Using Plant Growth Regulators on Red Alder and Douglas-Fir Plugs

Nabil Khadduri

Nursery Scientist, Webster Forest Nursery, Washington Department of Natural Resources, Olympia, WA

Abstract

Treatments of 50 ppm, 50 ppm (two applications), 100 ppm, and 200 ppm and also 5 and 10 ppm drench applications of the plant growth regulator (PGR) Bonzi® (paclobutrazol) significantly reduced height growth while maintaining stem diameter growth in red alder (*Alnus rubra* Bong.) container seedlings, resulting in a sturdy, compact seedling at transplant. Although the use of PGR facilitated the midseason transplanting process, end-of-season height, stem diameter, and packout totals of field-transplanted seedlings were not significantly different than the control group. In a second trial, Bonzi and Sumagic® (uniconazole-P) PGRs were applied to coastal Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) container seedlings to help stimulate shutdown. Treatments of 10, 20, and 40 ppm Sumagic® significantly reduced height growth compared with control seedlings, but stem diameter growth was significantly reduced as well. Bonzi® treatments of 50, 100, and 200 ppm did not significantly reduce height growth, while stem diameter growth was slightly lower than controls. Only the 10 ppm Sumagic® treatment produced sturdier (lower height-to-stem diameter ratio) seedlings compared with control seedlings. Used in conjunction with other cultural techniques, PGRs may offer the grower another tool to manipulate seedling growth. At this time, PGRs show more promise in red alder than Douglas-fir seedling production. This paper was presented at a joint meeting of the Western Forest and Conservation Nursery Association, the Intermountain Container Seedling Growers Association, and the Intertribal Nursery Council (Boise, ID, September 9–11, 2014).

Introduction

Both red alder (*Alnus rubra* Bong.) and coastal Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) are known for their rapid, at times excessive, vegetative growth in nursery culture. While a grower must push the production cycle to achieve final root and stem morphology specifications in one season, plant growth regulators (PGRs) might help moderate rapid height growth in the goal of producing a balanced seedling.

The bulk of PGR research on Pacific Northwest reforestation species was done in the late 1980s and early 1990s following the release of paclobutrazol (Bonzi®, Syngenta, Wilmington, DE). Wheeler (1987) found no effect of paclobutrazol on 4- to 5-year-old Douglas-fir seed orchard trees, but did note height reduction when applied to 6-week-old seedlings. van den Driessche (1988) found that, in sand culture, paclobutrazol reduced height and shoot:root ratios of Douglas-fir seedlings. Rietveld (1988) used Bonzi® over pine (*Pinus* spp.) in a bareroot nursery to successfully achieve height control. He noted the disadvantage of using a PGR, however, because of the residual nature of the chemical in the soil for up to 2 years. In a three-nursery study, Smith et al. (1994) found that sturdiness quotients (height to stem diameter ratios) of western larch (*Larix occidentalis* Nutt.), white spruce (*Picea canadensis* (Mill.) Britton, Sterns & Poggenb.), and lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) were all improved with Bonzi® applications, without negative effects on root growth.

Despite these promising early results, little research exists on paclobutrazol or any other PGR applied to reforestation species in the past 20 years. Two possible explanations are the early experiences of some growers when applying excessively high rates of PGR that resulted in stunting of seedlings for multiple seasons. Also, patents for chemicals such as paclobutrazol have since expired. While paclobutrazol and other PGRs are still considered expensive, several companies now make these products and the price has dropped. For example, paclobutrazol is now sold as Paczol® (OHP, Inc., Mainland, PA), Downsize® (Greenleaf Chemical, Henderson, NV), and Piccolo® (Fine Americas, Walnut Creek, CA), in addition to Bonzi®.

Duck et al. (2004) investigated foliar application of commonly used PGRs to several conifer species for tabletop Christmas tree production. They found that uniconazole (Sumagic®, Sumitomo Chemical, New York, NY; also sold as Concise®, Fine Americas) was most effective in controlling height growth across a range of *Pinaceae* and *Cupressaceae* species. Like paclobutrazol, uniconazole is a triazole (PGR Mode of Action 1), but is not labeled for chemigation or outdoor nursery use. Uniconazole-P is considered the most potent PGR available (Runkle 2013) (figure 1).

