Keynote

Challenges and Predictions in Artificial Regeneration

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Abstract

We owe much to the dedicated regeneration professionals of the 20^{th} Century who helped make their visions of the future a reality. Due to their efforts, we now benefit from significant improvements in nursery technology, genetics and site preparation methods. No doubt our profession will also see many changes during this century. Future advances will depend, in part, on the priorities we establish today. We can rest assured that new and unforeseen discoveries will shape our future in ways we cannot easily predict. The following paper provides a few challenges that our profession should consider. In addition, some predictions regarding regeneration practices are provided.

Keywords

dogmas, plantations, economics, optimum seedling, tree planting.

Introduction

During the 20^{th} century, technological advances occurred in both nursery management and artificial regeneration techniques. For example, early sowers were designed for agriculture but now we have vacuum sowers that are designed especially for tree nurseries. We have established seed orchards to produce improved genotypes. Various chemicals are used to reduce the loss of seeds and seedlings to pests and weeds. Some chemicals are now applied to seedbeds to reduce soil erosion. Use of these chemicals reduces production costs. As a result, the number of people required to produce a crop of seedlings is much lower today than 100 years ago. At some nurseries, the ratio of people to seedlings is 1 to 4 million. We also now have various sizes and types of containers that can be used in the production of hard to establish species. In addition, new methods of vegetative propagation are being developed. In the area of tree planting, we know more about seedling storage and we use improved storage facilities. For flat or sloping land, we now have several types of machine planters. For steep or rough land, we now have specially made shovels, dibbles, planting bars and augers.

Challenges

With all these advances, what challenges will the profession meet during the 21st Century? To be sure, nursery and plantation managers will be faced with new problems and opportunities. The following are some challenges that need consideration.

Integrating nursery management with stand establishment

During the last century, many organizations viewed the nursery as a cost center while tree improvement and site preparation activities were viewed as profit centers. As a result, the cost of seedlings was often minimized while benefits from extra site preparation costs were not questioned. For example, Paul Rudolf (1937) said "Many foresters, not fully understanding the need for sturdy, hardy, well-balanced planting stock, still worship the fetish of low initial planting costs. It is known that increasingly better stock is required as conditions become more severe, and that transplanting and certain other nursery treatments produce sturdier, better-balanced stock. Such measures, however, increase the cost of stock, so there is often a failure to put two and two together." There is still a need for more company leaders to put two and two together.

For example, I told one organization they could save $75/ha in site preparation costs by simply increasing row spacing and decreasing inter-row spacing. The reply was…oh we can't do that, our operational foresters would not accept the change. I then suggested they spend an additional $32/ha by investing in large-diameter seedlings. The reply this time was…oh we can't do that, it would cost too much. Accepting both recommendations would have saved the organization $33/ha but the idea that the nursery should be treated as a cost center was too ingrained a concept to overcome. This segregated approach to regeneration still exists in many organizations. The challenge now is to educate CFOs to the economic advantage of having an integrated regeneration program. Such a program would combine "optimal" nursery stock with improved genotypes and appropriate site preparation treatments (South et al. 1993; South et al. 1995; South and Mitchell 1999; South et al. 2001).

Reducing false dogmas

False dogmas have been with us for millennia and will continue to suppress progress during the next 100 years. In order to remove these impediments to knowledge, we need more people who are willing to ask "where are the data?" A challenge for the future is to conduct more hypothesis testing of strongly held myths. The following are a few examples of dogmas that exist in our profession.

Planting depth dogma

This dogma says that for all species and for all sites, seedlings should be planted with the root-collar at the groundline. However, for survival there is an interaction between species, planting depth and site (South 2001). On sites where survival is affected by a lack of soil moisture, some pine species will benefit from planting the root-collar 10 to 15 cm below the ground. On some sites, the root-collar of some trees actually moves upwards with time as the root volume increases and displaces soil below the tree.

Top-pruning dogma

This dogma says that for all species, proper top-pruning of seedlings in the nursery is bad. This dogma is based on appearance and intuition. It is not based on the many studies with conifers that show either improvement in survival due to top-pruning (South 1998) or no detrimental effect (Duryea 1987; South 1996b). Like any cultural practice, improper top-pruning can have negative effects on field performance.

