GROWTH OF EIGHT-YEAR-OLD AMERICAN GINSENG IN A RED MAPLE FOREST AS INFLUENCED BY LIME AND ORGANIC FERTILIZER APPLICATION

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ABSTRACT

In Québec, the suitability of nutrient-depleted, acidic soils of red maple (*Acer rubrum* L.) forests to American ginseng (*Panax quinquefolius* L.) production is an area of concern. Thus, an eight-year experiment has been conducted in such a forest in order to evaluate the effects of lime and organic fertilizer application on survival and growth parameters of American ginseng. Although no lime was added later than at the beginning of the third growing season, liming had a significant and positive impact on American ginseng survival rate, as compared to control. It also increased leaf area, as well as root biomass of American ginseng. Adding organic fertilizer alone did not have such a positive impact. These results seem to indicate that liming can provide a significant improvement in the survival and growth of American ginseng in very acidic maple forest soils. Such an improvement could be due, at least partly, to increased calcium content in the soil, as well as alleviation of the aluminum toxicity. However, survival and growth rates were extremely low during the last growing seasons, pointing out the importance of frequent and adequate applications of lime in order to make cultivation of American ginseng in red maple forests a valuable alternative to field-cultivation in Québec.

Keywords: Calcium, lime, maple forest, organic fertilizer, *Panax quinquefolius*, wild-simulated cultivation

INTRODUCTION

American ginseng (*Panax quinquefolius* L.), a native species from the deciduous forests of the Eastern half of North America, has been used for its medicinal properties by Amerindian peoples for hundreds of years (Polczinski 1982). However, it is only at the beginning of the eighteenth century that the plant was officially identified by a French Jesuit priest living in Canada as the North American relative of the famous *Panax ginseng* Meyer (White 1988).

In the following decades, extensive stands of American ginseng were found (Proctor and Bailey 1987), and North Americans rapidly developed a lucrative market with China. The quantities of roots that were exported were so important that American ginseng was second, just after beaver furs, in the economic exports of New France (Chartrand et al. 1987). However, by 1900, wild populations of American ginseng had already been severely altered by overharvesting and gradual destruction and degradation of their habitat (White 1988; Nault et al. 2001). Nowadays, these populations are all but extinct in Canada. It is estimated that there are less than 20,000 plants left in all of the country (Nault et al. 1998).

In view of the decrease in the availability of wild American ginseng, cultivation methods were developed as soon as at the end of the nineteenth century. Today, American ginseng supply relies mainly on intensive field-cultivation under artificial shade structures, which provides Canadian farmers with tens of millions of dollars in income every year. Yet, in Québec, only a few farmers had initiated American ginseng production until recently, when they became interested in growing alternative crops for revitalizing an ailing local agricultural sector. Following other growers in North America (Beyfuss 1994; Persons 1995; Pritts 1995), most of the Québec farmers that made the choice to cultivate American ginseng decided to grow it in forests, in order to obtain roots of higher quality and higher retail value than field-grown roots, while avoiding the costs associated with artificial shade structures.

Unfortunately, the forests that are the most suited for producing American ginseng, e.g., mature sugar maple (*Acer saccharum* Marsh.) forests standing on relatively nutrient rich, slightly acidic, deep and well-drained soils in which the abundant litter is rapidly decomposed (Nault 1997), cover only a small portion of the rural landscape and are found almost exclusively in the southern part of Québec.

Consequently, a significant proportion of the production occurs in forests that do not correspond to the ideal type of environment for American ginseng cultivation. Thus, the suitability of their soils is an area of concern for many producers. Many of these soils are nutrient depleted, acidic (pH between 4.0 and 5.5) and have a slow-decomposing litter.

It is well known that soil pH has a large influence on American ginseng growth and development. It affects shape, size, as well as weight of the roots. It was shown that producing American ginseng at pH 5.5 doubled its yield as compared to pH 4.4 (Konsler and Shelton 1990). The growth of American ginseng is also greatly affected by soil nutrient status, especially calcium content. Beyfuss (2000) reported that wild populations of American ginseng in United States typically grow in soils with a high calcium content. Deficiency symptoms appear very rapidly and seriously restrict root weight gain (Stoltz 1982; Konsler and Shelton 1990).

