SOIL TEXTURE AND MOISTURE AVAILABILITY IMPACTS ON THE EFFICACY OF SOIL-APPLIED PACLOBUTRAZOL

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Abstract. Soil-applied paclobutrazol has been shown to reduce tree growth and pruning costs in trees occupying utility rights-of-way. Uptake and efficacy of soil applied chemicals is often influenced by soil texture and moisture status at the time of application. To test the influence of these conditions on paclobutrazol efficacy, Profile 2SC growth regulator (DowElanco) was applied at three rates (control, 0.3 or 0.6 ml ai/cm stem diameter) to potted sweetgum and white pine seedlings under factorial combinations of soil texture (clay loam or sandy clay loam) and water availability (drought or well-watered). Under well-watered conditions, terminal leader elongation was reduced 53 and 23% by paclobutrazol for sweetgum (*Liquidambar styraciflua*) and white pine (*Pinus strobus*), respectively. Sweetgum shoot elongation was responsive to paclobutrazol in the clay loam, but not the sandy clay loam soil. Sweetgum total leaf area and specific leaf area and white pine needle length were reduced by paclobutrazol treatments across water availabilities and soil textures. The results of this study suggest that drought during and following application of paclobutrazol does not reduce efficacy of this chemical. Further research is needed to clarify the impact of soil texture on paclobutrazol efficacy.

Introduction

Removal of tree branches near overhead utility lines represents a significant maintenance cost to electric and communication companies. Further, in residential areas, homeowners often find themselves needing to remove shade trees that have caused or may cause service losses to themselves or other line customers, a process that is both expensive in itself and often reduces property value.

Paclobutrazol is a plant growth regulator with demonstrated efficacy in retarding growth of several woody species through inhibition of gibberellin synthesis (8). Reduced height growth, and root and shoot biomass have been widely observed in deciduous tree species treated with paclobutrazol (2,12,13). However, growth reduction in coniferous species has been less consistent (3,9,11). An operational study reported less biomass production and reduced trimming and chipping times in red maple (*Acer rubrum*) and silver maple (*Acer saccharinum*) ten years following treatment with paclobutrazol (5), suggesting that single applications may provide long-term benefits.

Soil application of growth regulators offers a number of advantages over foliar application. These include greater sensitivity of roots relative to foliage to growth regulators as well as more precise placement of chemical (15). However, efficacy of soil herbicides and other growth regulating chemicals is often reduced by conditions that increase the amount of chemical adsorbed to soil particles such as high clay content and drought at the time of application (1,4,10). Commercial efforts to control crown growth of trees under utility lines would benefit from a better understanding of the potential impacts of soil texture and moisture conditions on tree response to paclobutrazol application.

The objectives of this study are to determine whether the efficacy of soil-applied paclobutrazol is influenced by soil texture or moisture status at the time of treatment.

Methods

This study was conducted in a greenhouse on the campus of Virginia Polytechnic Institute and State University in Blacksburg, Virginia. Seedlings of sweetgum (*Liquidambar styraciflua*) and white pine (*Pinus strobus*) obtained from the Virginia Department of Forestry were planted during March 1996 in 12.5 cm (5in.) diameter plastic pots in one of two soil types taken from the Ap horizons of two Virginia Piedmont soils representing clay loam and sandy clay loam textures (Table 1). Soils were mixed in a 1:1 ratio with white, washed sand to ensure adequate drainage. Following planting, seedlings were maintained under well-watered conditions until initiation of drought treatments and application of paclobutrazol.

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Table 1. Characteristics of soils used to determine effects of soil texture on paclobutrazol efficacy. Particle size distribution apply to the Ap horizon in both soils.

Soil Textural Class	Clay Loam	Sandy Clay Loam
Taxonomic Class	Fine-loamy, mixed, thermic Typic Hapludults	Coarse-loamy, mixed, thermic Typic Hapludults
% sand	34	60
% silt	33	15
% clay	33	25

Drought treatments began at the onset of budbreak, six and two weeks following planting for sweetgum and white pine, respectively. Water was withheld from droughted seedlings until the onset of leaf wilting in sweetgum and lowered xylem water potential in white pine. Fascicle mid-day xylem water potentials for droughted and well-watered white pine averaged -1.8 and -1.2 MPa, respectively. Averages are based on measurements taken at the end of three drought cycles on a total of 25 seedlings per drought treatment.

Over the course of the six week drought period, sweetgum and white pine were subjected to five and eleven drought cycles, respectively. Intermittent applications of water were provided during drought cycles when necessary to prevent mortality in visibly stressed individuals. Soil in which well-watered seedlings were planted was maintained visibly moist. Paclobutrazol (Profile 2SC, DowElanco) was applied as a soil drench at a rate of 0, 0.3 and 0.6 g a.i. per cm stem diameter one and four days following the initiation of drought treatments for sweetgum and white pine, respectively. Following the six week drought period, all treatments were well- watered and grown an additional seven and nine weeks for white pine and sweetgum, respectively.