Terminal bud dogma

This dogma says that all other things being equal, the presence of a well-formed terminal bud is critical for survival and long-term growth (regardless of species). This dogma is based mainly on appearance and intuition. Some say transplants (worth $0.25 or more) "probably should be culled" if they do not have a winter-resting bud (Cleary et al. 1978). Others say that for some conifers, "loss of the terminal bud means the tree remains a cabbage for as long as 3-5 years" (Tinus 1974). However, data are lacking to show that removal of a terminal bud at time of transplanting makes any difference in either survival or long-term performance. In fact, Wakeley (1949) found no short-term effects and, therefore, questioned the validity of morphological grades that included the presence of a terminal bud. Also, many container-grown seedlings do not have well-formed terminal buds at time of transplanting and yet they often have high survival rates. In fact some species do not form terminal buds in the nursery and they seem to survive and grow quite well after transplanting.

Root washing dogma

Some recommend washing roots to remove excess soil prior to storage (DeYoe 1986). However, washing pine roots can reduce seedling survival on some sites (Alvarez and Linderman 1983; Carey et al. 2001). Mullin (1978) even warns against dipping pine roots in water. This effect might not be noticed when soil moisture is adequate but the effect can be expressed on sandy soils where moisture is a limiting factor for survival.

Relative growth rate dogma

Regeneration researchers have used the mean relative growth rate method of growth analysis for decades. This dogma has persisted because many authors have extolled the "superiority" of this method of growth analysis without questioning its validity. The claim that mean relative growth rates are independent of differences in initial tree size has been proven wrong for many types of growth curves (South 1993). Typically, small seedlings have higher mean relative growth rates than larger seedlings (when both are growing according to the same non-exponential growth curve) and this can lead to confusion and incorrect conclusions (South 1993). It will be interesting to see how many forestry journals in the 21st Century continue to accept papers that promote this dogma.

Adding spores in the planting hole dogma

When outplanting bare-root seedlings, some regeneration researchers recommend adding mycorrhizal spores to the planting hole. However, I know of no published research to show this practice (which might cost $0.10 or more per seedling) is of any benefit. In fact, in some cases this practice could be detrimental (Alvarez and Trappe 1983). Attempts to improve survival by adding ectomycorrhizal spores at time of planting have failed to show any benefit (Pilz and Znerold 1986, South and Skinner 1998). Simply adding soil to the planting hole may prove to be more beneficial (Amaranthus and Perry 1989; Colinas et al. 1994).

Maintaining regeneration research

In the last century there were a number of nursery and regeneration researchers employed by state and federal governments and industry. This number has dwindled and is now reaching a low level. Although we are still in need of answers to operational problems, this area of research no longer attracts as many bright, energetic students as it did 40 years ago. Some industry funded graduate assistantships (like the Union Camp Assistantship) no longer exist due to company mergers. A challenge for the future is to renew some of the old ways of attracting young, bright researchers to the tree planting profession.

Quantifying area in plantations

Estimates for plantation acreage are available for the eastern U.S. but not for several western states. I estimate that in 1997, there were 2.4 million ha of plantations in Oregon but some may doubt an estimate based solely on annual planting reports (1953 to 1997). Since some newspaper articles have overestimated the amount of tree plantations, I predict knowing the amount of plantations will be politically important. Knowing which stands were planted or seeded will become more important if the general public decides that wood from certified plantations is preferred to wood harvested from certified natural forests.

Getting researchers to consider economics

Researchers conducting basic research usually do not need to consider costs. In contrast, regeneration researchers who conduct applied research should consider the costs of their treatments. Unfortunately, many researchers say that "Money is not the issue here" (Moreno 2000). For example, I remember a meeting where a researcher told the manager of a container nursery to reduce the application of nitrogen since it affected the growth of introduced mycorrhiza. The manager ignored the recommendation for two reasons. The cost of the mycorrhizal treatment far exceeded the cost of the fertilizer and the reduction in nitrogen produced low quality seedlings. Researchers make all kinds of economic decisions at home but some seem to lose this ability when at work. A challenge for the future is to get applied researchers to consider economics in their work.

Developing an economical method of vegetative propagation of pines

The use of vegetative propagation is a common nursery management practice for some easy to root tree species. Although about 30% of the nursery stock of *Pinus radiata* is vegetatively propagated in New Zealand, pines in general are not easy to root. For example, over 50 years ago, Duffield and Stockwell (1949) said that "Vegetative propagation,… has not yet reached a stage of development for pines which would permit economical propagation of forest planting stock except in New Zealand, where it is practiced with Monterey pine." A challenge is to make this statement invalid by the year 2050.

