4. EVIDENCE-BASED TARGET CHARACTERISTICS FOR SEEDLINGS: EXPERIMENTAL DESIGN, INITIAL RESULTS FROM FIELD TRIALS AND FUTURE RESEARCH

John Herbohn, Jerry Vanclay and Nestor Gregorio

Low seedling quality is a pervasive problem for smallholder forestry in the Philippines. Intervention measures to improve seedling quality are being examined in a research project funded by the Australian Centre for International Agricultural Research. Field trials have been established as part of this 'seedling enhancement project' to compare performance on outplanting of *Gmelina arborea* when imported, selected and non-selected seeds are used. It is expected that this research will provide important information for the development of evidence-based guidelines for seedling quality, and assist in refining the best practice manuals for seedling production.

INTRODUCTION

The problem of low quality of seedlings and other forest reproductive materials was identified at the Seedling Sector Policy Modelling and Analysis Workshop for the ACIAR seedling project in Ormoc City on 12 February 2008[1]. During a workshop session, low seedling quality was recognized as one of three intervention areas, and interventions for this problem were identified as summarized as in Figure 1.

A variety of seedling quality issues are readily observable, some of which are illustrated in Figures 2 to 5. One of the most common problems found in almost all nurseries in Leyte is the use of poor potting and associated nursery practices, which typically involve the use of inappropriate potting mixture such as soil placed in poly bags which are in turn simply placed on the ground under shade with no subsequent hardening up in the sun before outplanting. Many nurseries also have at least some seedlings, and often many, which have been attacked by insects or disease. In addition, poor seedling form and less than ideal seedling morphological characteristics are commonly observed. Poor pricking-out techniques of seedlings germinated in seed beds result in J-rooting. It is common for seedlings to be overgrown in polybags and exhibit moderate to severe root coiling. Growing seedlings in shade results in high shoot to root ratios. Poor root pruning and potting practices for wildlings typically results in poor root form and J-rooting.

In proposing interventions to improve seedling specifications, it is critical to consider the following desired characteristics:

- *Effective*: will they make a difference?
- *Achievable*: can they be implemented?

[1] This was one of three areas where the need for intervention in the seedling production sector was identified in a workshop session on 'Using a Bayesian Belief Network Model to Formulate Policy Interventions to Improve Nursery Efficiency in Leyte, the Philippines, with computer demonstration'.

- *Measurable*: show that it works!
- *Sustainable*: can they be sustained?

Also, it is critical to identify how to test these interventions to find evidence that they will succeed.

Seedling quality affects outplanting success. There is substantial anecdotal evidence that low quality seedlings perform ‘badly’ in the field, i.e. have poor growth once the seedling are outplanted. For example, J-rooting of seedlings is often linked to increased susceptibility to windthrow (Figure 5), although most of the evidence for this link is anecdotal. Large industrial plantation companies typically have rigid quality control procedures in place for the planting material they use. These usually involve seedlings having to possess key morphological characteristics such as illustrated in Figure 6. However, there is limited experimental evidence to support the importance of seedling quality, and its impact on initial outplanting success and subsequent growth. Most of the research to date has been conducted on pine species in the United States and New Zealand, mainly by David South, and most of the guidelines for seedling quality are based on temperate research. Figure 7 – which reproduces a graph from South et al. (2001) – illustrates the impact that a key seedling morphological characteristic (root collar diameter) can have on tree volume four years after outplanting.

There is little information published on the desirable characteristics of seedlings for tropical species and the impact that seedling quality has on outplanting success. Evidence-based guidelines are needed for local species under local conditions, i.e. for *species and site specific research*.

TARGET CHARACTERISTICS FOR QUALITY SEEDLINGS

There are a number of ways that seedling quality can be defined.

Seedling morphology is the most commonly used indicator of seedling quality, largely because morphological characteristics can be easily measured in the nursery and simple target characteristics can be set. The following are the most common morphological characteristics:

- sturdiness quotient (a root collar:height ratio greater than 6 is desirable)
- root:shoot ratio (of about 1.0)
- well formed roots
- root growth potential

Leaf physiology characteristics typically relate to how well a plant is functioning. Leaves are the primary mechanism through which gas exchange takes place – CO_2 is absorbed from the atmosphere and converted into cellular carbon through the process of photosynthesis. Photosynthesis is typically measured in the field by a portable infrared gas analyser or IRGA (Figure 8) while fluorescence is measured using a fluoremeter. Photosynthesis and leaf fluorescence are two excellent measures of how well a plant (e.g. seedling) is functioning. The higher the rate of photosynthesis, the more CO_2 is fixed and the faster the plant can grow. Leaf fluorescence is a closely related measure of performance and is an indicator of the plant stress. Both measures can be related to field performance, i.e. survival and growth.