The active ingredient of most PGRs can be absorbed through stems and roots. Spray-to-wet applications, in which an

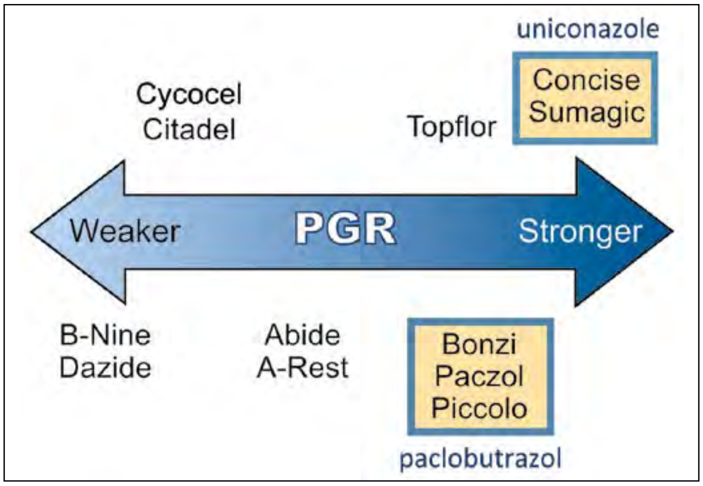

Figure 1. Relative strengths of commonly used plant growth regulators (PGRs). Adapted from Runkle (2013).

appropriate volume of solution is applied to the point of first runoff from foliage, focus on stem uptake, whereas drench applications are primarily taken up through roots. After the chemical is in the plant, it is transported through the xylem tissue and inhibits gibberellin synthesis. The most noticeable effect is the development of shorter stem internodes (with accompanying height reduction) due to smaller, more compact cell development. Other changes, such as in poinsettia production, may include thicker stems, increased rooting, darker green leaves (due to increased chlorophyll production), and improved water use efficiency (Lattimer and Whipker 2012).

It is important to apply PGRs in conjunction with sound cultural practices. "Wet" growers will find less use for PGRs, because keeping seedlings constantly wet may override or dilute PGR effects. In general, higher rates of PGRs are needed for crops grown in warm climates, high light intensity, wet growing medium, high fertilization, tight plant spacing, and with vigorous species. Conversely, lower rates of PGRs can be used in cooler, lower light, drier, lower fertility, wider plant spacing, and with less vigorous species. Note that PGRs can be tied up by bark media mixes and will require higher rates in this situation or may not be effective at all (Currey and Lopez 2010). Accurate application is also vital. Along with product concentration, the volume of application will determine the longevity of the product in the plant. Foliar sprays tend to have the shortest effect, dips have a moderate-lasting effect, and substrate drenches have the longest effect (Runkle 2013).

The objective of this study was to test (1) the effects of paclobutrazol (Bonzi®) on red alder and (2) to compare uniconazole (Sumagic®) with Bonzi® on Douglas-fir. Knowing that conifers are less affected by PGRs than hardwoods and herbaceous perennials, we chose to include Sumagic® in the Douglas-fir trial (trial 2) for its high activity.

Materials and Methods

Trial 1: Bonzi® Applications on Red Alder Small Plugs for Transplant

At the Department of Natural Resources, L.T. Mike Webster Nursery (Olympia, WA), we grow red alder seedlings as a plug+1/2. This stocktype consists of roughly 3 months grown as a container seedling (plug) followed by 5 or so months in a bareroot field. The challenge for a greenhouse grower is to achieve good root fill in the plug cavity without excessive height at the end of the plug stage. These targets can be achieved in part with moisture and nutrient management, but red alder has a notoriously sensitive plant wilting point and does not always react well to reduced irrigation. A tall, skinny plug seedling can be hard to transplant to the bareroot field, because it may get caught in the wheels of a mechanical transplanter or fail to stand up well after transplanting. Hot weather in the first couple of weeks following transplanting can damage the greenhouse-grown leaves and plants may decline before adequate soil-root contact has been established. The goal of this trial was to achieve a more compact seedling able to withstand the rigors of transplanting.

Red alder seed was sown in late February 2014 in 2 in^3 (40 ml) 240-cell Styroblock™ Containers (Beaver Plastics, Acheson, Alberta, Canada) in an 80:20 peat:perlite medium. Four seed lots, representing the four lowland red alder seed zones of western Washington, were included in the trial in a randomized complete block design (blocked by seed lot).