Convert to the metric system

Philip Wakeley (1927) challenged U.S. foresters to adopt the metric system. Unfortunately, his challenge was ignored and, therefore, we are still working with ounces, cords, chains and two kinds of gallons. Mistaking ounces (liquid) with ounces (weight) can result in incorrect pesticide applications. Once the U.S. government finally decides to make the conversion (to increase international trade and to reduce the potential for embarrassing and costly mistakes like the Mars probe), nursery managers and foresters will be challenged to convert to metric units. Since nursery managers and foresters in Australia, Canada, Scotland, and South Africa have already made the switch, I am sure that our professionals will also meet this challenge.

Predictions

It is relatively easy to make predictions but the difficult part is to make accurate predictions. Even so, I will take a professional risk and make some predictions for artificial regeneration. But to take an easy way out, I will not include dates with most of my predictions. That way, I can take credit for those that come true and simply say "time will tell" for the others.

Use of "optimum" seedlings will increase

A "plantable" seedling can be just slightly larger than a "cull" seedling. A "target" seedling helps to ensure regeneration success and is the type the nursery would like all seedlings to be like. An "optimum" seedling is one that will achieve the goals for initial survival and growth while minimizing overall reforestation costs (South and Mitchell 1999). Before we can define an "optimum" seedling, a cost analysis is required that includes information from a matrix of site preparation methods and stock types (this information is usually lacking). For economic reasons, I predict some companies with limited regeneration budgets will reduce investments in expensive mechanical soil cultivation while increasing their use of "optimum" seedlings.

Annual wood use will double

Before the end of the 21st century, the population of the U.S. will exceed 550 million people. Due in part to population growth and to energy requirements for alternative building materials, I predict annual consumption of wood in the U.S. will eventually exceed 13 million cubic meters. Much of this wood will come from plantations (South 1999).

Pressures from the urban population will increase

On both an absolute and percentage basis, the urban population will increase; shifting political power to the urban voter. This will result in increased pressures on rural lands as land-use-planning becomes increasingly popular with the urban voter. Regeneration tools such as fire, clearcutting, and even some types of tree planting will be determined by the vote of non-landowners.

Bioenergy farms

I believe that wood is a more sustainable source of energy than fossil fuels. Therefore, in a letter to the editor of the "The Economist" (March 27, 1999 issue), I made a $1,000 bet that by the year 2010, the price of a barrel of oil would be greater than $12 (in 1999 dollars). Although some believe the development of "free" energy (Manning 1996) will drive the price of oil to $5 a barrel, no economist has taken me up on my wager. It is much easier to claim that oil prices will continue to decline (in constant dollars) than to back up such claims with cash. In any event, I believe Shell Oil Company's predictions regarding future trends in energy sources (The Shell Report 2000). This energy company is investing in reforestation and believes that energy from biomass will make up about 8% of the world's energy by 2025. I predict the demand for such "green" energy will increase the demand for planting stock.

Miniature GPS units will aid tree planting

The accuracy of GPS units will increase and their size and cost will decrease. This will allow each tree planter to have a GPS unit. At the end of each day the units are downloaded and missed areas and errors in spacing are identified. The planting contractor uses this information to fill in the missed areas and to help new planters improve their between-row and inter-row spacing. This technology is already being used during the application of fertilizers and herbicides.

Alternate rows will be used for some restoration projects

Mixed species plantations are becoming more common in the West but are rare in the South. I predict that some restoration projects for longleaf pine (*Pinus palustris*) will adopt a mixture of species using alternate rows of loblolly pine (*P. taeda*) or slash pine (*P. elliottii*). The alternate rows will be removed at the first thinning (at 13 to 16 years). When there is a seed shortage, this practice would result in twice the amount of area restored to longleaf (when compared to 100% pure longleaf plantings).

Use of certain container types will increase toppling

Use of certain types of containers can result in stability problems of young stands (also know as toppling). Toppling of container-grown stock has been observed in Canada, New Zealand, Sweden, South Africa, and recently in Alabama and North Carolina. In some cases, the problem appears to be related to root spiral and lateral roots forced to grow in a downward pattern. In other cases, it appears to be related to a lack of a strong taproot. The problem may not be noticeable in areas not vulnerable to high winds. But due to hurricanes and other high wind events, I predict toppling of some container-grown species will become more of a problem in the future.

