EFFECTS OF PLANT GROWTH REGULATORS, NITROGEN FERTILIZATION, AND IRRIGATION ON ELDARICA PINE SEEDLINGS

Amal O. Darwiche and Peter F. Ffolliott
School of Renewable Natural Resources, University of Arizona,
Tucson, AZ 85721

Abstract

Effects of applications of cytokinin-like and gibberellic growth regulators, nitrogen fertilizer, and irrigation on the development of containerized eldarica pine (Pinus brutia var. eldarica) seedlings was studied in a greenhouse for 13 weeks. All concentrations of growth regulators reduced nitrogen content of needles and dry weight of shoots; importantly, medium and high concentrations also adversely affected root collar diameter growth and shoot elongation. Nitrogen fertilization alone was not significant in its effect on seedling development, due probably to the nitrogen-rich nature of the potting medium. It is suggested that contentration is a critical factor when applying growth regulators, as phytotoxicity of seedlings can result at high rates.

Introduction

Use of containerized seedlings is common in establishing forest plantations in dry regions of the world. However, only better-developed seedlings can compete and thrive in these harsh environments, where nutrients and moisture and nutrients generally are limiting. To increase the chances of seedling survival, it may be desirable to enhance the development of propagules in the greenhouse before planting the seedlings in the field.

Attempts to improve developmental growth of seedlings in the greenhouse stage include exogenous applications of growth regulators and applications of mineral nutrients. For example, foliar applications of a cytokinin-like compound (BA) and gibberellic acid$_{4+7}$ (GA) in combination with fertilizers applied to foliage have been beneficial to the shoot and root growth of Quercus alba seedlings (Dixon et al. 1984). In another study, gibberellins were reported to enhance shoot growth of Pinus ponderosa seedlings when applied as a root-soak during seedling dormancy (Heidmann 1982). Other studies on effects of growth regulators on tree seedlings can be found in the literature (Al-Kinani et al. 1981, Bidwell 1974, Coffman and Loewenstein 1973, Jensen and Dochinger 1972). The study reported upon in this paper was undertaken to test the effects of foliar applications of growth regulators, nitrogen fertilization, and irrigation on the development of containerized eldarica pine (Pinus brutia var. eldarica) seedlings.

Description of Study

The study, which lasted 13 weeks, was conducted in a greenhouse

environment at the University of Arizona, Tucson, in the spring-summer of 1987. One-year-old eldarica pine seedlings were transplanted into plastic pots, approximately 20 l in size, containing a mixture of organic peatmoss, perlite, and vermiculite in proportions of 74%, 16%, and 10% (v/v), respectively. One-hundred ppm of elemental phosphorus (from monocalcium) and an equal amount of elemental potassium (from potassium sulfate) were added to each pot on the first day of the study. All pots were irrigated regularly thereafter, with a watering regime such that only the upper 1.25 cm of the potting medium was allowed to dry between waterings, avoiding moisture stress. Average daily air temperatures in the greenhouse ranged between 24° and 32° C.

A four-replicate split-plot experimental design was chosen. Nitrogen fertilizing treatments were the main-plot factor, while growth regulating treatments constituted the sub-plot factor, with 4 treatment levels in the former and 7 treatment levels in the latter. Nitrogen fertilizer was 50% urea and 50% ammonium nitrate, applied at 0, 10, 50, and 100 ppm in 2 l of tap water. The low concentration (10 ppm) was applied at each irrigation, while the medium and high concentrations were applied once every 4 weeks.

Growth regulators, specifically BA and a mixture of BA and GA (BA+GA), were applied only once during the study, on day 20. Seven treatment levels included a control and 500, 1,000, and 2,000 ppm of BA, and 500, 1,000, and 2,000 ppm of BA+GA, applied to the foliage in an aqueous solution using a portable sprayer-mister. Each seedling was sprayed from above, until the foliage was covered uniformly with a fine mist. Once dripping occured, spraying was stopped. This method of application had been used in other studies (Dixon et al. 1984, Lewis and Haun 1975). An acidifying-wetting agent was used in conjunction with growth regulators to ensure penetration through the thick waxy cuticle.

On the first day of study and periodically thereafter, root collar diameter and shoot elongation of each seedling were measured. Phytotoxicity was evaluated at the end of the study on a visual scale from (1) to (10), with (1) indicating a healthy seedling and (10) denoting death. Seedlings then were cut at the soil line, put into paper bags, and dried at 18° C. for 48 hours. Dried needles of each seedling were pulverized and digested in a block digestor for determination of nitrogen content by the Kjeldahl method (Bremner and Mulvaney 1982).

