Five Years of Irish Trials on Biostimulants—The Conversion of a Skeptic

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Abstract: Three biostimulants, Lysaplant (Bugico, Switzerland), Plantali (Vossen, The Netherlands), and Kerry Algae (Kerry Algae, Ireland), were tested over 5 years in Irish nurseries on a variety of conifer and broadleaf forest tree species. The trials were designed to test the following biostimulant claims: improved growth, disease protection in rooting cuttings, and reduced need for fertilizer.

Lysaplant seed coating was found to produce nearly a 2-fold increase of first order root length in 6-month-old Douglas-fir grown in nonfumigated soil. Lysaplant, Plantali, and Kerry Algae (foliar sprays), were used in growth experiments in the bareroot and container nurseries over 2 years on 10 species. Plantali and Lysaplant both increased height and diameter growth in most of the species tested, with some height increases greater than 20%. With the Lysaplant spray, fungicide use in the rooting of cuttings could be reduced to nearly zero with improved rooting (51% with fungicide, 68% with Lysaplant) under stressful rooting conditions. Lysaplant and Plantali were both effective in promoting growth even when the standard fertilizer rate was halved. Foliar analysis and visual color assessment indicated that the biostimulants improved N uptake.

The conclusion from this extensive series of trials is that Lysaplant and Plantali are biostimulants that work as insurance against the vagaries of the Irish weather conditions. These biostimulants improve growth and reduce fertilizer requirements. Lysaplant spray can be used to decrease the need for fungicide in the rooting of Sitka spruce cuttings while Lysaplant Root improves root morphology.

Keywords: reduced fertilizer, reduced fungicide, disease protection, growth improvement

Introduction

Ireland is a small country with an area of only 27,135 mi^2 (70,280 km^2). It is smaller than 40 of the 50 states in the US, and would rank in size between West Virginia and South Carolina. It has been under constant habitation by humans for at least 5000 years. During that time, much of the native species and the extensive prehistoric forests have been lost. Ireland is currently the least forested country in Europe with only 7% of the land forested. This is after 20 years of active government-funded afforestation!

Forestry plantations in Ireland would have a familiar feel to a forester from the Pacific Northwest. Many of the major conifer species have their origin in North America. For example, the major Irish conifer species are Sitka spruce, Japanese larch, hybrid larch, lodgepole pine, Scots pine, Norway spruce, and Douglas-fir, half of which are native to North America and none of which are native to Ireland.

Some native broadleaves are grown, but most of the plantations of these trees are not commercially viable because of their very slow growth rate. The most commonly grown broadleaves are pedunculate oak, sessile oak, European ash, and European beech.

There is very little natural regeneration in Ireland, so most of the stock for forest planting is grown in nurseries. Because the climate is similar to the Pacific Northwest and the species are the same, the growing regimes and the relative growth rates of the major species are quite similar. One of the major climatic differences, however, is that the winters are warmer and the summers are cooler in Ireland than in the Pacific Northwest. This means that the plants often grow faster in Ireland over a forest rotation than in their native habitat. However, a very cool, wet summer can have a negative effect on the growth in the nursery.

Over the years, we have tried various treatments to improve the consistency of nursery growth during variable years. We had little success until we began to test some sprays referred to as biostimulants. The term biostimulant is a bit of a catchall phrase. A biostimulant has been defined as a substance that is not a plant nutrient or pesticide but which in some manner has a positive impact on plant health. The biostimulant may enhance metabolism, increase chlorophyll efficiency and production, increase antioxidants, enhance nutrient availability, and increase the water holding capacity of the soil. With such an all encompassing definition, it is not surprising that almost anything that has a positive effect on growth under some circumstances, but has no obvious mode of action, has been lumped into the category of biostimulants. This has led to a wide variety of compounds and extracts of various things, from humus to algae, being classed as biostimulants. With this sort of "anything goes" definition, wild claims for various products have been made through the years, but vigorous research has often not corroborated the claims.

The objective of the studies outlined in this manuscript was to test the claims of 3 biostimulants on forest nursery species in Ireland. The 3 compounds were: 1) Lysaplant (Bugico, Switzerland), an extract of a number of organic compounds from specific sources (Table 1) that can be used both as a seed treatment and a foliar spray (Coates 1999); 2) Plantali (Vossen, Netherlands), an extract of the seaweed *Ascophyllum nodosum*; and 3) Kerry Algae, another seaweed extract produced in western Ireland. The claims tested are improved root morphology, disease protection with reduced fungicide use, improved growth under less than optimal conditions, and reduced need for fertilizer.