Use of certain types of belt-lifters will decrease

The use of certain types of belt-lifters can cause a reduction in survival and growth of pine seedlings (Barnard et al. 1980; Greene and Danley 2000). This likely results from a loss of fine roots during the lifting process. Stripping of roots can reduce root growth potential and survival (Marx and Hatchell 1986; South and Stumpff 1990). Due, in part, to an increasing concern for seedling quality, changes in lifting method are predicted, especially when lifting large-diameter stock.

The internet will change the marketing of seedlings

In the past, there were basically two types of customers for tree seedlings. Large-lot customers would make contracts with nursery managers prior to sowing. Customers needing small-lots would place orders for seedlings a short time before shipping. As a result, the nurseries without large-lot contracts often sowed seed based on a speculation of the market. I predict some nurseries will develop internet sites to encourage small-lot customers to order seedlings before sowing (South 1996a). These nurseries ill provide a range of prices that are depenent, in part, upon (1) use of a binding contract; (2) the deposit amount; and (3) how early the seedlings are ordered. Over time, the price information provided on the web sites will increase the efficiency of nurseries by reducing the amount of seedbeds sown on speculation.

Tree planting guides will be rewritten

Many tree planting guides are written by simply modifying previous tree planting guides. As a result some recommendations can be traced back to 19th century practices in Europe. Most guidelines promote old dogmas by not citing any new research findings. In the future, tree planting guides will avoid recommending unnecessary practices (based solely on intuition) and will instead cite references to support the prescribed planting techniques.

Triad planting pattern

Some future stock types will be more expensive (due to high demand or to high production costs) than traditional planting stocks. Some who choose to use the more expensive stocks my decide to use a "triad" pattern of planting where the expensive stock type is planted between two less expensive "trainer" rows. The spacing will look like this [… … … … …] so it will be easy to identify the middle row that contains the expensive stock type. Thinning will be concentrated in the "trainer" rows while final harvest will be mainly on the center row. I have seen this method of planting used for sawtimber production in New Zealand.

Conclusions

The future will be different from what we can imagine. Hopefully, tree planting will continue to be an important human activity in the future. I expect that wood production from tree plantations will be an increasingly important source of fiber as the U.S. population doubles. Meeting some of the challenges put forth in this paper will take lots of work.

Literature Cited

Alvarez, I.F. and R.G. Linderman. 1983. Effects of ethylene and fungicide dips during cold storage on root regeneration and survival of western conifers and their mycorrhizal fungi. Canadian Journal of Forest Research 13:962-971.

Alvarez, I.F. and J.M. Trappe. 1983. Dusting roots of *Abies concolor* and other conifers with *Pisolithus tinctorius* spores at outplanting proves ineffective. Canadian Journal of Forest Research 13: 1021-1023.

Amaranthus, M.P. and D.A. Perry. 1989. Rapid root tip and mycorrhiza formation and increased survival of Douglas-fir seedlings after soil transfer. New Forests 3:259-264.

Barnard, E.L., C.A. Hollis, and W.L. Pritchett. 1980. A comparative evaluation of seedling quality in commercial forest nurseries in Florida. In: Proceedings of the 1980 Southern Nursery Conference; 1980, September 2-4; Lake Barkley, KY: 34-41.

Carey, W.A., D.B. South, M. Williford, and J.R. Britt. 2001. Washing seedling roots reduces vigor of loblolly pine seedlings. Southern Journal of Applied Forestry (In Press).

Cleary, B.D., R.D. Graves, and P.W. Owston. 1978. Chapter 6: Seedlings. In: Regenerating Oregon's Forests. Oregon State University Extension Service, Corvallis.

Colinas, C., D. Perry, R. Molina, and M. Amaranthus. 1994. Survival and growth of *Pseudotsuga menziesii* seedlings inoculated with biocide-treated soils at planting in a degraded clearcut. Canadian Journal of Forest Research. 24: 1741-1749.

DeYoe, D.R. 1986. Guidelines for handling seed and seedlings to ensure vigorous stock. Forest Research Lab. Oregon State University. Corvallis. Special Publication 13. 24 p.

Duffield, J.W. and P. Stockwell. 1949. Pine breeding in the United States. In: Trees: Yearbook of Agriculture 1949. U.S.D.A., Government Printing Office: Washington, D.C.