We applied a range of Bonzi® treatments in our greenhouse facility (table 1). Capsil® (Aquatrols, Paulsboro, NJ), a nonionic adjuvant, was added to lower treatment rates and to determine if it would enhance treatment effects. Treatments were applied with a backpack sprayer April 17, 2014, 7 to 8 weeks after sowing. Whole Styroblocks™ (240 seedlings) were treated within each seed lot (block), randomly assigned a location in the greenhouse, and grown under operational growing conditions. Spray treatments wetted the foliage just to the point of runoff. Drench treatment volumes of approximately 1.5 fl oz (44.0 ml) solution per cell were applied to achieve roughly 10 percent leaching from application.

Seedling heights were measured every 2 weeks following transplant through the end of the growing season in early November. Stem diameters were measured 6 weeks after treatment (upon lifting from containers and transplanting to the bareroot field) and at the end of the growing season. ANOVA analyses were conducted using the R statistical

Table 1. PGR treatments applied to red alder container seedlings.

Treatment	Rate (ppm)	Application method	Number of applications	Adjuvant
Control	NA	NA	NA	NA
Bonzi®	50	Spray	One	None
Bonzi®	50	Spray	One	Capsil*
Bonzi®	50	Spray	Two, 17 days apart	None
Bonzi®	100	Spray	One	None
Bonzi®	100	Spray	One	Capsil*
Bonzi®	200	Spray	One	None
Bonzi®	5	Drench	One	None
Bonzi®	10	Drench	One	None

NA = not applicable. PGR = plant growth regulator.
*Applied at a rate of 0.10 oz/gal (0.75 g/L).

package (R Core Team 2013). Treatment means were subjected to Tukey's HSD test and considered significantly different at the $p < 0.05$ level.

Trial 2: Bonzi® and Sumagic® Applications on Large Douglas-Fir Plugs for Outplant

Perhaps the main challenge a grower faces in culturing large, coastal Douglas-fir plugs is effectively shutting down shoot growth in late summer. Timely shutdown results in improved shoot:root and sturdiness quotient, while timely budset correlates with earlier development of cold hardiness. The goal of this trial was to evaluate the efficacy of the PGRs Bonzi® and the more active Sumagic® in limiting late-season Douglas-fir top-growth.

Douglas-fir seed was sown in mid-February 2014 in 15 in^3 (250 ml), 60-cell Styroblock™ containers (Beaver Plastics) in an 80:20 peat:perlite medium. Four seed lots, representing four low-elevation seed zones of western Washington, were included in the trial in a randomized complete block design (blocked by seed lot).

Treatments (table 2) were applied with a backpack sprayer to whole Styroblocks™ (60 seedlings) within each seed lot

Table 2. PGR treatments applied to Douglas-fir container seedlings. With the exception of the untreated control, all treatments included the adjuvant Capsil at a rate of 0.10 oz/gal (0.75 g/L).

Treatment	Rate (ppm)	Application method	Number of applications
Control	NA	NA	NA
Bonzi®	50	Spray	One
Bonzi®	50	Spray	Two, 16 days apart
Bonzi®	100	Spray	One
Bonzi®	200	Spray	One
Sumagic®	10	Spray	One
Sumagic®	10	Spray	Two, 16 days apart
Sumagic®	20	Spray	One
Sumagic®	40	Spray	One

NA = not applicable. PGR = plant growth regulator.

(block) July 8, 2014, approximately 5 months after sowing. Spray treatments wetted the foliage just to the point of runoff. Seedling heights were measured every 2 weeks following treatment through the remainder of the growing season. Stem diameters were measured in mid-November at the end of the greenhouse growing season. ANOVA analyses were conducted using the R statistical package (R Core Team 2013). Treatment means were subjected to Tukey's HSD test and considered significantly different at the $p < 0.05$ level.

Results and Discussion

Trial 1: Bonzi® Applications on Red Alder Small Plugs for Transplant

All Bonzi® treatments produced a rapid and pronounced reduction in height growth of red alder plugs. PGR-treated seedlings also had noticeably thicker, darker green leaves with shorter stem internodes and smaller leaf areas (figure 2). Treatments, including the Capsil adjuvant, did not differ from stand-alone treatments and are dropped here for clarity. Four weeks after application, all Bonzi® treatments were significantly shorter than the control (figure 3). In early June (7 weeks after treatment), seedlings were transplanted to a bareroot field. At the time of transplant, significant height differences remained between controls and all other treatments (figure 3). No statistical differences were evident in stem diameter on any date or packout number by treatment (data not shown).