Materials and Methods

Study 1. Seed Coating with Lysaplant Root

Seeds of 5 species—hybrid larch (*Larix eurolepis*), Japanese larch (*Larix kaempferi*), Douglas-fir (*Pseudotsuga menziesii*), lodgepole pine (*Pinus contorta*), and Scots pine (*Pinus sylvestris*)—were mixed with Lysaplant Root prior to sowing at the recommended rate of 0.1 kg Lysaplant/kg moistened seeds (0.1 lb/lb). The larch and Douglas-fir were sown at Coillte's Ballintemple Nursery at Ardattin in County Carlow, Ireland. The larch plots were replicated at Coillte's Aughrim Nursery at Tinahely, County Wicklow, Ireland, where the pines were also sown. At both nurseries, the fields were treated with metam sodium as a soil fumigant. Treated seeds were sown in 3 nonadjacent nursery beds for each species. Surrounding beds were sown with nontreated seeds of the same seedlot and served as the control.

At the end of the first growing season, 50 plants were lifted from each of the treatments in each of the 3 blocks per species. Height and root collar diameter were measured, and a standard analysis of variance (ANOVA) was done.

Study 2. Rooting of Sitka Spruce (*Picea sitchensis*) Cuttings with Biostimulants and Reduced Fungicides

Two experiments were carried out to examine the effect of biostimulants on the rooting of Sitka spruce cuttings with reduced fungicides. Coillte grows Sitka spruce cuttings in raised beds filled with a mixture of 1:1:1 peat:perlite:bark in an unheated polytunnel. Cuttings are stuck in March, rooted, and then removed in September when they are transplanted to the bareroot nursery. They are then grown for a further year before planting in the forest.

In the first trial the plots were small, only 3 m^2 (32 ft^2). This was done so that a true control (no fungicide and no biostimulant) could be used. It was expected that the control would have a high level of infection with *Botrytis* spp., which commonly attacks cuttings in the humid environment. The treatments for this study were control, Lysaplant sprayed at a rate of 0.015 ml/m^2 every 3 weeks, and fungicide (a rotation of Captan, Benlate, Bravo®, and Rovral® sprayed at approximately 10-day intervals at recommended rates). The treatments were replicated randomly in each of 3 blocks that were widely spaced in the tunnel.

During the summer, a visual assessment was done every 2 weeks on the percentage of cuttings in a 10 by 10 block (100 cuttings sample) that had visible fungal infection on the needles in each treatment. In September, the cuttings were lifted. One hundred plants in each treatment per block were assessed. The number of plants with visible roots and the quality of the roots were assessed. The quality was on the following scale: no roots, less than 6 roots, more than 6 roots but not branching, more than 6 roots and fibrous. The last 2 categories were considered "good" root systems. Statistical analysis was carried out.

The second study was carried out in the subsequent year (2000) and was done on much larger plots (150 m^2 [1614 ft^2]) to confirm the results from the previous year. It consisted of the following 3 treatments: fungicide at full rate, fungicide at half the recommended rate with Lysaplant, and Lysaplant

Table 1—List of ingredients in Lysaplant (taken from the German patent DE 38 25 312 C2 29.05.91). Note: Lysaplant was formerly named Elorisan.

1. Aluminum nicotinate (natural source: *Nicotiana rustica* [Tobacco])
2. Sodium salicylate (natural source: *Filipendula ulmaria* [Meadow Sweet])
3. Anthraquinone (natural source: *Rheum palmatum* [Chinese Rhubarb])
4. Agininc acid silylester (natural source: *Laminaria digitata*)
5. Lithium carbonate
6. Urea/Saponine (natural source: *Carex arenaria* [Sedge])
7. Guanidinium nitrate (natural source: *Symphytum officiale* [Comfrey])
8. Potassium-o-ethyl dithiocardamate (natural source: *Carnellia sinensis* var. *assamica* [Green Tea])

alone. (Spraying the full rate of fungicide every 20 days with the full Lysaplant rate produced the fungicide at half rate with Lysaplant treatment.) The assessments were the same as in the first year. Cuttings were lifted in September and the percentage of plants rooted was determined. Statistical analysis was carried out.

