Three plantation establishment models for pine

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Abstract

This paper provides a brief overview of three establishment models for pine. These models can be important tools for guiding landowners' decisions when selecting establishment practices. Currently, only a few plantation establishment models have been developed. Three models currently available for pine include *CNIIGM for Pinus radiata* in New Zealand, Plant-PC for *P. banksiana* in Ontario, and Ptaeda2v for *P. taeda* in the southern United States. The CNIIGM is an establishment model that was developed from 17 establishment studies. Plant-PC (Version 2.2) was developed using regression equations fitted to data from 9 pine plantations. Ptaeda2v was developed from a single-tree growth and yield model (Ptaeda2) that simulates growth starting at age 8 years. These programmemes can be used to address questions such as "should I invest in either weed control or larger planting stock?"

Keywords: establishment, site preparation, seedling quality, weed control, growth and yield

Introduction

A recent survey of software users indicated that 63% (17 out of 27 respondents) were involved with plantation establishment and management analyses (Bigsby 2000). Plantation establishment models are rarely used in New Zealand (none were listed in the survey) but growth and yield programmes are commonly used when making management decisions. Standpak and most growth and yield models in the public-domain do not permit the user to examine the effects of various establishment practices on initial growth. However, a holistic forest management system should include establishment models as an aid to optimizing stand establishment costs (Kaila 1991; Mason 1991). Plantation establishment models allow the user to compare the predicted outcomes of using various combinations of establishment practices such as use of herbicides, fertilisation, mechanical site preparation and use of large-diameter planting stock. In the absence of establishment models, managers are forced to make establishment choices based on tradition, personal experience, research reports and the advice of chemical distributors. However, in some cases, traditional establishment practices may not provide the best economic returns (South and Mitchell 1999; South et al. 2001).

Establishment models can be classified as either inductive, deductive or a hybrid. An inductive model begins with data from establishment trials and then builds its conclusions based on the biases inherent in the original data. Deductive establishment models are based on theoretical relationships (based on the experiences and opinions of regeneration experts). A hybrid model is based on some data and some theory.

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Today, there are only a few establishment models in the public domain. Some model seedling survival (Hitch et al. 1996) while others model survival and growth (Payandeh and Wood 1988; Kaila 1991). This paper reviews three software programmes, two are from North America.

Central North Island Initial Growth Model (CNIIGM)

The first version of this establishment model was based on 27 establishment experiments (Mason 1992). This inductive model provides output for mean survival, mean height, mean basal area/ha, and expected distributions of height and DBH (outside bark) five years after planting. The independent variables include altitude, initial stocking, two mechanical site preparation methods (ripping and mounding), weed control and fertilization with diammonium phosphate (DAP) at planting. Version 2 is based on 17 experiments and includes two seedling variables (initial groundline diameter and quality of seedling handling). The programme can be downloaded from the web at: www.fore.canterbury.ac.nz/igmv2.exe . As far as I know, this establishment model is the first to include these important variables (Table 1).

A unique aspect of this model is that groundline diameters (GLD) can be varied from 3-mm to 9-mm. For all elevations, survival is positively related to GLD. However, the effect of GLD on diameter distribution at year 5 is minimal on highly productive sites (180 m elevation) but is magnified on less productive sites (760 m elevation). On some sites there was an interaction between GLD and weed control (Mason et al. 1996) and this is reflected in the model. GLD was more important when seedlings were more stressed. Users should note that this model was a preliminary investigation and therefore some management factors affecting initial plantation development are not included in the model. Stock used in the experiments was from climbing select seed, or from open-pollinated seed orchard seed (GF ranking 6 to 15). Independent validation of the model with more improved genotypes showed that the model represented growth of those genotypes well (Mason 2001). The fertiliser was placed in a slit near the seedling at a rate of 80 g of DAP. The programme allows the user to compare up to four establishment regimes in one run.

PLANT-PC

This programme was developed by researchers at the Great Lakes Forestry Center and was intended for use by managers in Ontario (Payandeh et al. 1992). This hybrid model includes three phases of plantation establishment: nursery phase, seedling storage, and plantation establishment. Data used in developing the model included *P. banksiana* plantations (7 stands established with bareroot stock and 2 established with container stock). These stands were operationally established from 1949 to 1979 and each stand represents one specific management regime. Bareroot stock types used in these stands varied with stand and ranged from

Table 1. Comparison of three plantation establishment models for pine.