Root physiological characteristics have also been used as indicators of seedling quality. The most common measures are:

- root growth potential (RGP)
- root electrolyte leakage
- root carbohydrates and nutrient status

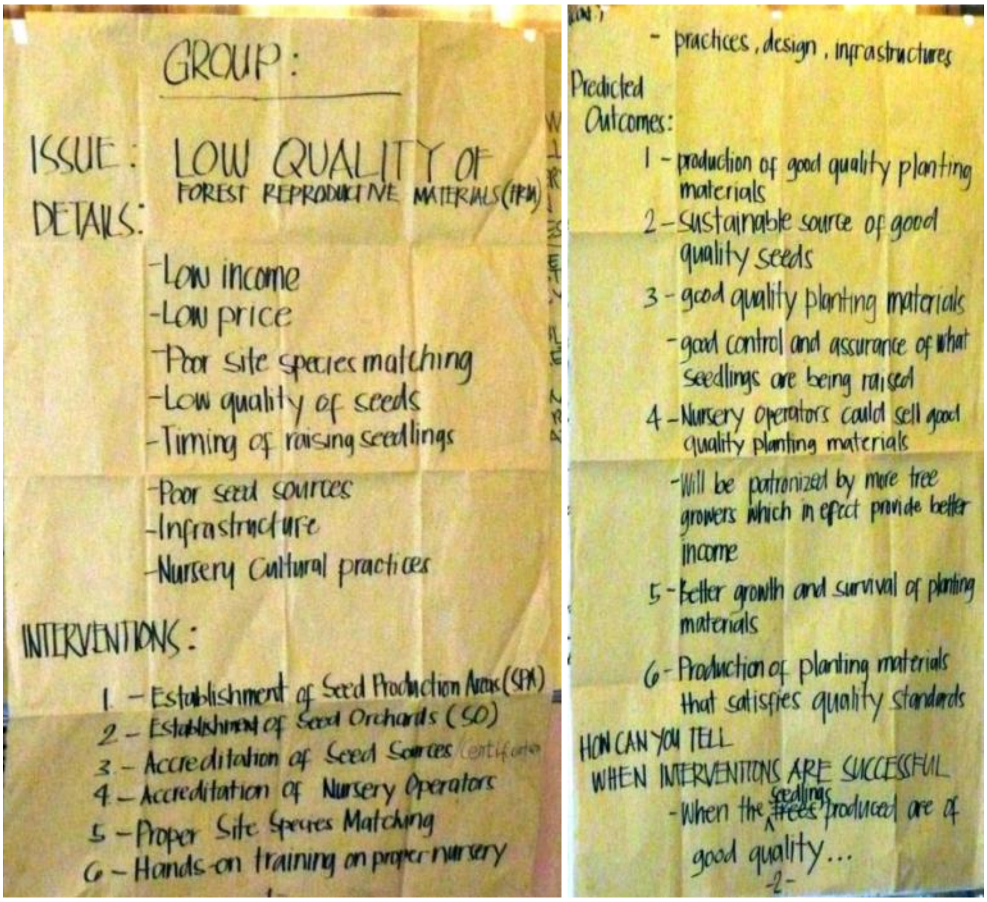

Figure 1. Interventions identified in relation to improving forestry seedling quality on Leyte Island in the Philippines

Figure 2. Examples of low seedling quality

Seedling Quality Issues – Wildlings

Figure 3. Low quality of wildlings

Figure 4. Low seedling quality (deformed root systems)

Figure 5. Low seedling quality – lack of wind-firmness, probably due to J-rooting