Study 3. Effect of Different Algal Sprays on Growth of Bareroot Plants in the Nursery

Three crops were selected on which to try the algae sprays. Crops of 1+1 hybrid larch (*Larix eurolepis*), 2+0 lodgepole pine (*Pinus contorta*), and 1+0 sycamore (*Acer pseudoplatanus*) were treated with either Plantali or Kerry Algae at 3-week intervals over the summer to see if it improved growth. The Plantali was sprayed at a rate of 1 l/ha in 300 l water (0.1 gal/ac in 80 gal water). Plantali must be activated by beating the chemical into water. This was done using the supplied mixing tool on a drill. For the full rate, 500 ml (17 oz) of Plantali was added to 5 l (1.3 gal) of water and mixed for 5 minutes. This solution was then added to a sprayer and made up to 150 l (40 gal) for spraying on 0.5 ha (1.2 ac).

The Kerry Algae was also sprayed at the rate of 1 l/ha in 300 l water. Kerry Algae does not require activation, so was added directly to the sprayer and made up to 150 l to spray 0.5 ha.

Both chemicals were sprayed 6 times during the summer on the following dates: June 8, June 22, July 6, July 20, August 3, and August 17. An adjacent area of unsprayed plants was designated as a control. All normal fertilizer, herbicide, and protection sprays were used on the test areas.

Plants were lifted the following winter and measured for height and root collar diameter. Three replicates of 50 plants each were lifted and measured for each treatment by species combination for a total of 1350 plants. ANOVA was done on the data.

Study 4. Effect of Lysaplant and Plantali on the Growth of Seedlings in Containers in Two Very Different Seasons

Trials were conducted at Coillte's container facility at Clone, Aughrim, County Wicklow, Ireland during the summers of 1999 and 2000. Seeds were sown into 100 cc (6 in^3) containers in early spring each year. In 1999, the species used was European ash (*Fraxinus excelsior*); in 2000, pedunculate oak (*Quercus robur*), common birch (*Betula pubescens*) and common alder (*Alnus glutinosa*) were used. Plants were treated from mid-May to late September with Plantali at a rate of 0.1 ml/m^2 and Lysaplant at a rate of 0.015 ml/m^2 at roughly 3-week intervals. The Plantali was agitated as directed and both chemicals were applied using a backpack sprayer onto 1 pallet each (a pallet holds 1600 plants) in each of 3 blocks that were randomly located within the species. A neighbouring pallet to the treated pair was designated as a control in each block.

At the end of July 1999, and at the end of the growing season in October 2000, 40 plants from each treatment and block were measured for height and root collar diameter. ANOVA was done on the data.

Study 5. Growth of a Variety of Species and Stocktypes in a Bareroot Nursery Sprayed with Biostimulants

A pilot trial was conducted to examine the growth response of a number of species and stock types to treatment with biostimulants. At Coillte's Ballintemple Nursery the following species and stock-types were treated: 2+0 oak (*Quercus robur*), 2+0 ash (*Fraxinus excelsior*), 1+0 Japanese larch (*Larix kaempferi*), 2+1 Norway spruce (*Picea abies*), 2+1 Douglas-fir (*Pseudotsuga menziesii*), 1.5+0.5 Douglas-fir, transplanted July 7), 1+0 Norway spruce, and 1+0 birch (*Betula pubescens*). In Coillte's Aughrim Nursery, 2+0 oak was also treated.

The plots received the following treatments: Lysaplant sprayed at 100 ml/ha (1.4 oz/ac) and Plantali sprayed at 1 l/ha (0.1 gal/ac). Adjacent beds were designated as controls. Spraying began on June 6 and continued until mid-September at roughly 3-week intervals for a total of 8 sprays. The 1.5+0.5 Douglas-fir seedlings were only sprayed 5 times after transplanting on July 7.

At the end of the growing season, 3 samples of 50 plants each were lifted from the treatments and measured for height and root collar diameter. Statistical analysis was done on the data to compare the treatments.

Study 6. Effect of Biostimulants on the Fertilizer Requirement for Optimal Growth of 1.5+1.5 Sitka Spruce in the Final Year in the Nursery.

Sitka spruce (*Picea sitchensis*) were grown for 1.5 years in the seedbed and then transplanted at a spacing of 100 plants/m (30 plants/ft) in July of the second growing season. The biostimulant treatments were begun in the spring of the third growing season.

