EFFECT OF TRUNK INJECTION OF THREE GROWTH REGULATORS ON SPROUT GROWTH IN SILVER MAPLE

by Geoffrey P. Arron

Abstract. A short term greenhouse study was conducted to evaluate growth retardation capabilities of potential plant growth regulators for silver maple. Two-year-old silver maple seedlings were pruned and trunk-injected with the growth regulators MBR 18337 {N-[4-(ethylthio)-2-(trifluoromethyl)phenyl]-methane-sulfonamide}x EL-500 {α-(1-methylethyl)-α-[4-(trifluromethoxy)phenyl]-5-pyrimidine-methanol]} and PP 333 {(2RS, 3RS)-1-(4-chlorophenyl)-4,4-dimethyl-2-(1,2,4-triazol-1-yl)pentan-3-ol}. All three growth regulators caused a significant reduction in the number of internodes per unit sprout length, when measurements were made three months after injection. EL-500 and PP 333 were the more effective. A high application rate of MBR 18337 (5 mg/seedling) caused the initial growth to exhibit phytotoxic symptoms, although this was temporary. Neither EL-500 or PP 333, at the application rates used, caused any malformed growth.

The control of tree growth without producing noticeable injury symptoms, is a major problem under both electrical transmission and distribution lines. Pruning of problem trees under distribution lines on city streets and in rural areas is routinely performed at intervals of one to four years depending on the individual species growth rate and the amount of line clearance required (1). Such pruning operations, although effective, are time consuming, can be hazardous and are often expensive for the utilities involved (4). The extension of such pruning cycles would result in a substantial cost saving (5,11).

Much effort has been spent in developing chemicals for the horticultural industry to retard the growth of woody and herbaceous plants. Several such chemicals, which can be applied as foliar sprays (18), wound dressings (7), bark banding (3), soil drenches (13), soil injection (15), trunk infusions (10) and trunk injection (6,12,14,15) were effective in the control of tree sprout growth. The latter application method offers obvious advantages such as avoidance of drift, more precise application rate control and greater applicator safety (11). In 1974, the Electric Power Research Institute (EPRI) initiated a project in which various chemicals were trunk injected into seedlings grown in the greenhouse and mature trees situated across the U.S. (5,6). In field studies both maleic hydrazide and dikegulac were successful in controlling regrowth in most of the fourteen species investigated and in several instances regrowth was controlled for two growing seasons following treatment. Variability in regrowth was observed both among trees of the same species treated under different geographic and climatic conditions, and also among trees of the same species growing at one location (5).

Recently a group of new growth regulators was introduced which was shown to be effective in controlling the growth of trees without producing noticeable injury symptoms. The present study was conducted to determine the effect of trunk injection of three of these growth regulators, MBR 18337, EL-500 and P 333, on sprout growth in two-year-old silver maple seedlings.

Materials and Methods

Two-year-old dormant seedlings of silver maple (*Acer saccharinum*), approximately 1.5 m in height, were obtained from the Ontario Ministry of Natural Resources and planted in 37 cm diameter plastic pots in a mixture of shredded topsoil (sandy loam) and peat (1:1). The potted seedlings were placed in the greenhouse (21°C), watered twice a week, and fertilized every two weeks. Supplemental lighting [110 $\mu Em^{-2}s^{-1}$ PPFD (400 to 700 nm) (16 h photoperiod)] was supplied. When the seedlings achieved full leaf development 90 specimens were selected. At random, nine seedlings were chosen for each treatment.