Terminal leader elongation was measured periodically over the course of the study. All surviving seedlings of both species were harvested in mid-August, after shoot elongation had ceased. At the time of harvest, terminal leader length and number of stem units on the terminal leader were determined for white pine. Terminal leader length, number of leaves and total leaf area were determined for sweetgum. Foliage, stems, and roots were then separated and weighed following oven drying to a constant weight.

Data were analyzed for each species separately using analysis of variance in a completely randomized, full factorial design with six replicates of each treatment combination (total seedlings per species=72). Plant biomass excluding present year growth was used as a covariate when appropriate.

Table 2. Sweetgum and white pine terminal leader elongation (mm) in response to paclobutrazol application rate and water availability. Means within a species followed by the same letter are not significantly different ($p<0.05$).

Paclobutrazol Rate (ml ai/cm stem diam)	Sweetgum		White pine	
	Well-watered	Droughted	Well-watered	Droughted
control	31.8 a	19.0 b	117.7 a	52.0 c
0.3	15.8 b	15.3 b	90.4 b	62.3 c
0.6	14.2 b	17.4 b	90.2 b	56.8 c

Results and Discussion

Growth. Terminal leader elongation was reduced by paclobutrazol and droughted conditions (Table 2). Under well-watered conditions paclobutrazol reduced terminal leader elongation 53 and 23% averaged across application rates for sweetgum and white pine, respectively. Droughted conditions alone or with

Table 3. Sweetgum terminal leader elongation (mm) in response to paclobutrazol rate and water availability. Means followed by the same letter are not significantly different (p<0.05)

Paclobutrazol Rate (ml ai/cm stem diam)	Clay Loam	Sandy Clay Loam
control	27.5 a	23.8 ab
0.3	14.7 cd	16.5 bcd
0.6	11.3 d	20.3 abc

paclobutrazol also resulted in reduced terminal leader elongation. Paclobutrazol treatments did not result in reduction of growth beyond that induced by drought in either species. Due to the severity of drought, it is not possible to determine whether paclobutrazol efficacy in reducing present year shoot elongation is negatively impacted by drought at the time of application. However, paclobutrazol-induced reduction of peach seedling shoot elongation was unaffected by water stress as severe as 25% field capacity (4) suggesting that the severity of drought in our study masked paclobutrazol effects on stem elongation.

Total biomass of sweetgum was reduced 21 and 29% by the 0.3 and 0.6g/cm treatments, respectively. This response was driven to an almost equal extent by reductions in leaf and total root biomass (data not shown). Total white pine biomass was reduced 22% by drought but was unaffected by chemical applications. These results concur with those of a study using Douglas-fir (*Pseudotsuga menziesii*) and loblolly pine (*Pinus taeda*) seedlings (11).

Soil texture impacted sweetgum terminal leader height growth response to paclobutrazol. The 0.6 g/cm treatment produced a 59% growth reduction with an intermediate response for the 0.3 g/cm treatment in the clay loam soil (Table 3). Seedlings planted in the sandy clay loam did not show a significant height growth response to either rate of paclobutrazol. Terminal leader biomass showed a similar, but weaker response to the interaction between paclobutrazol and soil (data not shown). In white pine, no interaction between paclobutrazol and soil texture was observed.

Greater efficacy of paclobutrazol in the clay soil is difficult to explain and appears to be anomalous in light of chemical-soil interactions and observed differences in soil productivity. We would expect lower efficacy in the clay loam soil because higher clay content is usually associated with adsorption and reduced efficacy of soil applied chemicals (15). Further, our results show that untreated controls in the clay loam soil had greater shoot elongation than those in the sandy clay loam. This was unexpected since sandy clay loams are locally more productive for forest tree species (6).

Foliar Morphology. Paclobutrazol affected foliar morphology of both sweetgum and white pine. Sweetgum leaf area and specific leaf area were both reduced 13% by the 0.6 g/cm treatment relative to controls (Table 4). Although white pine leaf area was not determined, this species showed a similar response to paclobutrazol, a 21% reduction in needle length accompanied by a 11% (non-significant) reduction in leaf biomass. Needle length was also affected by water availability (26% reduction under droughted conditions) and soil texture with 16% shorter needles in clay loam versus sandy clay loam soils (data not shown). Sweetgum showed non-significant trends toward

Table 4. Effects of paclobutrazol on foliar morphology in sweetgum and white pine. Means within a column followed by the same letter are not significantly different (p<0.05).

	Sweetgum		White pine
Paclobutrazol Rate (ml ai/cm stem diam.)	Total leaf area (cm^2)	Specific leaf area (cm^2/g)	Leaf length (mm)
control	306.5 a	172.7 a	41.9 a
0.3	253.4 b	165.7 a	46.0 a
0.6	235.5 b	150.5 b	32.9 b

a paclobutrazol-induced reduction in number of leaves and total leaf weight. Reduced whole plant leaf area and specific leaf area have been widely reported responses to paclobutrazol (13,14).