The biostimulants used were Lysaplant at the rate of 100 ml/ha and Plantali at 1 l/ha. The biostimulants were sprayed at roughly 3-week intervals from early May to mid-September for a total of 8 sprays. The control consisted of no biostimulant but all other treatments applied. Each biostimulant was sprayed in 5 nursery bed strips in each of 3 blocks, with a control of 5 beds in each block.

The nitrogen (N) fertilizer treatments were imposed over the biostimulant treatment. Each of the 3 middle beds of the 5-bed biostimulant plots was randomly assigned to 1 of the 3 levels of N fertilizer: full rate (best rate as determined in the nursery over many years), two-thirds of the full rate, and half of the full rate. The fertilizer was sulfa-calcium ammonium nitrate (S-CAN) (26.5N:0P_2O_5:0K_2O:6.5Ca:5S), a coated fertilizer that is neutral in pH effect and nonexplosive. Full rate was 600 kg/ha (536 lb/ac) S-CAN (160 kg/ha [143 lb/ac] N); two-thirds rate was 390 kg/ha (348 lb/ac) S-CAN (100 kg/ha [89 lb/ac] N), and half rate was 300 kg/ha (268 lb/ac) S-CAN (80 kg/ha [71 lb/ac] N). The fertilizer was applied in 6 equal applications from late April to mid-July.

The following winter, foliar samples were taken from the transplants for nutrient analysis. Samples of 50 trees were taken from each of the treatment plots in each of the 3 blocks for height and root collar diameter measurements.

Results of the foliar analysis were compared and morphological measurements were analysed using standard ANOVA procedures.

Results and Discussion

Study 1. Seed Coating with Lysaplant Root

The results of the study (Table 2) were very disappointing. Although there were some slight differences that were significant, they did not indicate that the Lysaplant had any positive effect on growth. Looking at the root systems of the larches and the Douglas-fir in some areas of the field, however, you could see a large positive difference in the root morphology with the Lysaplant. The areas where the better root systems were found corresponded to areas where the fumigation did not appear to have been successful (based on the rapid appearance of weeds).

We discussed our results with Dr. Derek Mitchell and Suzanne Monaghan, researchers at University College Dublin. They decided to study the effect of Lysaplant Root more thoroughly in the laboratory for Douglas-fir. Their results (Monaghan and Mitchell 1998) indicate that the root architecture of Douglas-fir is greatly affected by the Lysaplant in nonfumigated soil (Table 3). First order root length was nearly doubled. When a colleague of theirs tried the same experiment in sterilized soil, they found no effect (Monaghan 2000).

Lysaplant Root has a positive effect on the root growth of conifer seedlings in nonfumigated ground where it can act on the natural bacteria in the soil. Trials of Lysaplant root in containers in a peat-based media showed negative results (experimental data not reported) when a similar study was done on cherry (*Prunus avium*). It is believed that this is, again, due to the low level of microflora in the nearly sterile root environment.

Study 2. Rooting of Sitka Spruce (*Picea sitchensis*) Cuttings with Biostimulants and Reduced Fungicides

The results from the first study were encouraging. Disease incidence, as measured by the number of visible infections on the needles, was highest in the control at 11%. The visible incidence was only slightly less in the Lysaplant at 7% (Table 4). Remarkably, the incidence of disease did not correspond to the rooting percentage. All the treatments rooted at a significantly higher percentage than the control with no significant difference between the treatments (Table 5). This would indicate that Lysaplant was as effective as the fungicide in controlling the disease problems and rooting. The year of this study (1999) was cool and wet. These are good conditions for rooting and the 80% rooting in this study reflected this.

Table 2—Comparison of growth of 1 + 0 seedlings after seed treatment with Lysaplant Root at 2 nurseries. Pairs of numbers followed by * are significantly different at the *P* = 0.05 level.

		Ballintemple Nursery		Aughrim Nursery	
Species	Test	Height	Diameter	Height	Diameter
		cm	*mm*	*cm*	*mm*
Japanese larch	Control	8.9	1.4	11.0	1.7
	Lysaplant	9.1	1.4	11.0	1.7
Hybrid larch	Control	9.3	1.6*	13.8	1.9*
	Lysaplant	10.3	1.9*	12.7	1.6*
Douglas-fir	Control	12.7	1.8		
	Lysaplant	10.6	1.6		
Scots pine	Control			6.9*	2.4
	Lysaplant			6.4*	2.5
Lodgepole pine	Control			7.3	2.3
	Lysaplant			6.7	2.1

Table 3—Morphometric measurement (mean ± SEM) of the root systems of 6-month-old Douglas-fir seedlings (from Monaghan and Mitchell 1998).