The stock solutions of the three growth regulators MBR 18337, EL-500 and PP 333 were diluted with methanol to give an appropriate weight of active ingredient in an injection volume of .05 ml. Small volumes of methanol have been shown to be non-phytotoxic to trees (2). Three application rates, either in the range recommended by the manufacturer (1,2) or similar to those used in earlier studies (17), were used for each growth regulator. An electric drill with a 2 mm bit was used to drill a 10 mm deep hole, at an angle of 45° from the vertical, in each tree stem between 4 and 5 cm above the soil surface. Any shavings were removed and .05 ml of experimental solution introduced. The hole was covered with silicone grease to prevent evaporation and pathogen entry. This application method is similar to that used by Sterrett and co-workers (16) except that the volume of solution introduced was smaller and not under pressure. After application of the growth regulators the seedlings were pruned to remove approximately one-third of the length of the single major stem and any laterals. A record was made of the location and length of the laterals and the length of the main stem of each seedling. Control seedlings received methanol alone. The seedlings were left in the greenhouse for three months and then the location and length of each new lateral and the number of internodes in each new lateral were recorded.

Data were statistically compared in a two-tailed t test or by analysis of variance and multiple range tests (SNK) after transformation (log + 1), where indicated.

Results and Discussion

Number and length of sprouts formed. Only the lowest application rate of EL-500 was effective in reducing the number of sprouts that formed on silver maple seedlings after pruning (Table 1). By four weeks after administration of the high application rates of MBR 18337 the initial sprout growth on many of the silver maple seedlings had a distorted shape, with twisted and cupped leaves. By ten weeks the new foliage appeared normal. Such phytotoxic responses have been reported before with high application rates of MBR 18337 in both white ash and red maple (17). Neither EL-500 nor PP 333, at the various application rates used, caused any malformed growth.

Foliar applications of EL-500 have been reported to be non-phytotoxic with loblolly and slash pines, although the dwarfed growth appeared darker green than normal (8). PP 333 applications have also been reported to result in intensified greening of new growth (2).

All the sprouts that formed on the control silver maple seedlings were located above the injection point. In the various growth regulator treatments,

Table 1. Effects of trunk injection on the growth regulators MBR 18337, El-500 and P333 on the number of new sprouts formed in pruned silver maple seedlings

		MBR 18377 mg/tree			EL-500 mg/tree			PP333 mg/tree		
Parameter	*Control*	*0.2*	*1.0*	*5.0*	*1.0*	*5.0*	*25.0*	*0.1*	*0.5*	*2.5*
Number of trees treated	9	9	9	8	8	9	8	9	9	9
Number of trees with sprouts	9	9	9	8	6	7	8	8	8	9
Total number of new sprouts	70	46	113	96	21	31	25	37	30	33
Mean number of new sprouts per treated tree (± s.d.)*	7.8[abc] ± 4.4	5.1[bcd] ± 3.7	12.6[a] ± 4.8	12.0[ab] ± 7.9	2.6[d] ± 2.1	3.4[cd] ± 3.5	3.1[cd] ± 1.9	4.1[cd] ± 3.3	3.3[cd] ± 3.0	3.7[cd] ± 3.2

*Values within a row followed by a different letter are significantly different at the 5% level using a multiple range test.

sprouts were located above and below the injection point (Table 2). The latter were located on the main stem or on laterals which originated at points on the main stem below the injection point. For each treatment the mean length of sprouts that formed above the injection point was compared with the mean length of sprouts that formed below by means of a two-tailed test. While injection of MBR 18337 had little or no effect in that there were no significant differences ($p = 0.05$) between the mean lengths of sprouts in these two groups, injection of both EL-500 (all three application rates) and PP 333 (the two higher application rates) resulted in the formation of significantly shorter sprouts above the injection point than below. This suggests that both EL-500 and PP 333 move predominantly upwards in the stem while MBR 18337 moves upwards and down-

Table 2. Effects of trunk injection of the growth regulators MBR 18337, EL-500 and PP 333 on the length of new sprouts and the number of internodes per unit length in those sprouts, in pruned silver maple seedlings