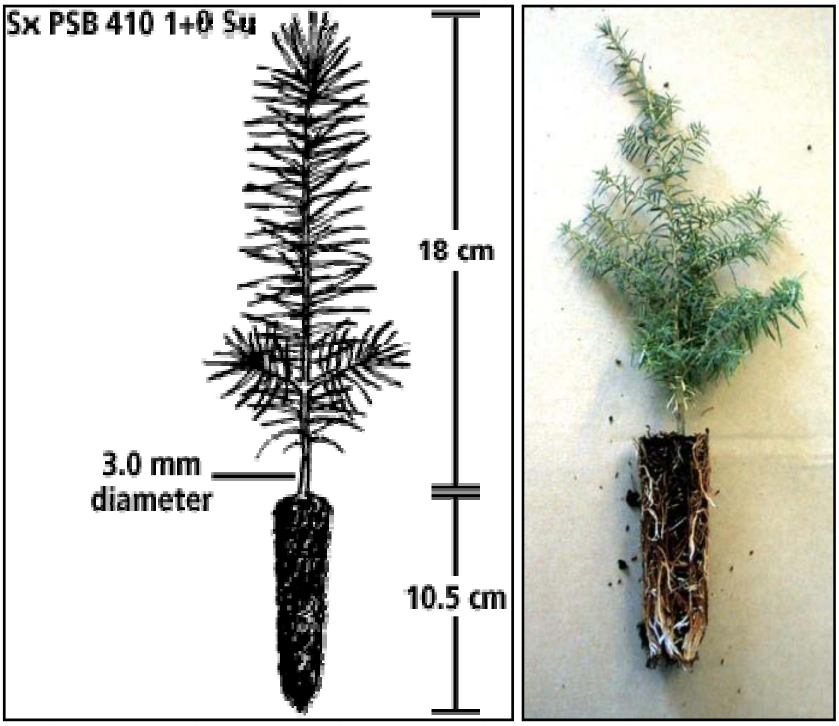

Figure 6. Example of the typical morphological characteristics of a seedling

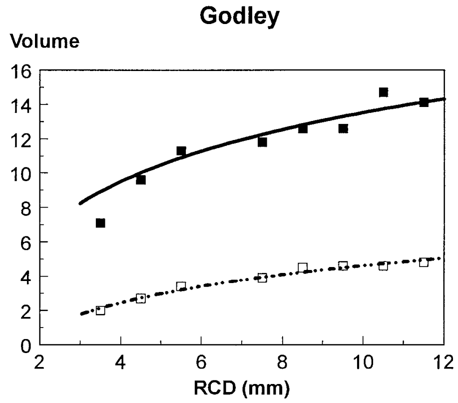

Figure 7. Relationship between initial root-collar diameter (RCD) and intensive management on volume per tree (dm3) after 4 years of growth. Each point represents the mean for a 1 mm diameter class. (Solid line = intensive management; dashed line = standard treatment).
Source: South et al. (2001)

Figure 8. Measurement of photosynthesis in ACIAR field trials using a portable infrared gas analyser

RESEARCH ACTIVITIES

A number of field experiments have been designed to develop best practices and define characteristics of a 'target seedling'. In broad terms these studies are designed to:

- identify characteristics of high quality seedlings *by species*;
- measure seedling quality and impact of improved, selected and unselected seed; and
- relate morphological and physiological characteristics in nursery to field growth.

The following is a brief outline of a series of field trials that have been established as part of the ACIAR nursery project.

1. Gmelina Demonstration Planting Trial at Mahaplag

This trial was established primarily to demonstrate to farmers the benefits of using high quality germplasm. The trial involved establishing plots of *Gmelina arborea* (gmelina or yemane) seedlings with three types of genetics (unselected, selected, improved) which have been subsequently managed using locally applicable best practice (Figure 9). A fourth plot using seedlings grown from unselected seed was also established in which the typical current poor management practices of tree farmers have been applied (i.e. no thinning or weed control). There has been regular monitoring of physical performance (height, dbh, crown) and physiology (photosynthesis, fluorescence, conductance).