	Lysaplant Root—treated	Control
First order root length (cm)	4.5 ± 0.6	2.5 ± 0.4[a]
Main root diameter (mm)	1.03 ± 0.03	0.73 ± 0.02[b]
First order root diameter (mm)	0.64 ± 0.03	0.48 ± 0.07[b]

[a] and [b] denote significantly different at 1% and 5% level respectively using Student's t-test.

Table 4—Visual assessment of *Botrytis* spp. on the needles of Sitka spruce cuttings given treatments as noted throughout the summer.

Treatments	Disease	Dead needles
	- - - - - - *percent* - - - - - -	
Control	11	22
Lysaplant	7	19
Fungicide	2	16

Table 5—Final rooting percentage and the percentage of good roots for Sitka spruce cuttings. Treatments followed by the same letter in a column do not differ significantly at the *P* = 0.05 level.

Treatments	Rooted	Good roots
	- - - - - - *percent* - - - - - -	
Control	57 a	43 a
Lysaplant	80 b	63 b
Fungicide	81 b	61 b

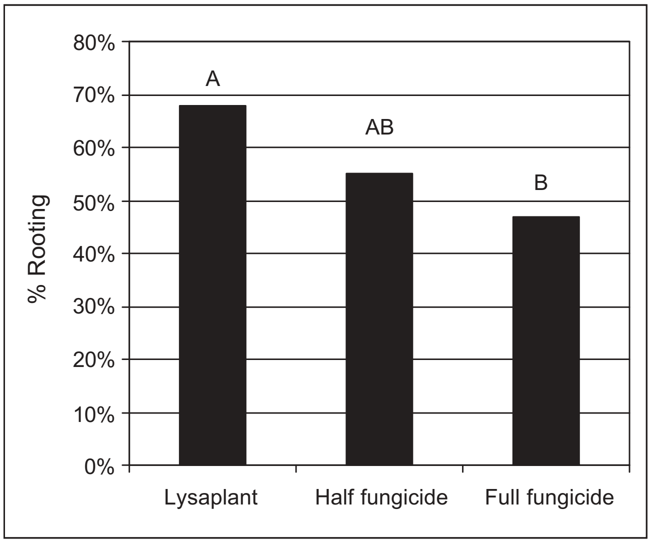

Figure 1—Rooting of Sitka spruce in a poor rooting year sprayed with full rate (1X/wk) fungicide, half fungicide rate (1X/2 wk), and Lysaplant only. Bars that have the same letter above them do not differ significantly at the *P* = 0.05 level.

In 2000 (a warm, sunny summer), rooting was reduced probably because of excessive heat in the tunnels. Under these conditions of stress, the Lysaplant improved the rooting by 17% over the standard fungicide treatment, from 51% to 68% (Figure 1). Only one spot spray of fungicide was needed to control disease in the Lysaplant treatment.

Study 3. Effect of Different Algal Sprays on Growth of Bareroot Plants in the Nursery

The lodgepole pine, hybrid larch, and sycamore all showed a similar response to the biostimulants applied (Table 6). Kerry Algae had no significant effect on the growth of any of the species tested. Plantali, on the other hand, worked on all the species tested to increase growth an average of approximately 10% for both height and diameter growth. After these poor results, no further trials were done with Kerry Algae.

Study 4. Effect of Lysaplant and Plantali on the Growth of Seedlings in Containers in 2 Very Different Seasons

The summer of 1999 was cold and wet. Growth was below average, even in the greenhouse. In that year, the results of the biostimulants on the growth of the ash were very impressive, with both sprays showing greater than 30% increase in height growth (Table 7). In contrast, 2000 was a much better growing season. Plants in the containers grew very tall and were probably restricted by the volume of the container. The growth of all 3 species was completely unaffected by the biostimulants (Table 8, only height data shown).