	CNIIGM	Plant -PC	Ptaeda2v
Pine Species	radiata	banksiana	taeda
Region	Central North Island	Ontario	Southern United States
Stock typ e	Bareroot	Bareroot/ container	Bareroot
Stock size at planting	Yes (RCD)	Yes	Use EQB
Storage treatment	No	Yes	No
Seed source	No	Yes	Use site index
Planting method	Hand	Machine/hand	Machine/hand
Seedling Handling	Good/poor	Good	Good
Mechanical site preparation	Rip/mound/none	Mechanical/none	Mechanical
Fertilisation at planting	Yes/none	Yes/none	Yes/none
Weed control at planting	Yes/none	Yes/none	Use EQB
Planting season	Winter	Spring/summer/fall	Winter
Ages modeled	0-5 years	0-20 years	8-100 ye ars
Maximum regimes per run	4	>16	1

2+0 and 3+0 seedlings to 2+1 transplant stock (stock size was not documented).

The programme allows the user to predict the performance of stock types and genetic sources not used in the operational stands. Regression equations are used to predict heights and survival for stands up to 20 years after establishment. The programme allows the user to compare numerous establishment regimes in one run. A benefit cost analysis is used to generate the cost for establishing 1,000 m of tree height by age 20 years. A unique aspect of this programme is the ability of the user to modify the regression coefficients. Therefore, if a user has sufficient data to indicate the model is overestimating survival for a local region, then the data file containing the survival coefficient can be modified (without having to know anything about the programme). The programme is written in Turbo Pascal and can be downloaded from the web at: www.forestry.auburn.edu/sfnmc/class/plantpc.htm. In addition to pine, the programme also can be used for spruce *(Picea mariana and Picea glauca).*

Ptaeda2v

In 1987, James M. Vardaman asked the question, "Is it possible that, with the right seedlings, we can eliminate site prep altogether?" A good establishment model could have provided an answer but, unfortunately, no such public-domain model for *P. taeda* existed at that time. Vardaman did not want to wait 20 years before someone developed a database which could provide an accurate answer. Therefore, he asked researchers at VPI to enhance Ptaeda2, an individual-tree, growth and yield programme (Burkhart et al. 1986). Researchers from the southern U.S. provided various theories for inclusion in the model (for details see: www.vardaman.com/greensheets/1998sale.htm). Ideally, Vardaman wanted a model that would account for growth differences due to using: (1) genetically improved seedlings; (2) morphologically improved seedlings; (3) ripping; (4) herbicides; and (5) fertilisation. Although this programme can be used as a deductive establishment model, it really is a modified version of an inductive model that simulates tree growth starting at 8 years.

A free demo of the current version is available from the web at: www.vardaman.com/ptaeda2v.html. This is a Windows-based version that is more user friendly than the older DOS based programme. This programme allows the user to modify the magnitude of treatment responses from: fertiliser at planting, genetic gain, control of competing hardwoods, and from practices that reduce the time to harvest. For the most part, it is up to the user to input appropriate responses to various establishment practices. A drawback of the current version is there is no option for batch runs so that stand averages can be obtained. Currently each output will be slightly different when a different random seed number is used.

Gains from planting seedlings grown at low seedbed densities (also called morphologically-improved seedlings in the southern United States) can be modeled using an Establishment Quality Boost (EQB). For example, an 8-year-old stand with a 1-year EQB has the same stand structure as a 9-year-old stand with a 0-year EQB. The application of appropriate herbicides early in the first spring following planting is also modeled with a 1-year EQB. It is assumed that gains from combining herbicides with morphologically improved seedlings are additive (South et al. 2001a).

Some practices (such as ripping and using improved genetics) are modeled by increasing the input value for site index. For example, the user can increase the site index value by 0.6 m to simulate the effect of ripping. To determine the benefit of these practices, separate runs (using the same random seed number) are required to compare outputs with and without the additional establishment treatments. A questionable assumption often made by users of this model is that growth gains from weed control, ripping, genetics, fertilisation and morphologically-improved seedlings are always additive.

Herbicides or Larger Planting Stock?

Establishment models can be used to ask hypothetical questions that were not addressed in the original trials. For example, none of the models above were based on studies that compared benefits of planting larger stock with benefits from applying herbicides around small planting stock. Answers to questions of this type can sometimes save an organization thousands of dollars in establishment costs (South et al. 1993; South and Mitchell 1999). These models were used to address the question "should I invest in either weed control or larger planting stock?"

When the basis of comparison is small *P. radiata* seedlings with a 3-mm root collar diameter (RCD), the CNIIGM model indicates that survival can be increased by either applying herbicides or by planting large-diameter stock (with a 9-mm root-collar diameter). With no weed control and at an altitude of 500 meters, survival of small and large seedling was 71% and 84%, respectively. Use of herbicides increased survival of small seedlings to 82%. For *P. radiata*, the increase in average height due to planting large stock or use of herbicides was about the same (Figure 1).