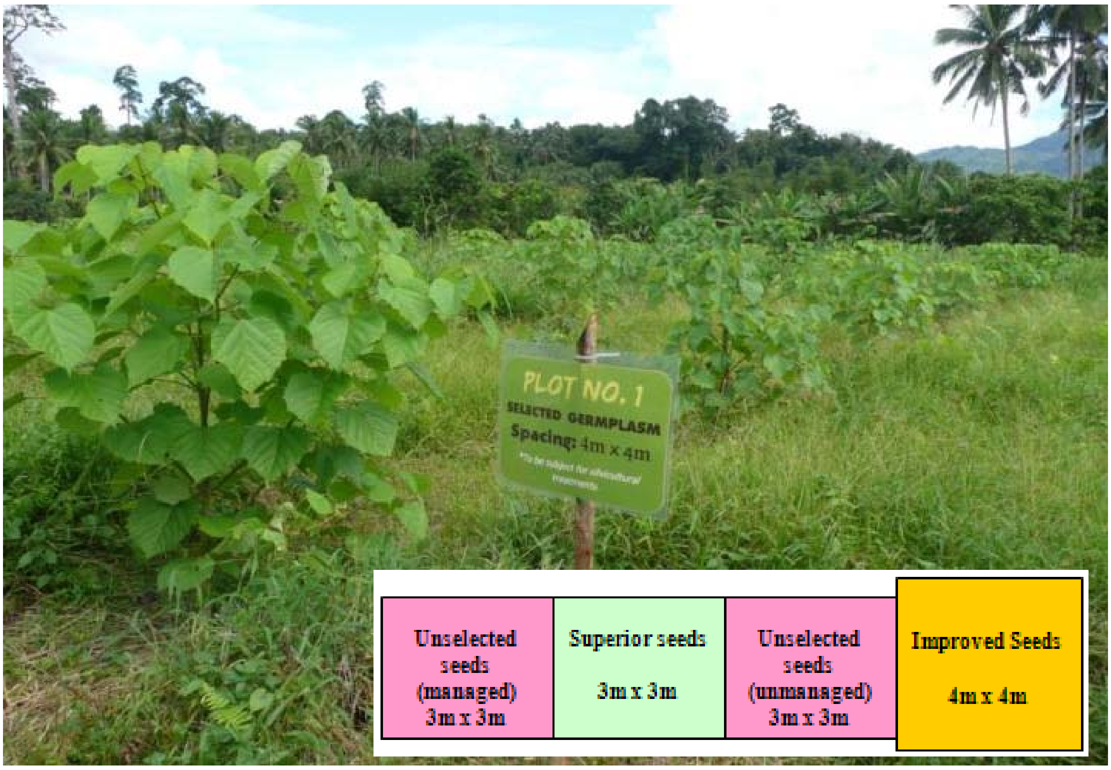

Figure 9. Experimental layout of gmelina germplasm trial

The field trials will also form an important extension tool. Even at an early age, there are statistically significant differences between the four treatments (Figures 10 and 11). Importantly, there are also clear visible differences (Figure 12) that are a powerful demonstration to nursery operators and smallholders of the importance of using improved genetic material and good nursery practices. The impact of the extension value of the trials will be closely monitored. The extension function is considered to be at least as important, if not more important, than the actual results from the field trials. Data collected from the outplanting trials will also be used in quantifying the economic impact of improved nursery practices.

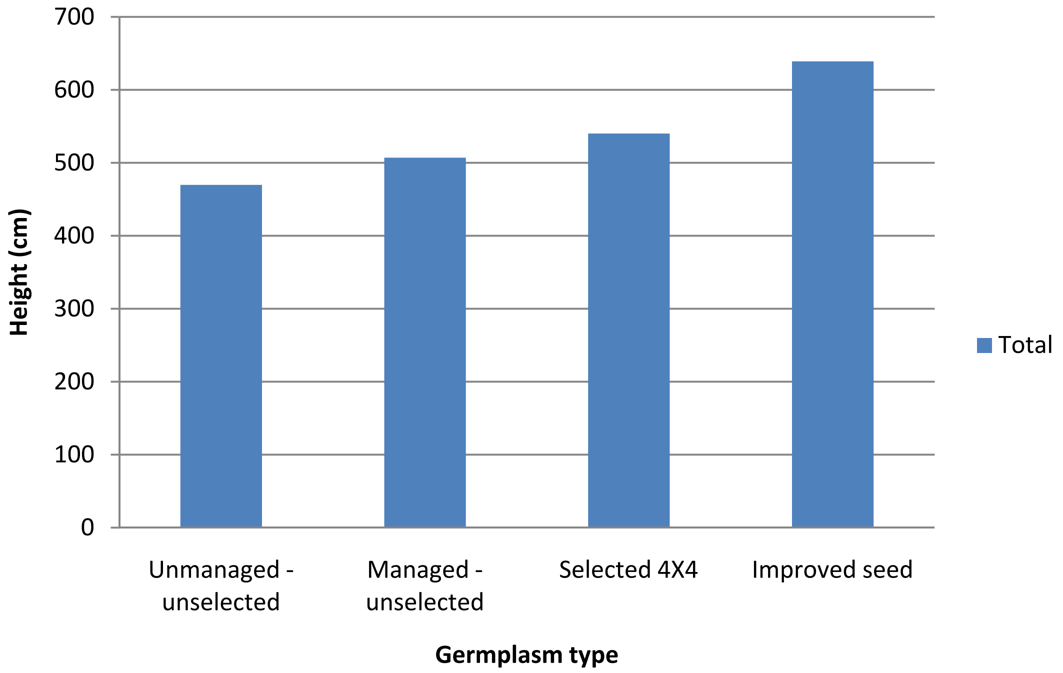

Figure 10. Height of trees from different germplasm sources after 19 months. All treatments at significantly different at p=0.05.