Analyses of variance were performed on all variables except phytotoxicity. Whenever study results were expressed as decimal ratios or ppm, an arc sine transformation was used. Orthogonal contrasts were employed to test for significant differences between BA and BA+GA. All differences reported are significant at the 5 percent level. Results of the statistical analyses performed are presented only qualitatively in this paper, however.

Results

The highest nitrogen contents of needles were associated with the no-growth-regulating treatment, with all other treatments resulting in lower nitrogen contents. Growth regulators were significant in their effects, while nitrogen fertilization alone was not. Orthogonal contrasts between BA and BA+GA at all levels also were not significant.

Dry weight of shoots at the end of study was lowered by all growth

regulating treatments. Nitrogen fertilization and its interaction with growth regulators were not significant, however. Low concentrations of both growth regulators and medium levels of BA+GA were less adverse in their effects than the other treatment levels. These results should be interpreted with caution, as the initial weight of the seedlings was unknown.

Growth regulators were significant in their effect on root collar diameter growth, expressed as a ratio of the increment to the root collar diameter at the start of study. Nitrogen fertilization did not affect root collar diameter growth. Interaction between the two factors, however, was significant.

No-growth-regulating and low nitrogen fertilizing treatments produced the greatest increase in root collar diameter growth. On the average, all growth regulating treatments, especially medium and high concentrations, were detrimental to root collar diameter growth. Moreover, a difference was detected between both growth regulators with a test of orthogonal contrasts, while the contrast between the low concentration of BA+GA and the no-growth-regulating treatment was not significant. This finding suggested that BA had a more adverse effect on root collar diameter growth than did BA+GA, although the latter was harmless when applied at low concentrations.

Results obtained for shoot elongation were similar to those found for root collar diameter growth. Only growth regulating treatments were significant, while both nitrogen fertilization and its interaction with growth regulators were not. Once again, BA+GA was less detrimental in its effects than was BA alone. Orthogonal contrast between the two growth regulators was significant. Contrast between the low BA+GA contentration and the no-growth-regulating treatments was not significant.

Visual evaluation of the seedlings showed that the no-growth-regulating treatment caused no phytotoxic effects, while high concentrations of both growth regulators resulted in phytotoxic symptoms. Other growth regulating treatments were intermediate in their phytotoxic effects. The effects of nitrogen fertilization were inconsistent.

Sixteen of the 112 seedlings initially transplanted into pots died by the end of study. One of the dead seedlings had received a medium concentration of BA, 10 received a high concentration of BA, and 5 received a high concentration of BA+GA. It seemed, therefore, that BA alone was more lethal at high concentrations than was BA+GA.

Nitrogen fertilization had no effect on seedling development throughout the study, except in its interaction with growth regulators on root collar diameter growth and nitrogen content of needles. This finding could be attributed to the nitrogen-rich potting medium. Another complicating factor might have been the assignment of nitrogen fertilization regimes to the main-plot in the split-plot experimental design; this could have lessened the precision of measurements of the main-plot effects (Gomez and Gomez 1984). Nitrogen fertilization might have shown a greater effect had another potting medium and a different experimental design been used.

On the other hand, both growth regulators showed significant effects on the growth parameters studied, although these effects do not appear to be favorable to seedling development. Neither growth regulator significantly

enhanced root collar diameter growth. However, in an earlier study, gibberellin alone and when applied with auxim had a significant effect on phloem and xylem production in needles of Pinus brutia (Ewers and Aloni 1985).

Discussion

Other studies have shown that major hormonal stimuli for cambial growth comes from auxins, and that cytokinins and gibberellins can enhance auxin action; but, gibberellins and cytokinins rarely have an effect on cambial activity by themselves (Pharis 1976). Increases in root collar diameter growth of Quercus alba seedlings from applications of BA and GA have been reported, although lower concentrations (50 ppm) were used (Dixon et al. 1984). Concentrations of growth regulators applied in the present study, especially those of BA, proved somewhat phytotoxic to the growth processes of eldarica pine seedlings. Perhaps, that is what contributed to the decreasing rate of root collar diameter growth.

Nitrogen fertilization alone and its interaction with the growth regulators tested were not significant in terms of shoot elongation of the eldarica pine seedlings. This result agreed with earlier work (Dixon et al. 1984), indicating that shoot elongation was not affected by nitrogen fertilization, and that although shoot height was enhanced by 500 ppm of GA, this response was decreased by increasing concentrations of BA. In the present study, the fact that shoot elongation was decreased by all concentrations of BA and a high concentration of BA+GA, while low and medium concentrations of the latter were not different in their responses than the control, could be attributed to antagonism between cytokinins and gibberellins. The latter are known to enhance apical dominance, while the former are known to decrease it (Bidwell 1974).