		Treatment								
		MBR 18377 mg/tree			*EL-500 mg/tree*			*PP 333 mg/tree*		
Parameter	*Control*	*0.2*	*1.0*	*5.0*	*1.0*	*5.0*	*25.0*	*0.1*	*0.5*	*2.5*
Number of trees treated	9	9	9	8	8	9	8	9	9	9
Total number of sprouts located above injection point	70	41	85	82	14	20	22	31	15	18
Total number of sprouts located below injection point	0	5	28	14	7	11	3	6	15	15
Mean length of sprouts located above injection point (s.d.)cm*	15.4^{a} ±10.7	17.7^{a} ±13.3	9.5^{b} ±9.2	5.8^{bc} ±7.0	1.0^{*d} ±1.6	0.8^{*d} ±1.6	0.4^{*d} ±0.3	9.3^{bc} ±10.5	4.1^{*cd} ±6.9	2.1^{*d} ±4.4
Mean length of sprouts located below injection point (s.d.) cm	0	26.9 ±12.8	9.4 ±11.5	10.2 ±10.5	15.9 ±14.6	10.9 ±13.3	4.4 ±5.8	14.7 ±11.8	20.6 ±10.5	11.2 ±13.9
Total number of new sprout internodes	560	396	645	616	92	111	57	241	193	123
Mean number of internodes per cm sprout length, for sprouts above injection point (s.d.)**	0.39^{a} ±0.48	0.40^{a} ±0.43	0.67^{b} ±0.66	1.20^{*c} ±1.00	1.88^{*de} ±0.83	$1{,}96^{*de}$ ±1.22	2.27^{*e} ±1.11	1.06^{c} ±1.06	1.38^{*cd} ±1.02	1.52^{*cde} ±1.05
Mean number of internodes per cm sprout length, for sprouts below injection point (s.d.)	0	0.17 ±0.05	0.79 ±0.95	0.58 ±0.49	0.65 ±0.67	0.66 ±0.63	0.89 ±0.63	0.47 ±0.56	0.24 ±0.17	0.78 ±0.65
Mean number of internodes per cm sprout length, for sprouts 0 to 8 cm in length, produced above injection point (s.d.)	1.00^{a} ±0.72	0.85^{a} ±0.52	1.32^{ab} ±0.63	1.88^{bc} ±0.96	1.97^{bc} ±0.79	2.14^{c} ±0.14	2.27^{c} ±0.11	1.90^{bc} ±0.97	1.67^{bc} ±0.94	1.76^{bc} ±0.97

*Mean values marked with an asterisk are significantly different from the mean value quoted directly below, at the $p = 0.05$ level in a two-tailed t test.

**Values within a row followed by a different letter are significantly different at the 5% level using a multiple range test.

wards. Sprouting below the injection point has been reported after injection of MBR 18337 into white ash and red maple trees (17).

Sprout length was found to vary considerably, ranging from less than 1 cm to greater than 100 cm. In order to determine if any of the growth regulator treatments had any effect on the number of short, medium and long sprouts produced, the