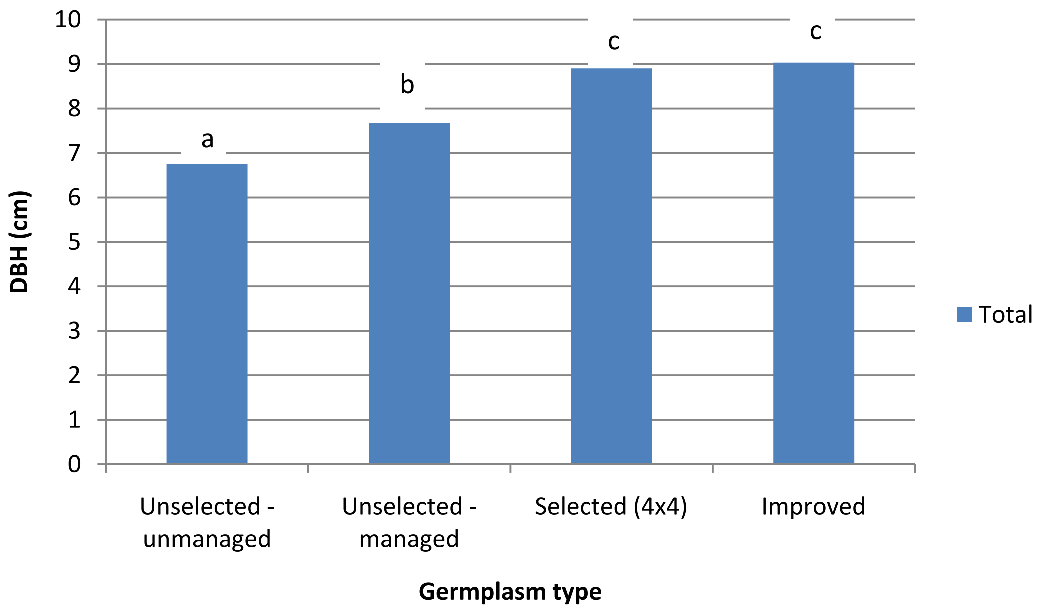

Figure 11. DBH of trees from different germplasm sources after 19 months. Treatments with the same letter are not significantly different at p = 0.05.\

Figure 12. Gmelina planting trial at 19 months

2. Other Nursery and Outplanting Trials

When the seedlings were raised for the gmelina extension trial planting, a high degree of variability in the height and possibly the sturdiness of the seedlings from unselected seed was observed relative to the seedlings produced from improved seed sourced from Puerto Rico (improved seedlings) (Figure 13). A high degree of variability was also observed in the seedlings produced from 'selected' seed collected from a superior mother tree.

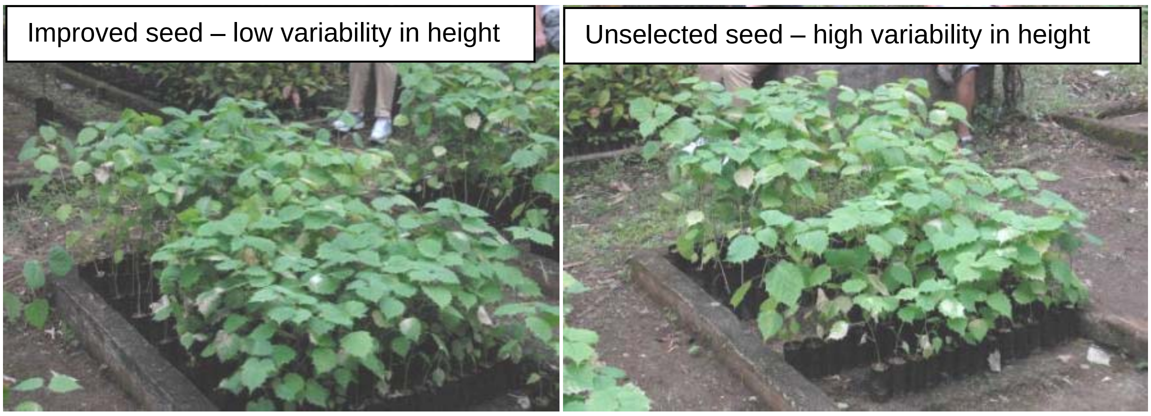

Figure 13. Variability of quality in gmelina seedlings from improved and unselected seed

It is possible that the variation within gmelina seedlings of the same genotype is inherently so high that a desirable practice may be to grow a large number of seedlings and then only select the best 30% for outplanting. This may be a much more cost-effective and reliable way of selecting seedlings rather than selecting superior mother trees for superior selected seed (where this superior seed may have a high degree of variability).