Had GA been applied alone, an increase in shoot elongation likely would have resulted, as demonstrated in a previous study (Al-Kinani et al. 1981). Moreover, it is felt that the present study might have been terminated prematurely, just as shoot elongation in the BA+GA treatments had started to increase at a rapid rate. It would have been interesting to determine whether this sudden increase in shoot elongation was significant.

Nitrogen content of the needles was lowered by all growth regulating treatments, which could have been due to a redistribution of photosynthates and other nutrients within the seedlings. Both cytokinins and gibberellins are known to alter the normal pattern of photosynthate allocation (Dixon et al. 1984, Little and Loach 1975).

Some investigators have indicated that use of cytokinins and gibberellins results in a decrease in dry weight (and, at times, green weight) of seedlings (Bilan and Kemp 1962, Roberts et al. 1963), while others reported an increase (Dixon et al. 1984). However, the observed change in dry weight could be a function of the concentrations of growth regulators used, as reported elsewhere (Bilan and Kemp 1962, Dixon et al. 1984).

Conclusions

The concentrations of BA and BA+GA used in this study do not appear to have a positive effect on the development of eldarica pine seedlings. This conclusion was attributed largely to excessively high concentrations, which

caused phytotoxicity in some seedlings. In future studies, it would be interesting to experiment with lower concentrations that are applied more frequently. Concentration, therefore, seems to be one of the more important considerations when applying growth regulators to promote development of tree seedlings. Timing also is an important factor in applying exogenous growth regulators. The fact that applying more than one hormon substance had less adverse effects on seedling development than did the application of only one deserves further examination. Future studies should use nitrogen-poor potting media if the nitrogen fertilizator-growth regulator interaction is to be further investigated.

References Cited

Al-Kinani, A. I., Y. Abdullah, and M. Abdullah. 1981. Effects of gibberellic acid on the growth of Pinus brutia seedlings and of cycocel on Eucalyptus camaldulensis seedlings. Mesopotamia Journal of Agriculture 16:75-99. (Arabic)

Bidwell, R. G. S. 1974. Plant physiology. MacMillian Publishing Co., Inc., New York, 643 p.

Bilan, M. V., and A. Kemp. 1962. Effect of gibberellin on growth and development of loblolly pine seedlings. Journal of Forestry 60:391-394.

Bremner, M. G., and C. Mulvaney. 1982. Nitrogen - total. p. 595-624. In: Page, A. L., R. H. Miller, and D. R. Keeney (eds.). Methods of soil analysis. Part II - Chemical and microbiological properties. American Society of Agronomy, 1,159 p.

Coffman, M. S., and H. Loewenstein. 1973. Growth regulators stimulate ponderosa pine seedling development. Tree Planter's Notes 24:23-25.

Dixon, R. K., H. Garrett, and G. Cox. 1984. Response of white oak seedlings to foliar applications of fertilizer and plant growth regulators. HortScience 19:523-524.

Ewers, F. W., and R. Aloni. 1985. Effects of applied auxin and gibberellin on phloem and xylem production in needle leaves of Pinus. Botanical Gazette 146:466-471.

Gomez, K. A., and A. Gomez. 1984. Statistical procedures for agricultural research. John Wiley & Sons, Inc., New York, 680 p.

Heidmann, L. J. 1982. Effect of selected natural and synthetic growth regulators on the growth of ponderosa pine seedlings. Forest Science 28:156-160.

Jensen, K. F., and L. Dochinger. 1972. Gibberellic acid and height growth of white pine seedlings. Forest Science 18:196.

Lewis, A. J., and J. Haun. 1975. Chemical pinching of "hetzi" holly with EHPP. HortScience 10:180-181.

Little, C. H. A., and K. Loach. 1975. Effect of gibberellic acid on growth and photosynthesis of Abies balsamea. Canadian Journal of Botany 53:1,805-1,810.

Pharis, R. P. 1976. Probable roles of plant hormones in regulating shoot elongation, diameter growth and crown form of coniferous trees. In: Cannell, M. G. R., and F. T. Last (eds.). Tree physiology and yield improvement. Academic Press, London, pp. 291-306.

Roberts, R., J. Kramer, and C. M. Carl, Jr. 1963. Long-term effects of gibberellin on the growth of loblolly pine seedlings. Forest Science 9:202-205.