Duryea, M.L and S.K. Omi. 1987. Top pruning Douglas-fir seedlings: morphology, physiology, and field performance. Canadian Journal of Forest Research 17:1371-1378.

Greene, T.A. and S.T. Danley. 2000. Effect of lifting method on first-year growth of loblolly pine seedlings. In: Proceedings of the Tenth Biennial Southern Silvicultural Research Conference; 1999, February 16-18; Shreveport, LA: 334-338.

Manning, J. 1996. The coming Energy Revolution: the search for free energy. Avery Publishing Group. 230 p.

Marx, D.H. and G.E. Hatchell. 1986. Root stripping of ectomycorrizae decreases field performance of loblolly and longleaf pine seedlings. Southern Journal of Applied Forestry. 10:173-179.

Moreno, R. 2000. New stocktypes and advances in the container industry: a grower's perspective. In Advances and Challenges in Forest Regeneration. D. Haase, ed. College of Forestry, Oregon State University, Corvallis.

Mullin, R.E. 1978. Root exposure, root dipping, and extended spring planting of white pine seedlings. The Forestry Chronicle 54(2):84-87.

Pilz, D. and R.M. Znerold. 1986. Comparison of survival enhancement techniques for outplanting on a harsh site in the western Oregon Cascades. Tree Planters' Notes 37(4): 24-28.

Rudolf, P. 1937. Lessons from past forest planting in the Lake States. Journal of Forestry 35:72-76.

South, D.B. 1993. Testing the hypothesis that mean relative growth rates eliminate size- related growth differences in tree seedlings. New Zealand Journal of Forestry Science. 21:114-164.

South, D.B. 1995. Relative growth rates: a critique. South African Forestry Journal 172:43-48.

South, D.B. 1996a. Adapting JIT principles to nursery production. Tree Planters' Notes. 47(1):1-2.

South, D.B. 1996b. Top-pruning bareroot hardwoods: a review of the literature. Tree Planters' Notes 47(1):34-40.

South, D.B. 1998. Needle-clipping longleaf pine and top-pruning loblolly pine in bare-root nurseries. Southern Journal of Applied Forestry 22:235-240.

South, D.B. 1999. How can we feign sustainability with an increasing population? New Forests 17: 193-212.

South, D.B. 2001. A review of the "pull-up" and "leave-down" methods of tree planting loblolly pine. Tree Planters' Notes (In Press).

South, D.B., and R.J. Mitchell. 1999. Determining the "optimum" slash pine seedling size for use with four levels of vegetation management on a flatwoods site in Georgia, U.S.A. Canadian Journal of Forest Research. 29:1039-1046.

South, D.B., R.J. Mitchell, B.R. Zutter, J.M. Balneaves, B.L. Barber, D.G. Nelson, and J.B. Zwolinski. 1993. Integration of nursery practices and vegetation management: economic and biological potential for improving regeneration. Canadian Journal of Forest Research. 23:2083-2092

South, D.B., J.L. Rakestraw, and G.A. Lowerts. 2001. Early gains from planting large-diameter seedlings and intensive management are additive for loblolly pine. New Forests (In Press).

South, D.B. and M.F. Skinner. 1998. Nursery stock and field fertiliser application affect early performance of Pinus radiata on a phosphorus-deficient site in Northland. New Zealand Journal of Forestry Science 28(3):361-372.

South, D.B. and N.J. Stumpff. 1990. Root stripping reduces root growth potential of loblolly pine seedlings. Southern Journal of Applied Forestry. 14:196-199.

South, D.B., J.B. Zwolinski, and H.L. Allen. 1995. Economic returns from enhancing loblolly pine establishment on two upland sites: Effects of seedling grade, fertilization, hexazinone, and intensive soil cultivation. New For. 10:239-256.

Tinus, R.W. 1974. Characteristics of seedlings with high survival potential. pp. 276-282. In: Proceedings of the North American Containerized Forest Tree Seedling Symposium. Great Plains Agricultural Council Publication No. 68.

Wakeley, P.C. 1927. American forestry and the metric system. Journal of Forestry 25:966-980.

Wakeley, P.C. 1949. Physiological grades of southern pine nursery stock. In: Proceedings of the Society of American Foresters ; 1948, December 16-18; Boston, MA: 311-322.