The aim of the research trial is to investigate whether the initial outplanting performance of gmelina seedlings can be improved by selection of better performing seedlings within a cohort of seedlings produced from unselected seed sources and whether these seedlings perform as well as germplasm (planting material) from selected mother trees and improved imported germplasm. The research has significance for the selection of planting material for smallholder tree farms in the Philippines and elsewhere, including the identification of best performing planting material. Identifying the morphological and physiological characteristics of seedlings that influence outplanting performance will aid in the development of benchmarks for seedling quality specific to *Gmelina arborea*. The research may also identify a strategy for smallholders to gain ready access to better performing genetic material from local sources at low cost rather than relying on the import of improved germplasm.

The specific research questions addressed are:

RQ 1: What is the natural variation in gmelina seedlings from local unselected germplasm?

RQ 2: Is germplasm from ‘superior’ mother trees and improved genetic material less variable than that from unselected sources?

RQ 3: Do the best seedlings become the best trees?

RQ 4: How does field performance differ in unselected, superior mother tree and improved germplasm (in terms of both mean and range of performance)?

RQ 5: How much cull in the nursery is required to ensure best performance?

RQ 6: Can morphology of nursery stock be used to predict outplanting performance of gmelina seedlings?

RQ 7: Can physiology of nursery stock be used to predict outplanting performance of gmelina seedlings?

RQ 8: Can morphology characteristics be used to predict physiological characteristics and outplanting performance?

RQ 9: Do the best seedlings from unselected material perform as well as seedlings from selected mother trees and imported germplasm (and hence is using best seedlings from unselected material an effective strategy for smallholders to obtain better seedlings)?

2 a. Outplanting trials of gmelina germplasm from unselected, selected and improved germplasm

The aim of this research is to compare performance of seedlings produced from deciles of *unselected, selected and improved* germplasm and assess how the best seedlings of unimproved germplasm compares with improved material. The results will shed light on whether selective use of seedlings produced in the nursery is an effective strategy for smallholders to improve tree growth performance.

Seedlings were produced using unselected, selected and superior seeds. A total of 1000 seedlings were grown from each germplasm category. The seedlings were assigned with an identity number and randomly placed on elevated hardening beds three months from potting. After two months of sun-hardening the seedlings were graded according to their height and assigned to deciles (Figure 14). Assignment to deciles was based on the position of seedlings after grading, i.e. the first 100 seedlings belong to the first decile and the last 100 seedlings belong to the last decile. Seedling height, base diameter and number of leaves were recorded every month. Maximum photosynthesis was measured a week before seedlings were outplanted. Also, ten seedlings were randomly selected from each decile for biomass, root to shoot ratio and root length measurements.

Figure 14. Gmelina seedlings graded for allocation in deciles prior to planting out.

From each decile, 48 seedlings were randomly selected for outplanting (40 as sample seedlings and 8 as buffers). The planting design was random stratified comprising of three plots with four strata consisting 100 randomly selected seedlings from each decile of each of the three germplasm sources i.e. unselected, improved and superior. For the purpose of complete randomisation across the deciles and germplasm sources, the 40 randomly selected seedlings from each decile were divided into four blocks comprising of ten seedlings per block. The first 100 seedlings from ten randomly picked blocks across all deciles of the three germplasm sources comprised the first stratum of seedlings planted at a spacing of 3 m x 3 m (coordinates X_i; Y_j) (Figure 15). The second stratum was established by offsetting 1.5 m in the X coordinate (i.e. $X_{i+1.5)}$; Y_j) (Figure 16). The third layer was established by offsetting 1.5 m in the Y coordinate (i.e. X; $Y_{j+1.5}$) (Figure 17). The fourth strata was established by offsetting 1.5 m in both X and Y coordinates (i.e. $X_{i+1.5}$; $Y_{j+1.5}$) (Figure 18). It is designed that at the time of thinning, 3 of the 4 strata are completely removed leaving a final spacing of 3 m x 3 m with even numbers of individuals for each of the deciles. For example, removing strata 2, 3, and 4 would result in the planting configuration shown in Figure 15. However, any combination of 3 strata could be removed resulting in a similar configuration after thinning. A total of 1200 seedlings were outplanted, 400 for each of the three plots.