Study 5. Growth of a Variety of Species and Stocktypes in a Bareroot Nursery Sprayed with Biostimulants

Biostimulants increased growth in most of the species and age classes tested. The results, however, were not entirely consistent (Table 9). In the 2+0 oak at 1 nursery, the growth nearly doubled with biostimulant spray; there was little difference in growth at the other nursery. At the nursery where the difference was pronounced, the plants were not fertilized as intended because of heavy rains after applications, and the plants suffered from mildew. Under these conditions, the biostimulants greatly promoted growth.

The 1+0 birch showed a good response to the biostimulant; the 2+0 ash showed little effect.

All the conifers tested, with the exception of the 1+0 Norway spruce, showed an improvement in height growth and diameter growth with biostimulant spray. There is little difference between the 2 types of biostimulants in the response. The 2+1 Douglas-fir appeared most responsive, with a 12% increase in height and a 7% increase in seedlings transplanted in June and sprayed twice.

The most impressive results were from the treatment of the Japanese larch, where the plants went from a size that was not large enough to transplant without the biostimulant to a size suitable for transplanting after treatment—an increase in height of 39%.

Table 6—The effect of spraying 2 biostimulant algae preparations for 1 growing season on the growth of 3 species in the nursery. All numbers in a column followed by the same letter are not significantly different at the *P*= 0.05 level. NS = not significant.

	2+0 lodgepole pine		1+1 hybrid larch		1+0 sycamore	
Treatment	Height	Diameter	Height	Diameter	Height	Diameter
	cm	*mm*	*cm*	*mm*	*cm*	*mm*
Control	12.7 a	2.9 a	42.9 a	6.3 ns	13.9 a	4.0 a
Kerry Algae	12.3 a	2.7 a	42.7 a	6.4	14.5 a	3.8 a
Plantali	14.8 b	3.2 b	46.3 b	6.5	15.5 b	4.4 b
(% increase over control)	(+16.5)	(+10.3)	(+7.9)		(+11.5)	(+10.0)

Table 7—The effect of biostimulatants on the 2-month growth of ash seedlings in a poor year (1999). Means followed by the same letter within a column do not differ significantly at the *P* = 0.05 level.

Treatment	Height	Improvement	Diameter	Improvement
	cm	*percent*	*mm*	*percent*
Plantali	18.3 b	42	4.2 b	14
Lysaplant	17.1 b	33	3.9 a	5
Control	12.9 a	—	3.7 a	—

Table 8—Effect of biostimulants on the height growth of 3 species grown in containers in a very good growing season. None of the differences are significant.

Treatment	Oak	Birch	Alder
	- - - - - - - - *cm*	- - - - - - - -	
Lysaplant	39	60	69
Plantali	40	60	69
Control	39	61	72

Study 6. Effect of Biostimulants on the Fertilizer Requirement for Optimal Growth of 1.5+1.5 Sitka Spruce in the Final Year in the Nursery

During the growing season, color differences were noted in the control treatments, with the reduced fertilizer levels appearing very yellow in the field. Lysaplant treated trees remained green at all levels of fertilization. Plantali treated trees were greener at the full and two-thirds rate, but appeared yellow at the half rate.

These visual observations were supported by the foliar analysis results (Table 10). Note that the decrease in foliar N level with decreasing fertilizer was much less pronounced in the biostimulant treatments than the control (Figure 2).

Growth was affected by the biostimulant x fertilizer interactions. In Figure 3, it can be seen that the Lysaplant treatment resulted in greater growth than the control at both two-thirds and half fertilizer rate. Although not statistically significant, Plantali treated plants appear to have grown better at all the fertilizer rates than the controls. As expected, the growth of the untreated plants was lower at the lowest fertilizer rates.

Conclusions

After this extensive series of experiments, what conclusions can we make about biostimulants? The first conclusion is that not all biostimulants are created equal. Kerry Algae did not work in any of the trials in which it was tested. (Only one trial was reported here; others were undertaken.) Plantali and Lysaplant both gave very good results in most of the trials. Biostimulants appear to work best when the plants are under some kind of stress, either environmental from poor growing conditions, disease, or reduced fertilizer (Blake 2002). They do not improve growth when all the factors are optimal, but act more as an insurance policy to protect the nursery against the vagaries of nature.