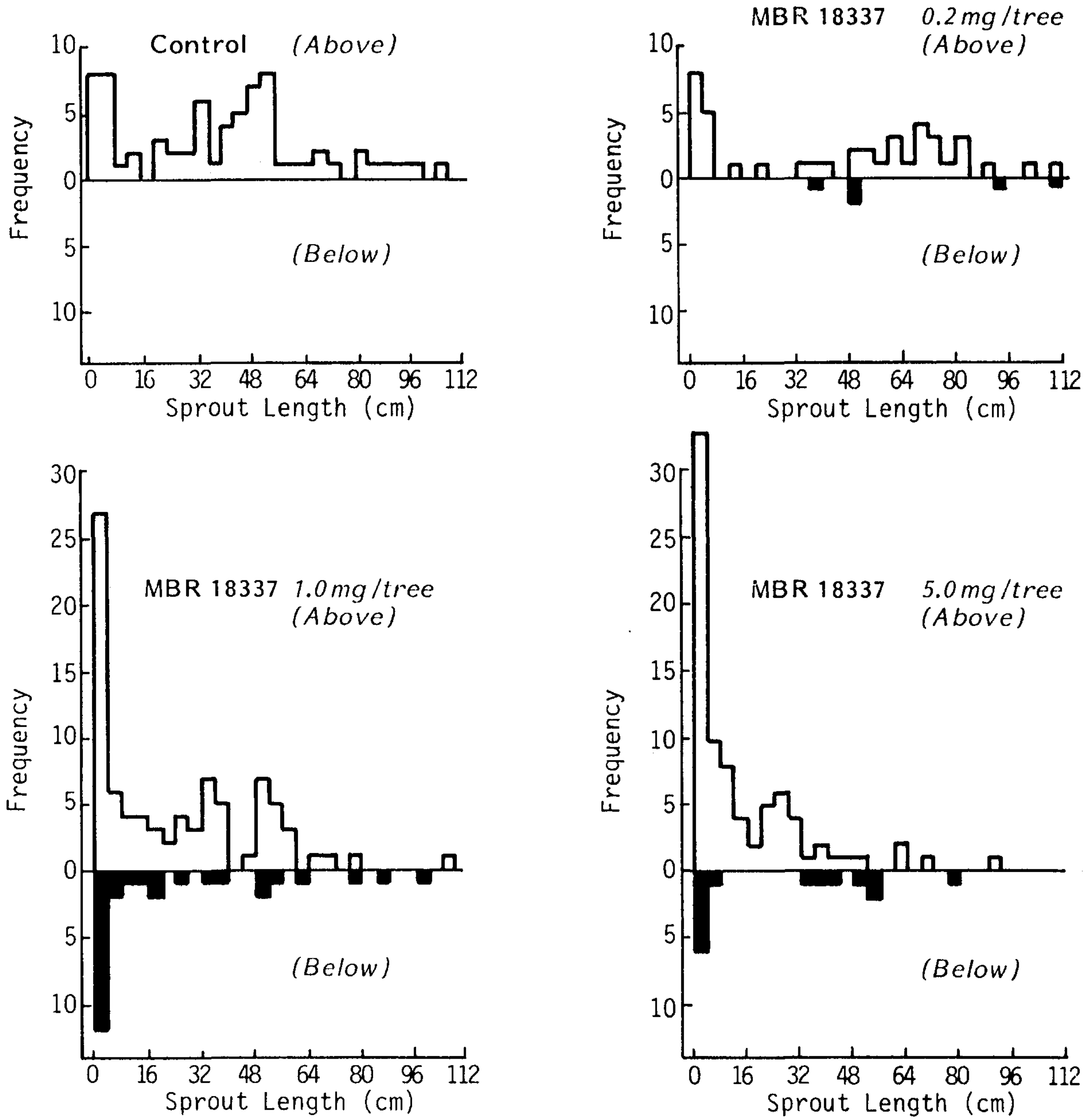

Figure 1. Effect of trunk injection of the growth regulators MBR 18337, EL-500 and PP 333 on the length of new sprouts, formed above and below the injection point, in pruned silver maple speedlings. Sprouts were grouped according to length into various classes, each length class was 4 cm, classes were 0 to 4, 4 to 8 cm etc.

frequency with which the various length sprouts were found was expressed graphically (Fig. 1). For ease of plotting, the sprouts were grouped into multiples of 4 cm each, with the first class being from 0 to 4 cm in length. In the control seedlings all the sprouts formed were above the injection point, and of these the majority were either from 0 to 8 cm or from 30 to 60 cm in length (Fig. 1). In seedlings treated with 0.2 mg of MBR 18337 the frequency of distribution of sprouts formed above the injection point was similar to that found in the control, while a few sprouts were found below the injection point. With the higher application rates of MBR 18337 more shorter sprouts were encountered above the injection point than in the control, and some sprouts were found below the injection point.

All three application rates of EL-500 had radical effects in that the vast majority of all the sprouts that formed above the injection point were extremely short while those sprouts that formed below the injection point varied in length and were few in number (Fig. 1). Injection of PP 333 had a striking effect in that, with the possible exception of the lowest application rate, most of the sprouts that formed above the injection point were extremely short. Some sprouts were found below the injection point for all three application rates of PP 333.

