bloom for bunch elongation, and applied at full bloom for bunch thinning. The GA-treatment caused an increase in size in the developing berries with an atypical flattening across the width of the berry. These green berries also lacked seed and did not ripen. Although gibberellic acid sprays induced parthenocarpic (seedless) fruit development and increased berry size (Miele *et al.,* 1978), as well as reduced fruit set and increased berry drop in 'Thompson Seedless' grapes (Coombe, 1976; Ben-Tal, 1990) no similar thinning effect was evident in ginseng.

Intact and bare seed head heights of ginseng plants treated four times (pre-bloom and bloom) with 100 mg L^{-1} GA_3 were larger than those treated with 100 mg L^{-1} one time (pre-bloom) or three times (bloom). No significant height difference occurred between pre-bloom and bloom-treated seed heads. A similar relationship was evident with GA_{4+7} applications; however, 100 mg L^{-1} GA_{4+7} applied three times (bloom) resulted in similar increases in seed head height compared to 100 mg L^{-1} GA_{4+7} applied four times (pre-bloom and bloom). It appears that the effects of multiple applications of GA on seed head height are additive.

By July 29, one month after the last GA sprays, maximum seed head diameter (seeds removed) increased quadratically and linearly as concentrations of GA_3 and GA_{4+7} increased, respectively (Table 4). Sprays of 100 mg L^{-1} GA_3 and GA_{4+7} applied once (pre-bloom) and 4 times

Table 4. Seed head diameter (seed intact and seed removed) of North American ginseng treated with GA. Measured on July 7 and 29, 1999, respectively

Treatment (mg L^{-1})	Mean Seed Head Diameter (mm)	
	Seed Intact	Seed Removed
Control	30.4 e[z]	20.8 e
100 GA_3 pre-bloom (x1)[y]	35.3 abcd	29.3 abc
100 GA_3 bloom (x3)	32.9 de	26.5 cd
100 GA_{4+7} pre-bloom (x1)	33.8 cd	25.8 cd
100 GA_{4+7} bloom (x3)	33.2 d	24.2 de
Control	30.4 e	20.8 e
50 GA_3 (x4)	37.1 a	28.3 bcd
100 GA_3 (x4)	36.6 ab	32.2 ab
200 GA_3 (x4)	36.1 abc	26.5 cd
Significance [x]		
L	**	**
Q	**	**
Control	30.4 e	20.8 e
50 GA_{4+7} (x4)	33.0 d	25.7 cd
100 GA_{4+7} (x4)	34.4 bcd	29.2 abc
200 GA_{4+7} (x4)	37.0 a	33.2 a
Significance [x]		
L	**	**
Q	NS	**

[z]Within columns, means followed by the same letter are not significantly different using LSD ($P \leq 0.05$)
[y]Sprays applied once (x1) on June 7, 3 times (x3) on June 15, 21, 29, or 4 times (x4) on June 7, 15, 21, 29
[x]Grouped GA treatment means analyzed by single-degree-of-freedom contrasts
NS, ** Effect not significant or significant at $P \leq 0.01$ respectively

Table 5. Pedicel and peduncle length of North American ginseng treated with GA. Measured on July 29 and 7, respectively

Treatment (mg L^{-1})	Mean Maximum Pedicel Length (mm)	Mean Peduncle Length (mm)
Control	9.5 f[z]	128 b
100 GA_3 pre-bloom (x1)[y]	18.8 bc	134 ab
100 GA_3 bloom (x3)	16.7 bcde	130 b
100 GA_{4+7} pre-bloom (x1)	13.7 e	143 ab
100 GA_{4+7} bloom (x3)	15.0 cde	137 ab
Control	9.5 f	128 b
50 GA_3 (x4)	17.2 bcde	139 ab
100 GA_3 (x4)	23.7 a	149 a
200 GA_3 (x4)	18.7 bc	140 ab
Significance [x]		
L	**	NS
Q	**	NS
Control	9.5 f	128 b
50 GA_{4+7} (x4)	14.7 de	137 ab
100 GA_{4+7} (x4)	17.7 bcd	136 ab
200 GA_{4+7} (x4)	19.7 b	150 a
Significance [x]		
L	**	NS
Q	**	NS

[z]Within columns, means followed by the same letter are not significantly different using LSD ($P < 0.05$)
[y]Sprays applied once (x1) on June 7, 3 times (x3) on June 15, 21, 29, or 4 times (x4) on June 7, 15, 21, 29
[x]Grouped GA treatment means analyzed by single-degree-of-freedom contrasts
NS, ** Effect not significant or significant at $P \leq 0.01$ respectively