In this series of trials, we set out to examine 4 claims of the biostimulants. The first was to determine if Lysaplant Root (a seed pre-sowing treatment) could affect the root architecture of poor rooting species by acting on the bioflora in the soil. Although our initial trial was unsuccessful in fumigated soil, when the trial was repeated in nonfumigated soil in laboratory conditions, it was found that the number of roots and branching of the root system was greatly increased in Douglas-fir. This claim was thus substantiated. For species such as Douglas-fir and hybrid larch, where root systems are often not well developed when the plants are sent to the field, this level of improvement in root morphology may play a significant role in improving outplanting success.

The second claim that we set out to test in the nursery was that Lysaplant spray could protect plants from disease attack. The manufacturers claim that the spray induces changes in the leaf membranes that make it more difficult for fungi to attack the plant. The only situation in the

Table 9—Results of biostimulant sprays in 2000 on the height (cm) and diameter (mm) of a variety of species and age classes. Means followed by the same letter within a row do not differ significantly at the *P* = 0.05 level.

Size measurements species-plot (age)	Measure	Lysaplant	Plantali	Control
2+0 Oak Aughrim	Height	72.5 b	70.4 b	49.6 a
	Diameter	10.7 b	9.6 a	9.3 a
2+0 Oak	Height	70.5	75.3	75.2
	Diameter	10.1 a	11.0 b	11.2 b
1+0 Birch	Height	23.2 b	22.2 b	17.4 a
	Diameter	3.9 a	4.4 b	4.5 b
2+0 Ash	Height	39.5	40.5	40.4
	Diameter	11.1 b	10.8 a	11.5 b
1+0 Japanese larch	Height	7.4 c	6.4 b	5.3 a
	Diameter	2.1 b	1.8 a	1.7 a
2+1 Norway spruce	Height	17.9 b	18.2 b	14.0 a
	Diameter	4.7 b	4.6 b	3.7 a
1+0 Norway spruce	Height	5.2	5.3	5.4
	Diameter	0.9 a	1.0 b	1.1 b
2+1 Douglas- fir	Height	43.3 b	43.3 b	38.6 a
	Diameter	8.6 b	9.2 c	7.1 a
2+0[a] Douglas-fir	Height	23.1 b	22.8 b	21.6 a
	Diameter	3.6 b	3.6 b	3.3 a

[a]Treated after transplanting in June until the end of the growing season.

Table 10—Foliar analysis of Sitka spruce transplants after 1 year of biostimulant treatments at varying fertilizer levels.

Biostimulant	Fert.	Na	P	K	Ca	Mg	Cu	Zn	Fe	Mn	B
		percent					*ppm*				
Control	Full	2.06	0.28	1.21	0.67	0.17	4	53	110	87	18
	Two-thirds	1.67[a]	0.30	1.23	0.70	0.16	4	55	116	67	11
	Half	1.63[a]	0.27	1.25	0.64	0.15	3	37	78	57	15
Lysaplant	Full	1.89	0.38	1.45	0.86	0.18	4	75	104	174	23
	Two-thirds	1.87	0.37	1.47	0.84	0.18	5	72	84	163	21
	Half	1.82	0.35	1.51	0.77	0.18	4	65	82	144	22
Plantali	Full	2.03	0.32	1.34	0.80	0.18	5	55	110	73	21
	Two-thirds	1.92	0.38	1.59	0.84	0.17	4	73	88	113	22
	Half	1.78	0.34	1.41	0.76	0.15	4	56	100	78	21

[a] N levels are below our recommended foliar N content (1.75%) for plants going to the field.

nursery where we predictably get disease attack every year is in the rooting of Sitka spruce cuttings. Because the cuttings are rooted under mist in low light levels for up to 3 months, disease is prevalent.

For 2 years, we tested the Lysaplant against our standard fungicide regime for protecting the cuttings from attack by *Botrytis* spp. In each year, the Lysaplant worked as well as the fungicide in reducing fungal attack. In a poor rooting year, it significantly improved rooting. Coillte's rooting tunnels have used Lysaplant as part of the standard regime for the last 3 rooting seasons with excellent results and an 80% reduction in fungicide usage. Only an initial overall spray of fungicide is given just after the cuttings are stuck to reduce the spore population, and small areas are spot sprayed if *Botrytis* patches are discovered.

With new regulations reducing the range of fungicides available to the nursery, products that help to stimulate the plant to protect itself may be the direction for the future. Further tests need to be conducted to see if Lysaplant can protect forest nursery plants against other common nursery diseases.