Thus, some efforts have been directed into adapting very acidic forest soils to American ginseng cultivation with the help of appropriate treatments. This has been done through wild-simulated techniques (Persons 1995) that were only slightly adapted by providing small amounts of lime and organic amendments in order to alleviate nutrient deficiencies or toxicities. This paper focuses on some of the results of an eight-year experiment that was conducted in order to evaluate the effects of such applications of lime and organic fertilizer on growth parameters of wild-simulated American ginseng in a nutrient-depleted, very acidic forest soil in Québec, Canada. Although the results from the first five years of the experiment have been discussed elsewhere (Nadeau et al. 1999, 2003), the present paper brings new insights on the effects of the treatments thanks to more recent data.

MATERIALS AND METHODS

Experimental site

The experiment was conducted in a red maple (*Acer rubrum* L.) forest at the Joseph-Rhéaume Experimental Farm (46° 39’ North and 72° 06’ West) of Université Laval at Sainte-Croix de Lotbinière, Québec, for eight years beginning in fall 1995. The soil is a very acidic Tilly silty clay (gleyed humo-ferric Podzol) with a mor humus type and low nutrient status (Table 1).

Table 1. Initial chemical and physical characteristics of the experimental site at Sainte-Croix de Lotbinière, Canada, on October 20, 1995.

Horizon	Depth (cm)	pH	Sand (g/kg)	Clay (g/kg)	P[z] (mg/kg)	K[z] (mg/kg)	Ca[z] (mg/kg)
Om	14 to 0	3.6	---	---	2.3	102	272
Ae	0 to 10	4.1	180	356	1.2	71	143

[z] Mehlich III extractable P, K and Ca

A few trees and shrubs providing excessive shade were removed prior to sowing, that was done on October 30 and 31, 1995, in 10 m x 2 m plots spaced 1 m apart. Leaf litter was removed, amendments were applied, and seeds were broadcast (40 kg ha^{-1}) and incorporated into the first two cm of the soil with the help of a pitchfork. Leaf litter was then put back on the soil.

Treatments and experimental design

Five combinations of lime, organic fertilizer and fungicide were tested in a randomized complete block design on five replicates: T1 = control; T2 = lime (6 t ha^{-1}); T3 = organic fertilizer (800 kg ha^{-1} of Sustane™ [5-2-10] + 582 kg ha^{-1} of bonemeal [2-11-0]); T4 = T2 + T3; T5 = T4 + 135 kg ha^{-1} of Nutri-Q™ (0-0-5 + 5 % Quintozene™). Lime was made of 90 % $CaCO_3$ and 0.76 % $MgCO_3$ (neutralizing value of 92 %). Sustane™ is an organic fertilizer made of composted poultry manure supplemented with potassium sulphate. Nutri-Q™ is a soil amendment composed of potassium sulphate and montmorillonite clay mixed with pentachloronitrobenzene, better known as Quintozene™, a fungicide used to control damping-off and root rots caused by *Rhizoctonia solani* (OMAFRA, 2001). Sustane™, bonemeal and Nutri-Q™ were supplied by Nutrite Hydro-Agri Canada, Québec, Canada. The choice of these brands was made for experimental purpose and does not mean that we recommend them.

Maintenance nutrient inputs were provided at the beginning of the second and third growing seasons (1997, 1998) only. In 1997 and 1998, 300 kg ha^{-1} of Sustane™ were applied on T3, T4 and T5 plots, and 135 kg ha^{-1} of Nutri-Q™ on T5 plots. In 1998, 3 t ha^{-1} of lime were applied on T2, T4 and T5 plots.

Variables measured

Because of the large set of data collected over the eight years of the experiment, and considering that the results from the first years of the experiment have been published before (Nadeau et al. 1999, 2003), only the measures most related to the new data are presented in this paper.

Soil samples were taken from each plot before sowing (October 20, 1995), and on September 12, 1996; September 19, 1997; September 28, 1999; November 29, 2000; and September 13, 2003, to determine pH and Mehlich III Ca (Tran and Simard 1993). Ginseng emergence and survival rates were noted in each plot on June 6 and August 20, 1996; June 19 and August 28, 1997; June 10, 1998; September 2, 1999; September 5, 2000; and September 13, 2003. Ten plants per plot were harvested on August 1, 1996; August 28, 1997; and September 15, 1998, to determine leaf area, as well as root biomass. Because of the decrease of the population, only five and three plants per plot were harvested on September 2, 1999, and September 8, 2000, respectively. Ten plants per plot were harvested at the end of the experiment on September 13, 2003.