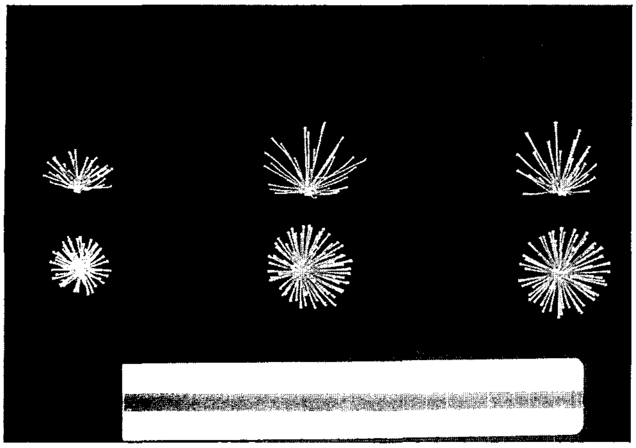

Fig. 3. Increase in seed head height, diameter and pedicel length of inflorescences of 3-year-old North American ginseng treated with 100 mg L^{-1} gibberellic acid (GA_3 and GA_{4+7}) four times (x4). The untreated (control) is on the left.

(pre-bloom and bloom) showed no significant differences in either intact or bare seed head diameter. However, seed heads treated with 100 mg L^{-1} GA_3 applied 3 times (bloom) had diameters approximately 10% smaller than those treated 4 times (pre-bloom and bloom). This indicates that early application may be the most important factor in increasing inflorescence expansion in ginseng. This may be due to the age, degree of lignification of cells, and stage of development of the pedicels.

GA increased pedicel length in a manner similar to seed head height and diameter. By July 29, one month after the last GA sprays, maximum pedicel length increased quadratically as concentrations of both GA_3 and GA_{4+7} increased (Table 5).

The large increase in mean seed head height, diameter, and pedicel length (Fig. 3) induced by GA may have benefits for growers, including fewer berries lost due to injury or crowding on the inflorescence, and better spray coverage of the inflorescence for disease control or ethephon sprays for berry removal.

4. Peduncle length

GA had few effects on peduncle length (Table 5). Multiple applications of 100 mg L^{-1} GA_3 pre-bloom and bloom (x4) did not increase peduncle lengths compared to pre-bloom (x1) and bloom (x3) sprays alone. Field-grown ginseng is a very heterogeneous crop, large variation in peduncle length within the plots confounded any increase in peduncle length due to GA treatment.

In summary, foliar sprays of GA increased seed head height and diameter, maximum pedicel length, and seedless green berry number. Although GA_3 and GA_{4+7} showed similar promoting effects on seed head expansion and parthenocarpic green berry development, GA_{4+7} also demonstrated increased root fresh weight, and a 50% lower incidence of perennating buds breaking dormancy. Previous studies have suggested that GA_4 may have additional and potentially greater biological effects (Swain and Olszewski, 1996), than most of the approximately 100 identified plant and fungi-based gibberellins (Sponsel, 1995). Inclusion of GA_{4+7} to these field experiments confirms this. When applied as a spray, GA_{4+7} sprays appear to have greater application in ginseng production compared to GA_3. Further evaluation of the effects of GA_{4+7} in combination with Ethrel may allow growers to improve spray coverage of the inflorescences for disease control and for better abscission response, and promote root development while minimizing the senescence effects of the Ethrel treatments.

ACKNOWLEDGEMENTS

This research was supported in part by the Ginseng Growers Association of Canada, the Ontario Ministry of Agriculture, Food and Rural Affairs, the National Research Council/IRAP/YES Award and Jeff Rice (JCK Farms). We are indebted to Dean Louttit and Brenda Noble for technical assistance.

REFERENCES

1. Abdel-Gawad, H. and Romani, R. J., Hormone-induced reversal of colour change and related respiratory effects in ripening apricot fruits. *Physiol. Plant.* **32**, 161-165 (1974).
2. Anon., Ginseng Production Guide for Commercial Growers, 1998 Edition. Associated Ginseng Growers of British Columbia, British Columbia Ministry of Agriculture, Fisheries and Food, Victoria (1998).
3. Beevers, L., Effects of gibberellic acid on the senescence of leaf discs of Nasturtium *(Tropaeolum majus)*. *Plant Physiol.* **41**, 1074-1076 (1966).
4. Ben-Tal, Y., Effects of gibberellin treatments on ripening and berry drop from Thompson Seedless grapes. *Amer. J. Enol. Vitic.* **41**, 142-146 (1990).
5. Choi, K.T., Yang, D.C., Kim, N.W. and Ahn, I.O., Redifferentiation from tissue culture and isolation of viable protoplasts in *Panax* ginseng C.A. Meyer. Page 1-11 in Proc. 4th. Int. Ginseng Symp., Korean Ginseng and Tobacco Res. Inst., Korea (1984).