Although it is clear from the results discussed above that injection of silver maple seedlings with all three growth regulators resulted in more short sprouts being formed, it is not clear whether these sprouts were indeed young or merely slow growing.

When a comparison was made between the mean lengths of the sprouts found above the injection point in control and treated seedlings, the most effective group of treatments included all application rates of EL-500 and the two higher application rates of PP 333 (Table 2). The lowest application rate of MBR 18337 had no significant effect.

Number of internodes per unit length in sprouts formed. Both EL-500 and PP 333 are known to reduce sprout growth by inhibiting gibberellin biosynthesis (1,2), and given the influence of gibberellins on internode elongation in dwarf dicots (9) it was decided to determine if there were any differences in the internode length in sprouts formed on the various seedlings. The mean number of internodes present per unit sprout length was calculated for the sprouts formed either above or below the injection point (Table 2). Analysis of the data revealed that for all the application rates of EL-500, the two higher rates of PP 333, and the highest rate of MBR 18337, there were significantly more internodes per unit length (i.e. a shorter internode length) in sprouts that formed above the injection point than in those below. When a comparison was made between the mean number of internodes per unit sprout length for sprouts above the injection point in the control and treated seedlings, the most effective group of treatments included all three application rates of EL-500 and the highest rate of PP 333 (Table 2). Although this comparison took into consideration all the new sprouts formed by the end of the experiment, it was observed in the control seedlings that the new sprouts varied in length considerably (see Fig. 1) and the number of internodes per unit length varied as a function of sprout length (data not shown). Longer sprouts had fewer internodes per unit length (i.e. the internodes were longer) than short sprouts. Thus, any comparison of the number of internodes per unit length made with sprouts from control seedlings where the length of the sprouts varied, and from treated seedlings, where most of the sprouts were short, would be expected to show a significant effect of the growth regulators. Alternatively, only those sprouts of the same length could be compared and the results of such a comparison are presented at the bottom of Table 2. Only sprouts from 0 to 8 cm in length were included in the calculations. Sprouts on both EL-500 and PP 333 treated seedlings had significantly more internodes per unit length than sprouts on the control seedlings. In seedlings treated with MBR 18337 there was a large increase in the mean number of internodes per unit length as a function of dose of growth regulator applied. Application of the two lower application rates of MBR 18337 had no significant effect on the number of internodes formed per unit length. These results demonstrate that EL-500 and PP 333 cause an increase in the number of internodes per unit length in sprouts formed on treated seedlings, and this is probably the result of an inhibition of gibberellin biosynthesis.

From the data described above both EL-500 and PP 333 appear to move predominantly upwards after injection, since sprout length and the number of internodes per unit length in sprouts formed above the injection point were shorter and greater, respectively, than in sprouts that formed below the injection point. Of the sprouts found below the injection point, those with the shortest length and the most internodes per unit length were formed as a result of administration of the highest application rate of EL-500. This suggests that although EL-500 moves predominantly upwards in the stem, at high dose rates it moves downwards also, either directly from the point of application or on a circuitous route via the shoot tips. PP 333 is thought to move upwards in the xylem, with little or no downward movement in the phloem (2) and the results presented do not refute this.

The effects of MBR 18337 on sprout growth and the number of internodes formed provide little or no information on the direction of movement of this chemical in the stem. Sterrett and co-workers (17) obtained conflicting results over the direction of movement of MBR 18337 in the stem of California privet.

The present study has demonstrated that trunk injection of both EL-500 and PP 333 resulted in a significant reduction in the length of sprouts produced on pruned silver maple seedlings. The effectiveness of these growth regulators is being evaluated in the field.

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Biologist
Chemical Research Department
Ontario Hydro Research Division
800 Kipling Avenue
Toronto, Ontario, Canada M8Z 5S4