Statistical analysis

The data were subjected to standard analysis of variance. Treatments were compared using *a priori* single contrasts ($P < 0.05$): T1 vs. T2, T1 vs. T3, T2 vs. T4 and T4 vs. T5. In 1999, 2000, and 2003, no plant was harvested from the control plots (T1). Hence, only T2 vs. T4 and T3 vs. T5 contrasts could be assessed for leaf area and shoot and root biomass. Soil H^+ content was analyzed after logarithmic transformation (pH) of data.

RESULTS

Soil pH

Lime application significantly increased soil pH between 1996 and 2003, as compared to control, except for the 10-20 cm layer in 1997 and the 0-20 cm layer in 2000, as revealed by contrasts (P = 0.0002 in 1996, 0.0001, 0.0001, and 0.1211 for the 0-5, 5-10, and 10-20 cm layer in 1997, 0.0420 in 1999, 0.2966 in 2000, and 0.0001 in 2003, respectively) (Table 2). Surprisingly, the effect of liming was still noticeable at the end of the experiment, although no lime was applied after 1998. Organic fertilizer application did not have any significant effect on soil pH as compared to control.

Table 2. Soil pH in the American ginseng plots at Sainte-Croix de Lotbinière, Canada, from 1996 to 2003.

Treatment	1996	1997			1999	2000	2003
	0-20 cm	0-5 cm	5-10 cm	10-20 cm	0-20 cm	0-20 cm	5-20 cm
T1	3.47 [z]	2.87	2.79	2.97	3.46	3.87	3.52
T2	3.95	4.39	3.41	3.10	4.24	4.18	4.08
T3	3.49	2.97	2.79	2.90	3.42	3.80	3.44
T4	3.89	4.84	3.52	3.20	4.66	4.06	4.13
T5	3.84	4.22	3.31	3.10	3.94	4.21	4.20
Treatment	0.0003 [y]	0.0001	0.0001	0.0174	0.0131	0.5416	0.0001
T1 vs T2	0.0002	0.0001	0.0001	0.1211	0.0420	0.2966	0.0001
T1 vs T3	0.8929	0.5326	0.9854	0.4183	0.9112	0.8176	0.2732
T2 vs T4	0.5406	0.0135	0.3146	0.2776	0.2514	0.6826	0.4604
T4 vs T5	0.6592	0.0014	0.0694	0.2776	0.0582	0.6218	0.3585

T1 = control ; T2 = lime ; T3 = organic fertilizer ; T4 = T2 + T3 ; T5 = T4 + fungicide
[z] Mean ; [y] *P* value

Soil calcium

The application of lime significantly increased soil calcium content, as compared to control, except for the 10-20 cm layer in 1997, as revealed by contrasts (P = 0.0365 in 1996, 0.0001, 0.0072, and 0.3308 for the 0-5, 5-10, and 10-20 cm layer in 1997, 0.0170 in 1999, 0.0044 in 2000, and 0.0014 in 2003, respectively) (Table 3).

Table 3. Mehlich III calcium (mg kg^{-1}) in the soil of the American ginseng plots at Sainte-Croix de Lotbinière, Canada, from 1996 to 2003.

Treatment	1996	1997			1999	2000	2003
	0-20 cm	0-5 cm	5-10 cm	10-20 cm	0-20 cm	0-20 cm	5-20 cm
T1	378 [z]	1436	745	523	420	362	502
T2	1615	6380	2528	724	1768	1973	2812
T3	447	2721	951	426	964	464	690
T4	1709	7495	2614	1072	1679	2797	3385
T5	1536	6078	2770	776	1277	3112	3705
Treatment	0.0501 [y]	0.0001	0.0044	0.0449	0.0953	0.0001	0.0001
T1 vs T2	0.0365	0.0001	0.0072	0.3308	0.0170	0.0044	0.0014
T1 vs T3	0.8995	0.1937	0.7264	0.6368	0.2980	0.8279	0.7588
T2 vs T4	0.8642	0.2564	0.8831	0.1023	0.8622	0.0989	0.3549
T4 vs T5	0.7532	0.1541	0.7912	0.1590	0.4391	0.5078	0.6022

T1 = control ; T2 = lime ; T3 = organic fertilizer ; T4 = T2 + T3 ; T5 = T4 + fungicide
[z] Mean ; [y] *P* value

The calcium content of the soil was especially high in 1997, because of lime dissolution, but decreased afterwards since no lime was applied after 1998. While the increase in calcium content was restricted to the first 10 cm of the soil in 1997, it was significant in all of the 0-20 cm layer afterwards. The calcium probably moved down with the infiltrating water.