It was surprising that seedlings treated with the drench treatments (5 and 10 ppm) were the first to catch up to control seedlings in height. No significant height differences were evident between drenched and control seedlings by July 24,

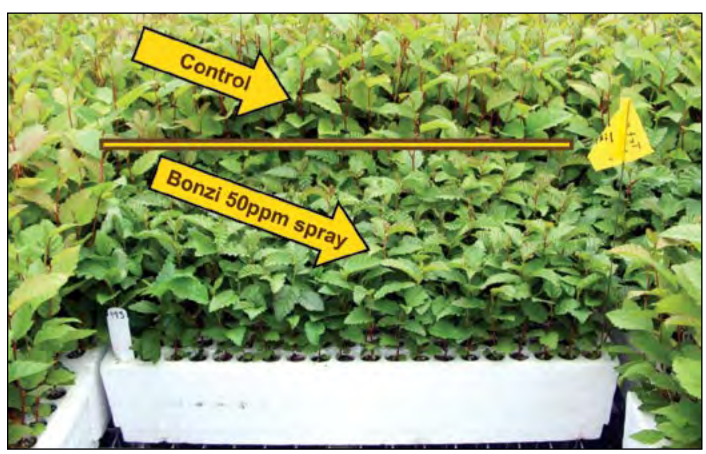

Figure 2. All Bonzi® plant growth regulator (PGR) treatments reduced red alder height growth, shortened internode distance, and decreased leaf area on new leaves before transplant. Leaves were noticeably darker green and thicker than those on the control seedlings. Photo taken 5 weeks after treatment. (Photo by Nabil Khadduri, 2014)

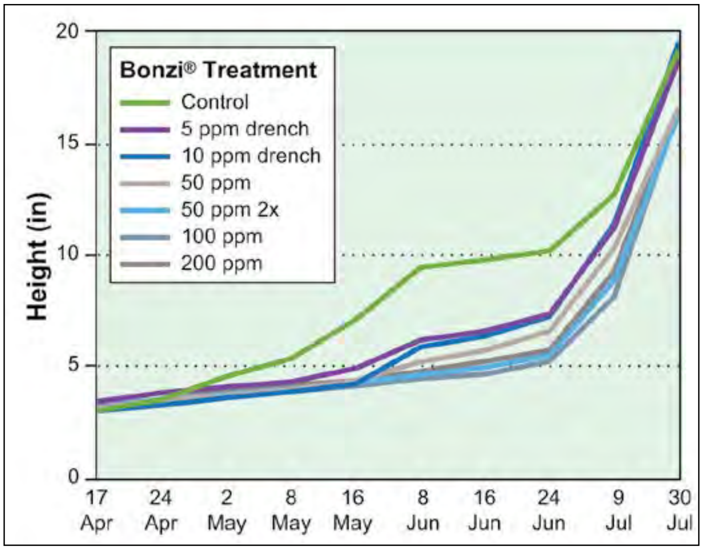

Figure 3. All Bonzi® treatments produced significantly shorter red alder seedlings compared with the control seedlings 4 weeks after application (mid-May) and at transplant (7 weeks after treatment; early June). By late July (14 weeks after treatment, 7 weeks after transplant), seedlings from the spray treatments were still significantly shorter than the control seedlings, but those in the drench treatments no longer differed significantly from the control.

but seedlings treated with spray treatments were still significantly shorter than control seedlings at this time. Even at lower application rates, drench treatments were expected to have a longer lasting effect because of the nature of uptake (Runkle 2012). Growing medium moisture at application was neither dry nor wet (approximately 80 percent gravimetric container weight). During application, there was roughly 10 percent leachate fraction of application volume, which rules out the possibility of overleaching. Perhaps rooting had not fully progressed for adequate uptake at the time of the drench application, resulting in the shorter duration of effect observed after transplanting.

By the end of the growing season (November 7), no significant differences were evident in height among treatments (data not shown). In the bareroot field, all treatments continued to be cultured operationally following mid-season transplant. Because red alder plugs are generally leggy and susceptible to drought stress at this intermediate transplant stage, operational watering for the first several weeks following transplant may have exceeded the needs of the more compact, thicker-leaved, PGR-treated seedlings. Irrigation, therefore, may have played a role in the elimination of treatment differences as the season progressed. Regardless of final morphology at the end of the season, nursery staff found the PGR-treated trees easier to lift and handle during mid-season transplant.

Spring 2015 operational experience demonstrated a cost of 8 cents per Styroblock™ (13.4 by 26.4 in [34.0 x 67.0 cm]) for a 50 ppm Bonzi® spray-to-wet application.