6. Coombe, B. G., The development of fleshy fruits, p. 507-528. In: W. R. Briggs, P. B. Green and R. L. Jones (eds.). Annual Review of Plant Physiology and Molecular Biology. Annual Reviews Inc. Palo Alto, California. Vol. 27 (1976).
7. Davies, P. J., The plant hormones: their nature, occurrence, and functions, p. 1-38 In: P.J. Davies (ed.). Plant Hormones: Physiology, Biochemistry and Molecular Biology. 2nd ed. Kluwer Academic Publishers, Netherlands (1995).
8. Dostal, H. C. and Leopold, A. C., Gibberellin delays ripening of tomatoes. *Science* **158**, 1579-1580 (1967).
9. Fiebig, A. E., Inflorescence development of American ginseng: abscission zones and ethephon. M.Sc. Thesis, Univ. of Guelph, Guelph, Ontario (1999).
10. Fletcher, R. A., Retardation of leaf senescence by benzyladenine in intact bean plants. *Planta* **89,** 1-8 (1969).
11. Goldschmidt, E. E., Hormonal and molecular regulation of chloroplast senescence in *Citrus* peel, p. 1027-1033. In: 8th International Conference on Plant Growth Substances, Tokyo, 1973. Hirokawa Publishing Co., Tokyo (1974).
12. Goldschmidt, E. E., Pigment changes associated with fruit maturation and their control, p. 207-217. In: K.V. Thimann (ed.). Senescence in Plants, CRC Press Inc., Boca Raton, Florida (1980).
13. Graebe, J. E., Gibberellin biosynthesis and control. *Annu. Rev. Plant Physiol.* **38**, 419-465 (1987).
14. Hong,Y., Wang, M., Peng, L. and Zhao, X., The development of ginseng cultivation in Jilin, China, p. 390-396. In: W.G. Bailey, C. Whitehead, J.T.A. Proctor, and J.T. Kyle (eds.). Proc. Int. Ginseng Conf. Vancouver 1994, Canada (1995).
15. Letham, D. S., Chemistry and physiology of kinetin-like compounds. *Annu. Rev. Plant Physiol.* **18**, 349-364 (1967).
16. Miele, A., Weaver, R. J. and Johnson, J., Effect of potassium gibberellate on fruit-set and development of Thompson Seedless and Zinfandel grapes. *Amer. J. Enol. Vitic.* **29**, 79-82 (1978).
17. Mosesian, R. M. and Nelson, K. E., Effect on Thompson Seedless fruit of gibberellic acid bloom sprays and double girdling. *Amer. J. Enol. Vitic.* **19**, 37-46 (1968).
18. Noodén, L. D. and Leopold, A. C., Phytohormones and the endogenous regulation of senescence and abscission, p. 329-369. In: D. S. Letham, P. B. Goodwin and T. J. V. Higgins (eds.). Phytohormones and related compounds: A Comprehensive Treatise. Vol. 2. Elsevier/North Holland, Amsterdam (1978).
19. Osborne, D. J. and Hallaway, H. M., The auxin, 2,4-dichlorophenoxyacetic acid as a regulator of protein synthesis and senescence in detached leaves of *Prunus*. *New Phytol.* **63**, 334-337 (1964).
20. Pérez, F. J. and Gomez, M., Gibberellic acid stimulation of isoperoxidase from pedicel of grape. *Phytochemistry.* **48**, 411-414 (1998).
21. Proctor, J. T. A., Percival, D. C. and Louttit, D., Inflorescence removal affects root yield of American ginseng. *HortScience* **34**, 82-84 (1999).
22. Proebsting, E. L., Jr. and Mills, H. H., Effects of 2-chloroethane phosphonic acid and its interaction with gibberellic acid on quality of Early Italian prunes. *J. Amer. Soc. Hort. Sci.* **94**, 443-446 (1969).
23. Richmond, A. E. and Lang, A., Effect of kinetin on protein content and survival of detached *Xanthium* leaves. *Science* **125**, 650-651 (1957).
24. Sponsel, V.M., Gibberellin biosynthesis and metabolism, p. 66-97. In: P.J. Davies (ed.). Plant Hormones; Physiology, Biochemistry and Molecular Biology. Kluwer, Dordrecht, The Netherlands (1995).
25. Swain, S. M., Olszewski, N. E., Genetic analysis of gibberellin signal transduction. *Plant Physiol.* **112**, 11-17 (1996).