American Ginseng Emergence and Survival

During the eight years of the experiment, liming had a positive impact on American ginseng emergence and survival rate, as indicated by population counts (*P* = 0.0059, 0.0001, 0.0001, 0.0001, 0.0003, 0.0012, 0.0187, and 0.0154, respectively) (Table 4). The application of organic fertilizer also had a positive impact, as compared to control, from August 1996 to August 1997 (*P* = 0.0001, 0.0215, and 0.0013, respectively). In 1998, an *Alternaria panax* infestation affected the plots that had received organic fertilizer alone, that may explain why, thereafter, American ginseng survival rate for this treatment was not significantly different from control. In 1999 and 2000, adding lime and organic fertilizer together positively affected population counts, as compared to adding lime alone (*P* = 0.0020 and 0.0002, respectively). Conversely, fungicide application reduced American ginseng survival rate (*P* = 0.0066 and 0.0065, respectively). An important decrease in population counts was noted in control, although no apparent disease or predation event was observed. Only a few plants have survived two winters in these plots, and there was no plant left in 2000. Population density became extremely low in all treatments during the last years of the experiment.

Table 4. American ginseng plant density (plants/m^2) in Sainte-Croix de Lotbinière, Canada, from 1996 to 2003.

Treatment	June 6, 1996	Aug 20, 1996	June 19, 1997	Aug 28, 1997	June 10, 1998	Sept 2, 1999	Sept 5, 2000	Sept 13, \2003
T1	44.5 [z]	22.1	8.0	7.1	4.1	1.6	0.0	0.0
T2	64.6	67.8	39.5	30.2	23.2	8.4	3.2	0.6
T3	55.0	52.3	17.4	20.3	11.2	3.6	1.0	0.3
T4	58.4	67.4	41.6	3.0	25.8	14.8	9.5	0.8
T5	61.8	64.6	32.5	33.3	18.9	9.4	5.6	0.6
Treatment	0.0575 [y]	0.0001	0.0001	0.0001	0.0004	0.0001	0.0001	0.0110
T1 vs T2	0.0059	0.0001	0.0001	0.0001	0.0003	0.0012	0.0187	0.0154
T1 vs T3	0.1443	0.0001	0.0215	0.0013	0.1037	0.2649	0.4318	0.1234
T2 vs T4	0.3869	0.9416	0.6086	0.0961	0.5437	0.0020	0.0002	0.1865
T4 vs T5	0.6409	0.6783	0.0262	0.3601	0.1149	0.0066	0.0065	0.2019

T1 = control ; T2 = lime ; T3 = organic fertilizer ; T4 = T2 + T3 ; T5 = T4 + fungicide
[z] Mean ; [Y] *P* value

American Ginseng Leaf Area

From 1996 to 1998, liming had a significant and positive impact on American ginseng leaf area per plant, as revealed by contrasts (*P* = 0.0002, 0.0002 and 0.0174 in 1996, 1997, and 1998, respectively) (Table 5). This impact was still obvious in 1999, as indicated by visual estimates, since measures on the control treatment were not conducted because of the low plant density.

The application of organic fertilizer also had a positive impact in 1996 and 1997 (*P* = 0.0004 and 0.0071, respectively). Combining lime and organic fertilizer significantly increased American ginseng leaf area, as compared to adding lime alone, in both 1996 and 2000 (*P* = 0.0061 and 0.0116, respectively). In 2003, American ginseng leaf area per plant had decreased in most plots as compared to 2000.

Table 5. American ginseng leaf area (cm^2) in Sainte-Croix de Lotbinière, Canada, from 1996 to 2003.

Treatment	1996	1997	1998	1999	2000	2003
T1	11.0 [z]	26.5	40.0	-	-	-
T2	13.4	54.0	105.6	182.5	311.4	202.7
T3	13.3	44.1	62.4	98.3	125.3	131.5
T4	15.2	57.4	132.5	200.7	474.4	197.9
T5	15.8	54.8	115.2	177	416.9	224.0
Treatment	0.0001 [y]	0.0003	0.0093	0.0068	0.0001	0.1969
T1 vs T2	0.0002	0.0002	0.0174	-	-	-
T1 vs T3	0.0004	0.0071	0.3869	-	-	-
T2 vs T4	0.0061	0.5379	0.2914	0.4788	0.0116	0.8739
T4 vs T5	0.3806	0.6308	0.4938	0.3609	0.3568	0.3964

T1 = control ; T2 = lime ; T3 = organic fertilizer ; T4 = T2 + T3 ; T5 = T4 + fungicide
[z] Mean ; [y] *P* value

American Ginseng Fresh Root Biomass

In 1997 and 1998, the application of lime significantly increased fresh root biomass per plant (P = 0.0005 and 0.0057, respectively) (Table 6). Combining lime and organic fertilizer had a significantly positive impact in 2000, as compared to adding lime alone (P = 0.0186). Although no measure was taken in the control plots in 1999, visual assessments indicated that all treatments were significantly superior to control. Since there was no plant left in the control in 2000, no root could be harvested from these plots.