Trial 2: Bonzi® and Sumagic® Applications on Large Douglas-Fir Plugs for Outplant

All Sumagic® rates significantly reduced Douglas-fir seedling height growth (by roughly 25 percent) compared with nontreated control seedlings (figures 4 and 5A). Seedlings treated with Bonzi® consistently trended shorter than the control seedlings, although this effect was not statistically significant (figure 4). While all PGR treatments suppressed stem diameter growth compared with the control, higher rates of Sumagic® suppressed stem diameter growth more than Bonzi® applied at 100 and 200 ppm. Higher rates of Sumagic® suppressed stem diameter growth by roughly 30 percent compared with control seedlings (figure 5B). Only the 10 ppm Sumagic® treatment significantly reduced the seedling sturdiness quotient compared with control seedlings, a 13-percent reduction (figure 5C). In other trials, sturdiness quotients have been more consistently improved with the application of PGRs to Douglas-fir, but these were usually drench treatments (van den Driessche 1988, Wheeler 1987).

We chose to test only Bonzi® (paclobutrazol) and Sumagic® (uniconazole) spray applications on Douglas-fir seedlings because of the relative ease and lower cost of application compared with drench applications. Uniconazole is most effective when applied as a soil drench, because the chemical is best transported throughout the plant via xylem tissue rather than phloem tissue (Duck et al. 2004). It appears that drench treatments hold the greatest promise for reducing late-season growth of Douglas-fir seedlings and will be the focus of future research for this species.

Figure 4. Effect of Sumagic® spray treatments at 20 ppm (on left) compared with untreated control seedlings (on right) 8 weeks after treatment. (Photo by Nabil Khadduri, 2014)