Implications for Management. The data indicate that stem elongation is more sensitive to paclobutrazol than leaf morphology, suggesting that dose response relationships can be developed to reduce tree growth without otherwise adversely affecting foliar growth and the aesthetic properties of the crown. These data also suggest that dose response relationships are likely to be affected by soil texture in at least one species. Within the experimental conditions of this study, it cannot be determined whether drought at the time of soil application of paclobutrazol adversely impacts present year terminal leader elongation. However, paclobutrazol-induced changes in leaf growth under both droughted and well-watered conditions suggest that long-term efficacy is likely not reduced by drought during and following application. Because foliage is reduced in size, total area and/or specific area, future growth would likely be reduced due to decreased photosynthetic production in trees treated with paclobutrazol (7).

Although not compared statistically, sweetgum appeared to be more sensitive to paclobutrazol than was white pine. These differences may be in part due to differences in growth characteristics in these two species. The number of leaves produced in white pine is pre-determined by the number of primordia formed in the bud prior to the onset of the growing season. In contrast, sweetgum foliage is not pre-formed and is more likely to vary in response to growing season environmental conditions. Differences in species response and the impact of soil texture on paclobutrazol efficacy will require long-term studies under a range of site conditions and tree species so that more sophisticated management strategies may be developed.

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Résumé. L'application sur le sol de paclobutrazol a déjà été démontrée pour permettre de réduire la croissance des arbres ainsi que les coûts d'élagage des arbres présents dans l'emprise des lignes électriques. L'assimilation et l'efficacité des applications chimiques sur le sol sont souvent influencées par la texture et le degré d'hunidité du sol au moment de l'application. Afin de vérifier l'influence de ces facteurs sur l'efficacité du paclobutrazol, trois taux différents de paclobutrazol (zéro (contrôle), 0.3 ou 0.59 ml/cm de diamètre de tige) ont été appliqués à des semis de copalme d'Amérique (*Liquidambar styraciflua*) et de pin blanc (*Pinus strobus*) qui étaient cultivés en pot avec des combinaisons de substrats de texture variable (argile ou loam) et avec des taux d'humidité variable (sec ou bien arrosé). Sous de bonnes conditions d'arrosage, la croissance apicale était réduite de 53 et de 22% respectivement. La sécheresse n'a pas semblé affecter l'efficacité du paclobutrazol. La croissance de la pousse terminale du copalme était conséquente à l'effet du paclobutrazol lorsque le sol était argileux, mais pas dans le cas d'un sol loameux. La surface foliaire totale ainsi que la surface foliaire individuelle de la feuille du copalme, de même que la croissance en longueur des aiguilles du pin, étaient réduites selon la disponibilité en eau et la texture de sol rencontrées. Les résultats de cette étude suggèrent qu'une sécheresse durant et après l'application de paclobutrazol ne réduit en rien l'efficacité du produit. Des recherches complémentaires seront nécessaires pour clarifier l'aspect de l'impact de la texture du sol.

Zussammenfassung. Die Bodenapplikation von Paclobutrazol reduziert das Bauwachstum und die Pflegekosten im Bereich von Überland-versorgungsleitungen. Die Aufnahme und die Effektivität von Bodenherzididen wird oft durch die Bodentextur und die Bodenfeuchte zum Zeitpunkt der Anwendung beeinflußt. Um den Einfluß dieser Faktoren auf die Effizienz von Paclobutrazol zu testen, wurden 3 Raten von Paclobutrazol (Kontrolle, 0.3 und 0.59 ml ai/cm Stammdurchmesser) bei verschiedenen Bodentypen (Lehm oder Ton) und Wasserbedingungen (Trockenheit oder ausreichend grewässert) an getopften Sämlingen von Liquidamber (*Liquidamber styraciflua*) und Strobe (*Pinus strobus*) appliziert. Unter ausreichender Bewässerung wurde das Terminaltriebwachstum um 53 % bzw. 23 % reduziert. Trockenheit schien keinen Einfluß auf die Effizienz von Paclobutrazol zu haben. Das Washstum des Liquidambers zeigte in Tonboden Reaktionen auf das Mittel, aber nicht bei Lehmboden. Die totale Blattfläche und die einzelne Blattgröße des Liquidambers und die Nadellänge der Strobe waren unter allen Wasser- und Bodenbedingungen reduziert. Die Ergebnisse dieser Studie zeigen, daß Trockenheit während und nach der Applikation von Paclobutrazol die Effizienz nicht reduzieren. Um den Einfluß der Bodenbeschaffenheit zu bestimmen, sind weitere Untersuchungen erforderlich.