Output from Plant-PC indicates that planting large stock can increase height and survival (at age 20 years) of *P. banksiana*. Survival of large stock (2+1 transplant) was 74% while survival of small stock (2+0 seedlings) was 69%. Applying herbicides had minimal effect on survival of 2+0 stock (71%) but it reduced heights (Figure 1). This may be a result of a limited database, or use of a phytotoxic herbicide, or possibly from increased competition from herbicide tolerant weeds.

The Ptaeda2v requires the user to make assumptions regarding the gains from using various establishment practices. Without weed control, I assumed large 1+0 seedlings (average of 9-mm RCD) will achieve a 1-year EQB and that small stock (average of 3-mm RCD) will have a 0-year EQB. Likewise, I have assumed that a one-time application of herbicides to small stock will also equal a 1-year EQB. Using the equation reported by South and Mitchell (1999), I set initial survival values of 72% and 91% for small and large stock and 72% for small stock with herbicides. Under these assumptions, year 8 heights are the same when comparing gains from herbicides with gains from planting larger stock (Figure 1). This programme relies on the user to make realistic assumptions about how much gain can be expected from various establishment treatments. Therefore, it is not appropriate for use by those who have no insight into how establishment treatments affect long-term tree growth. The best insights are obtained from long-term monitoring of establishment experiments.

Summary

In my opinion, there is a need for more establishment models, especially in North America. Both deductive and inductive establishment models can be useful in testing traditional beliefs held by forest man-

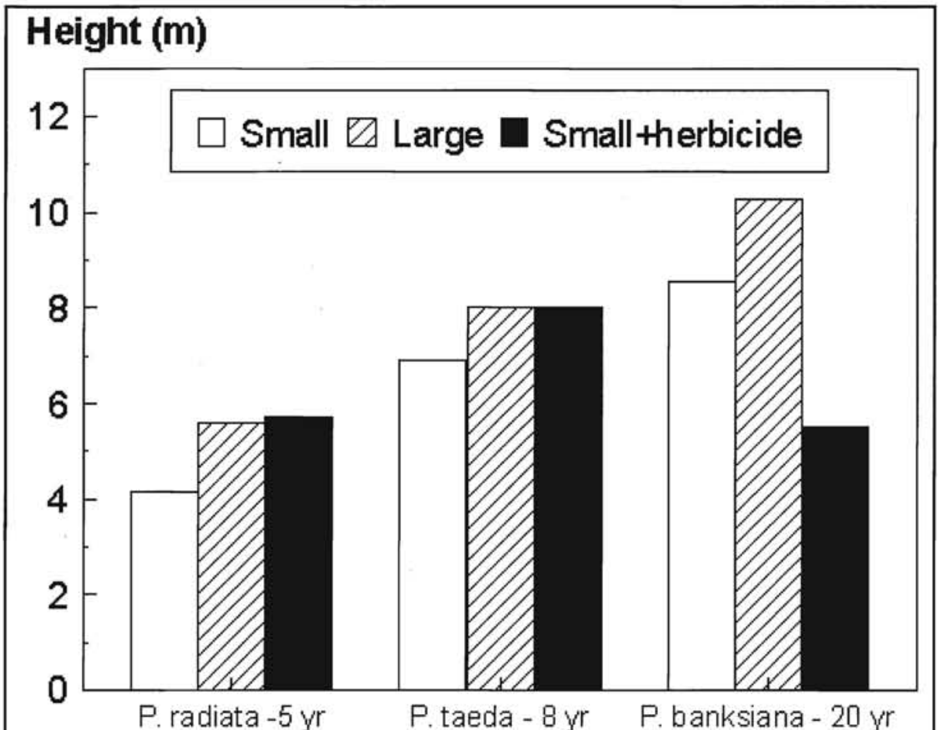

Figure 1. Heights of small and large bare-root seedlings with no weed control compared to heights of small seedlings with weed control from herbicides. P. radiata seedlings are planted at an altitude of 500 meters and the small and large seedlings have root-collar diameters of 3-mm and 9-mm, respectively. P. taeda seedlings are assumed to have root-collar diameters of 3-mm (small) and 9-mm (large). Small seedlings for P. banksiana are represented by 2+0 stock while the large stock is represented by 2+1 stock.

agers. For example, CNIIGM indicates no need for applying DAP in a slit on most sites in the mid part of the North Island, yet this practices is still used by some on a routine basis. Researchers in the United States are becoming aware that we know little about interactions among establishment treatments (South et al. 2001b). This realization has stimulated some research into defining the underlying causes of interactions. Perhaps in the not too distant future when foresters are asked which software programmemes they use, establishment models will be among those listed.

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