The third claim tested in the nursery was that biostimulants improved growth. This is the easiest claim to test, and all 3 biostimulants under consideration were tested. A variety of species and stock types were examined, both bareroot and container. Results were generally good with

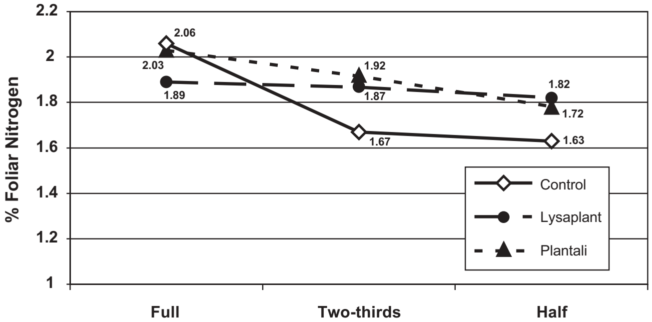

Figure 2—Effect of decreasing N application (full rate = 160 kg/ha N, two-thirds rate = 100 kg/ha N, and half rate = 80 kg/ha N) on the foliar N level of Sitka spruce at the end of the growing season.

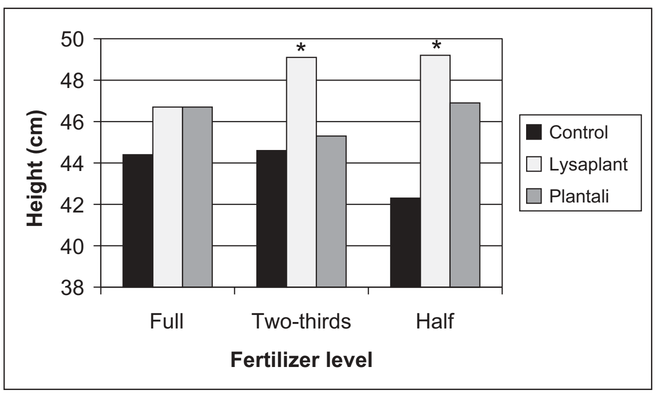

Figure 3—Interaction between fertilization level and biostimulant spray. Bars marked with * differ significantly at the $P = 0.05$ level from the control at full fertilizer rate.

Lysaplant and Plantali, while there was no effect with Kerry Algae. Some spectacular results were noted, with a 42% increase in height in container ash with Plantali and 46% increase in 2+0 oak height with Lysaplant where oak mildew affected the growth of the controls. The results, however, are not consistent. Where the growth of the controls was very good, the biostimulants did not improve it. For growth particularly, Lysaplant and Plantali act as an insurance policy against something else in the growing environment restricting growth.

The final claim tested was that, with biostimulants, the amount of fertilizer (N) needed to grow crops could be reduced significantly. This was the assertion that was the most difficult to believe. With the Lysaplant being sprayed at a mere 100 ml/ha (5 to 7 times per season), the claim that fertilizer could be reduced by up to 50% (80 kg/ha N) seemed very farfetched. In fact, the Lysaplant manufacturers maintain that high levels of N actually reduce the effectiveness of their product. In our controlled experiments with Lysaplant and Plantali, we found that their claims were indeed substantiated. While the growth and N content of the control 2+1 Sitka spruce was less with decreasing fertilizer, Plantali treatments showed little effect and seedlings treated with Lysaplant grew significantly better with decreasing fertilizer. In this era of increased awareness of water quality and N pollution, the fact that the fertilizer can be halved without decreasing growth with the use of biostimulants must be a welcome finding and should have important consequences.

Finally a personal note: I entitled this paper the "conversion of a skeptic" and I must admit that I began this series of studies under protest. When I was presented with the biostimulants and began to read up on the literature, I found many wild claims but very little good data or substantiation of the claims. This series of trials was started because of a request from a government official who wanted data on Kerry Algae, the Irish product. I decided that if we were going to test 1 biostimulant, we ought to test some that were considered successful in other countries. Plantali was chosen because it and its related product, Herbali, are used extensively in the nurseries in Holland. The Lysaplant was selected on the recommendation of a Danish grower who claimed good success with it.

I fully believed that the first study would be the last and we could say that none of this stuff works. Life isn't that simple. Some of the first studies had spectacular results. There was really something positive going on here. After 5 years and more studies than those reported here, I have to say I am now a believer. I still don't know how a compound that is used at such a low concentration can have such a large effect, but I'm now convinced it does.

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