Table 6. American ginseng fresh root biomass (g/plant) in Sainte-Croix de Lotbinière, Canada, from 1996 to 2003

Treatment	1996	1997	1998	1999	2000	2003
T1	0.69 [z]	0.33	0.85	-	-	-
T2	0.78	0.87	2.47	2.95	3.89	5.20
T3	0.87	0.58	1.30	1.44	2.57	3.65
T4	1.01	0.99	3.16	3.02	5.82	5.34
T5	0.98	0.89	2.55	2.59	4.37	5.21
Treatment	0.1521 [y]	0.0003	0.0017	0.0035	0.0020	0.4647
T1 vs T2	0.5480	0.0005	0.0057	-	-	-
T1 vs T3	0.2168	0.0550	0.3896	-	-	-
T2 vs T4	0.1013	0.3153	0.1884	0.8561	0.0186	0.8671
T4 vs T5	0.7959	0.3913	0.2431	0.2618	0.0720	0.8690

T1 = control ; T2 = lime ; T3 = organic fertilizer ; T4 = T2 + T3 ; T5 = T4 + fungicide
[z] Mean ; [y] *P* value

DISCUSSION

The results of this experiment clearly show that very acidic, nutrient-depleted soils of red maple forests in Québec are not suited for American ginseng cultivation. At the end of the fifth growing season, there was not even one plant left in all of the control plots.

Nevertheless, as pointed out before (Nadeau et al. 2003), the results also indicate that the application of lime can improve American ginseng plant density, as well as leaf and root growth, at least during the first years of its development in this very acidic maple forest soil. As discussed in Nadeau et al. (2003), the improvement could be due, at least partly, to increased calcium content in the soil. Soil calcium seems to be a key element for the success of American ginseng cropping in forest soils. It was shown that wild populations of this plant in United States are found in a wide range of soil pH, but always in calcium-rich soils (Beyfuss 2000). It is also known that lime stimulates nitrogen and phosphorus mineralization (Simard et al. 1994a, 1994b), increasing their availability to plants, what may explain the positive impact of liming on American ginseng.

A positive impact of organic fertilization on American ginseng survival and growth has also been noted. However, except during the first growing season, this impact was lower than that of lime. Since both low calcium and high aluminum contents were measured in the soils of these plots (Nadeau et al. 2003), these results could be explained by calcium deficiency or aluminum toxicity, resulting in higher susceptibility of American ginseng to abiotic and biotic stresses. Addition of organic fertilizer in this very acidic soil would only be beneficial as long as sufficient calcium is provided to alleviate the aluminum toxicity.

Fungicide application did not result in any improvement in emergence, survival rate, leaf area, nor fresh root biomass of American ginseng. These results should be taken with caution, however, since the last fungicide application was performed in 1998. Nevertheless, it is possible that, under certain circumstances such as the ones of the present experiment, wild-simulated American ginseng could be grown without any pesticide. However, the fact that the yield was extremely low in all plots at the end of the experiment does not permit to defend such hypothesis.

In conclusion, the results indicate that nutrient management is essential to produce viable quantities of healthy, marketable American ginseng roots in the very acidic, nutrient-depleted forest soil of our experimental site. The calcium content of the soil, in particular, may be critical to the success of cultivation. After five years of cropping, there was no American ginseng plant left in the control plots. In fact, the yield was still extremely low in the treated plots also. However, results from the first years of the experiment indicate that it could have been different if lime would have been applied more frequently. Due to the fact that no lime was added later than in 1998, soil pH was very low in all plots at the end of the experiment. After an initial pH increase in the first 5 cm of the soil due to lime dissolution, calcium seems to have moved down. Thus, the important decrease in American ginseng survival and growth rate observed during the last years of the experiment could possibly be related to decreasing calcium content in the first cm of the soil. As pointed out by Konsler and Shelton (1990), American ginseng would probably have benefited from a higher pH increase. Thus, to make sure that wild-cultivation of this crop is feasible in very acidic red maple forest soils, it is mandatory that sufficient amounts of calcium are added.

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