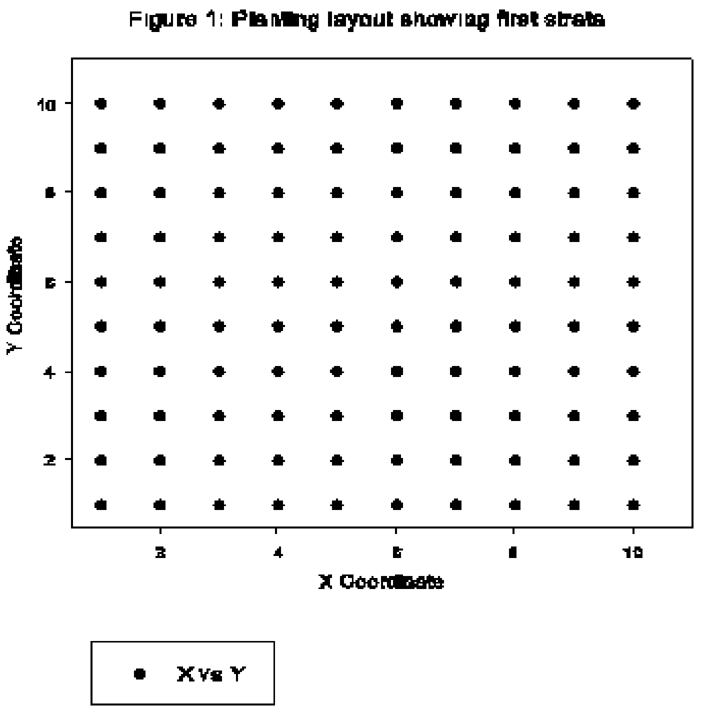

Figure 15. The planting design of the first stratum with a spacing of 3 m x 3 m

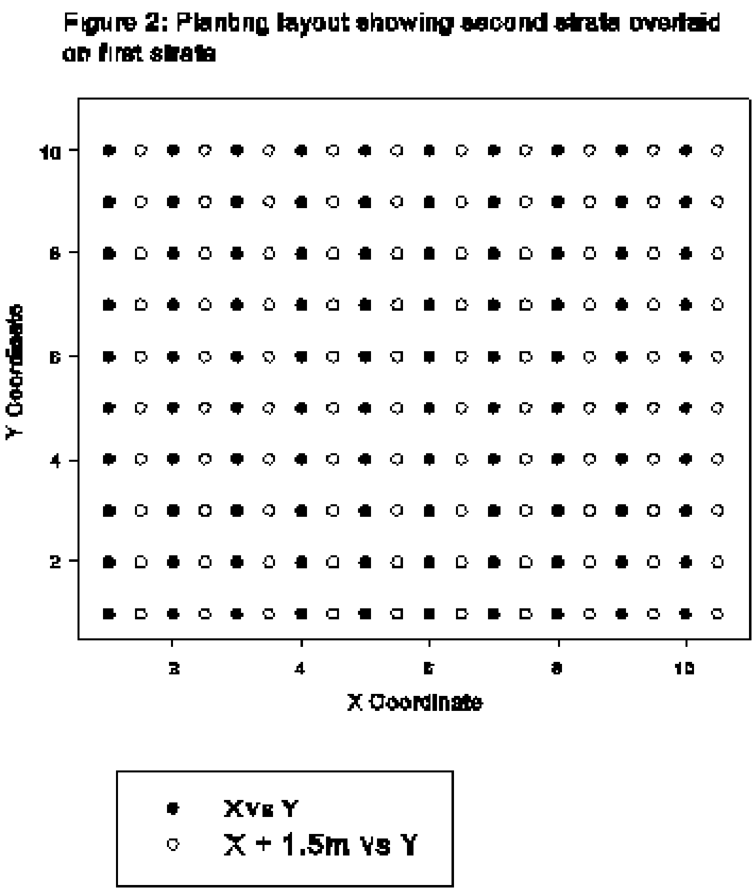

Figure 16. The planting design of the second stratum added to the first stratum

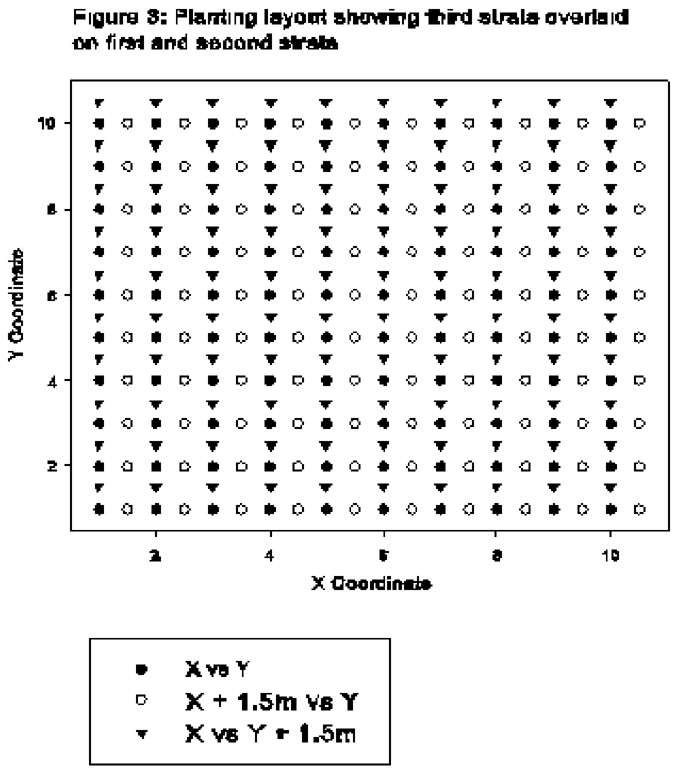

Figure 17. The planting design of the first and second strata plus the third stratum

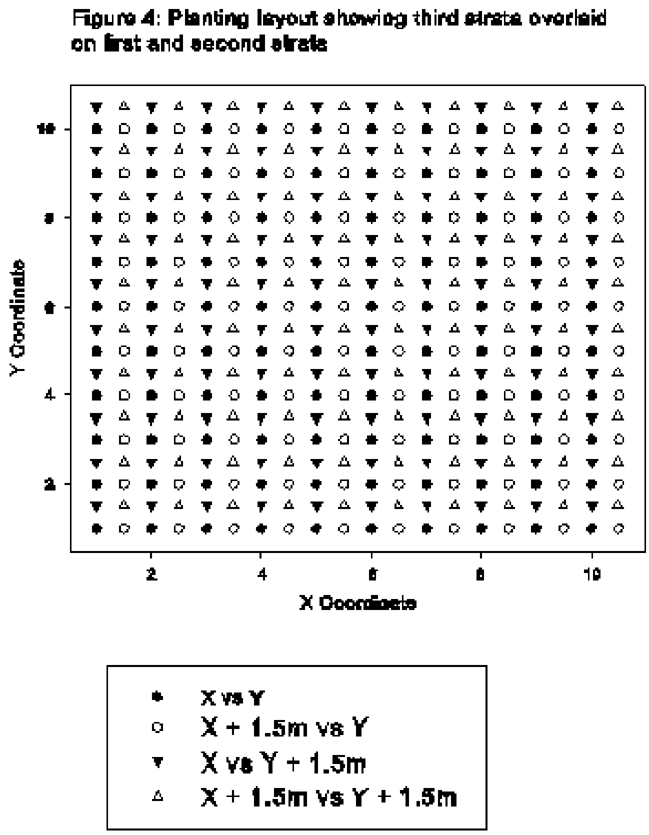

Figure 18. The planting design with all strata

Plant height and base diameter were measured immediately before outplanting and the number of leaves per seedling was counted. Post planting measurements include the maximum photosynthesis, seedling height, base diameter and health. The maximum photosynthesis was measured from 300 selected seedlings (100 seedlings from each germplasm source) two days after outplanting. Seedling height, base diameter and health are assessed quarterly.

2 b. Physical quality of gmelina and mahogany planting stock

The aim of this research is to investigate the impact of low seedling physical quality on growth of seedlings in the field. Gmelina and mahogany seedlings with bent stems, lanky shoots and damaged root system due to being over-mature were obtained from private and government nurseries, while seedlings with J-roots and those with the ideal characteristics (i.e. sturdy, straight stem and with straight taproot) were raised for this trial in the VSU nursery. The seedlings were planted in two blocks, with each block having five plots corresponding to the five treatments (i.e. bent shoots, lanky shoots, over-mature, J-rooted, and best quality). Twenty one trees were planted in each plot at a 3 m x 3 m spacing (with the inner five trees sampled). The performance of seedlings in terms of survival and increase in basal diameter and height is monitored every two months. The health condition of the seedlings is also assessed.

DISCUSSION

The field trials established as part of the ACIAR tree nursery project will provide important information for the development of evidence-based guidelines for seedling quality. The results will be important inputs into refining the best practice manuals that have already been produced based on currently available guidelines from temperate regions. In addition, the field trials are likely to make a significant contribution to the more general literature on seedling quality and how it affects outplanting.

REFERENCE

South, DB, Rakestraw, JL and Lowerts, GA 2001, ‘Early gains from planting large diameter seedlings and intensive management are additive for loblolly pine’, *New Forests*, vol. 22, nos.1-2, pp. 97–110.