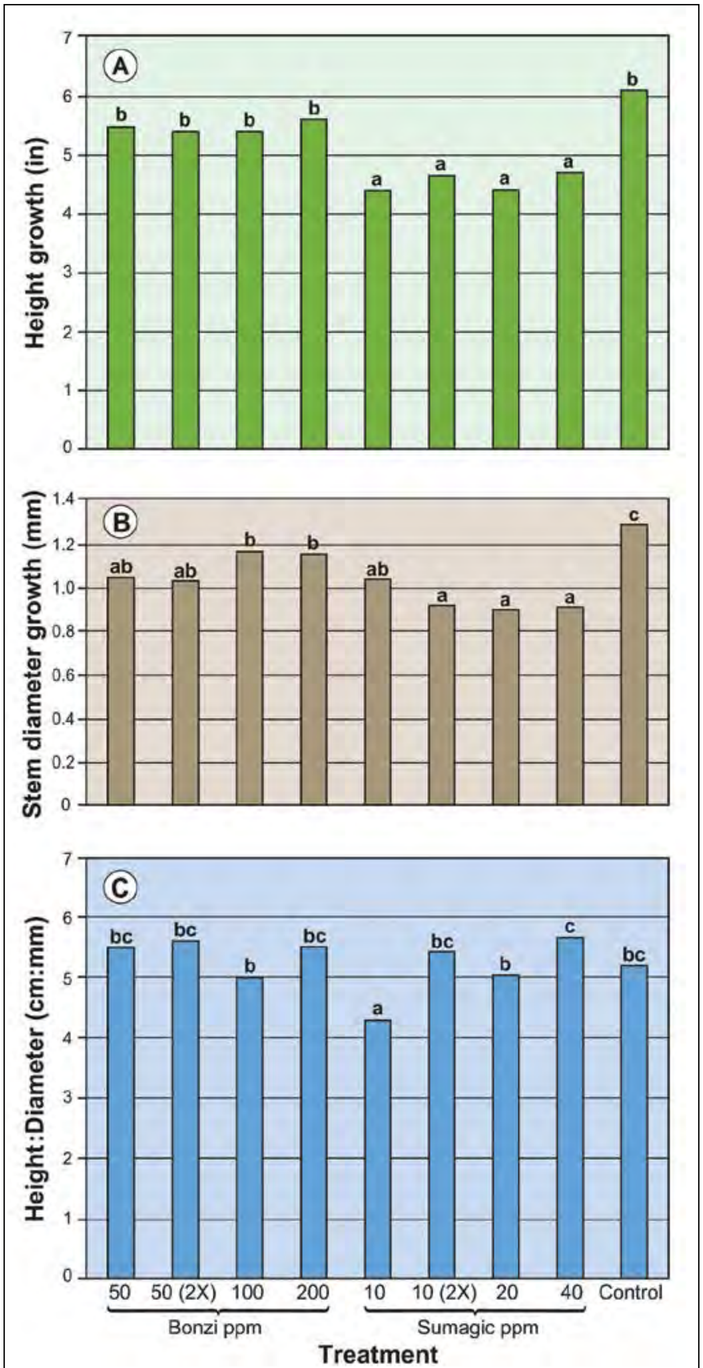

Figure 5. All Sumagic® spray rates significantly reduced height growth in Douglas-fir seedlings compared with those in the Bonzi® and control treatments (A). While all plant growth regulator (PGR) treatments suppressed stem diameter growth compared with the control, higher rates of Sumagic® suppressed stem diameter growth more than Bonzi® applied at 100 and 200 ppm (B). Only seedlings treated with 10 ppm Sumagic® had sturdier (lower height to stem diameter ratio) seedlings compared with the control seedlings. Bars with the same letter do not differ significantly at the $p < 0.05$ level.

Conclusions

Bonzi® effectively reduced early season height growth in red alder seedlings resulting in preferable morphology for operational handling during transplant. Height suppression from drench treatments unexpectedly wore off first, followed by spray treatments as the growing season continued. Both Bonzi® and Sumagic® sprays had a minor effect on Douglas-fir seedling morphology. While Sumagic® sprays reduced seedling height of Douglas-fir more than Bonzi® sprays and controls, these reductions were relatively small and were accompanied by an undesirable decline in stem diameter growth. Only the 10 ppm Sumagic® treatment produced a more balanced height to stem diameter ratio compared with control seedlings.

Because of the limited effect of PGR drenches on red alder and the increased cost of treatment, no drenches were applied to Douglas-fir plugs. In theory, PGR drenches should result in more profound and long-lasting growth regulation effects. Sumagic® drenches, in combination with other shutdown techniques, may yet prove to be an effective strategy in manipulating late-season Douglas-fir growth and will be further examined.

Address correspondence to—

Nabil Khadduri, Nursery Scientist, Webster Forest Nursery WADNR, PO Box 47017, Olympia, WA 98504; e-mail: nabil.khadduri@dnr.wa.gov; phone: 360–902–1279.

Acknowledgments

The author thanks Kila Benge, nursery technician, for her assistance and advice on these trials.

REFERENCES

Currey, C.J.; Lopez, R.G. 2010. Applying plant growth retardants for height control. Purdue Ext. HO-248-W.

Duck, M.W.; Cregg, B.M.; Fernandez, R.T.; Heins, R.D.; Cardoso, F.F. 2004. Controlling growth of tabletop Christmas trees with plant growth retardants. HortTechnology. 14(4): 528–532.

Lattimer, J.G.; Whipker, B. 2012. Selecting and using plant growth regulators on floricultural crops. Blacksburg, VA: Virginia Polytechnic Institute and State University. Pub. 430-102. http://pubs.ext.vt.edu/HORT/HORT-43P/HORT-43P-pdf.pdf. (23 December 2014).

R Core Team. 2013. R: a language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing.

Rietveld, W. 1988. Effect of paclobutrazol on conifer seedling morphology and field performance. In: Landis, T.D., tech. coord. Proceedings, combined meeting of the Western forest nursery associations. Gen. Tech. Rep. RM-167. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 19–23.

Runkle, E. 2012. Successful use of paclobutrazol. In: Greenhouse product news. http://flor.hrt.msu.edu/assets/Uploads/Useofpaclobutrazol.pdf. (23 December 2014).

Runkle, E. 2013. PGR application considerations. In: Greenhouse product news. http://www.gpnmag.com/sites/default/files/14_TechnicallySpeaking_GPN0513 FINAL.pdf. (23 December 2014).

Smith, D.B.; Lloyd, E.; O'Neill, G. 1994. Improving conifer seedling quality with CONFER®. In: Landis, T.D.; Dumroese, R.K., tech. coords. Proceedings, forest and conservation nursery associations. Gen. Tech. Rep. RM-GTR-257. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 281–284.

van den Driessche, R. 1990. Paclobutrazol and triadimefon effects on conifer seedling growth and water relations. Canadian Journal of Forest Research. 20(6): 722–729.

Wheeler, N.C. 1987. Effect of paclobutrazol on Douglas-fir and loblolly pine. Journal of Horticultural Science. 62: 101–106.