# Review of needs and opportunities for automation in tree nurseries

Author:

Simeon Smaill

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# Executive Summary

Various labour and regulatory based issues are increasingly eroding the viability of commercial tree nurseries in New Zealand. This represents a threat to the ongoing security of supply to the planted forest estate. The automation of various physical and chemical management practices, combined with appropriate suites of sensor packages, is being actively explored to address these issues. Research efforts are largely being channelled into the development of novel systems to physically manage stock and deliver chemical treatments in precise doses, although it is recognised that sensor technology is also a critical requirement to maximise the return on investment in these systems.

The progress made to date on various automation projects varies considerably, with some simple systems already in operational use, and more complex systems starting to be used to carry out multiple nursery tasks. However, it is clear that more time and resources will be required to produce the packages of automated systems required for a step-change in nursery management. In addition, the assembly of a significant body of operational data will be needed to provide nursery mangers with the confidence to invest in novel automated systems. It is suggested that the wider forestry sector should support efforts to automate nursery practices in order to provide greater security to this aspect of the forestry supply chain.

# Introduction

The FFR and GCFF programmes have provided a range of opportunities for Scion staff to discuss and implement research with commercial nursery managers with a regularity that had not occurred for several decades. This interaction has facilitated discussion on various issues that directly impact the sustainability of the nursery sector in the mid- to long-term. Critical issues include:

- Labour shortages and reliability
- Licence to operate issues associated with fertiliser use

Given the fundamental position of tree nurseries within the forestry supply chain, reductions in nursery production have the capacity to erode the overall viability and profitability of the sector.

The automation of various nursery processes has been explored in New Zealand itinerantly for several decades as a potential option to increase the efficiency of nursery practices. However, the growing pressures placed upon the sector suggests the integration of automation, where practical, may become a necessity for ongoing feasibility.

The purpose of this review is to collate information from nursery managers regarding the current issues facing the sector, the opportunities for automation within nursery practice, and the potential ramifications for other aspects of nursery practice and the wider forestry sector. An overview of comparable technologies used in similar settings will also be provided. This information will be evaluated to identify suitable targets for automation in nursery production processes, in terms of available technology, current and future labour pinch points, and the greatest return on investment.

# Critical issues

## Labour

Decreased staff availability, poor retention of staff during the lifting season and the issues associated with managing a large, fluctuating, low skilled labour force were common issues across the nurseries. It was readily acknowledged that lifting seedlings from beds is seasonal, unpleasant work:

*"who wants to spend three months kneeling in the dirt, in the rain and cold, when they can be sitting at home on a benefit?"*

The extent of staff retention issues is clearly apparent from statistics provided by nursery managers for this report. For example, at one nursery, in order to maintain a seasonal daily workforce of 40 lifters, a total of 240 staff needed to be found and employed throughout the season to maintain this number. This six: one ratio was due to staff not turning up on a given day, or abandoning the job after a few days or weeks. Similar numbers were evident across a range of other nurseries, in the order of five: one and four: one.

*"unfortunately, the reality is that this is a job for those without choice"*

This turnover and the need to continuously maintain an operational level of staff during the critical lifting period creates substantial amounts of paperwork relating to Health and Safety requirements, financial records, inductions, resolving conflicts between staff and drug testing. The extent of this additional administrative load led one nursery manager to comment that they now spend 90% of the lifting season dealing with "people issues", and only 10% of their time on crop management – clearly not a sustainable position.

The high turnover of staff also leads to a decline in work quality. A gradual decline in productivity per worker is evident in records from different nurseries, even after accounting for greater time allocated for stock grading. It is largely unknown how staff turnover is affecting stock quality leaving the nursery gate, but given the decreased numbers of experienced nursery workers present on site at any given time, it is likely to be negative.

At several nurseries short-term immigrant labour has been utilised as a solution, which has addressed a number of issues regarding staff retention throughout the season. However, this is not seen as a long term resolution to the problem due to the dependency on favourable government policies to support this activity, which is considered tenuous at best. In addition, a number of nursery managers involved consider the process as a last resort, as they can see the money going to the immigrant staff is not staying within their local community, and they generally still need to train each cohort of workers every season.

Of the nursery managers polled for this report, one did indicate that significant labour problems had yet to eventuate during the lifting season, largely due to ongoing access to a labour pool that has a strong affiliation with the forestry sector. However, it was indicated that competition from other aspects of the forestry sector was starting to have an impact of the availability of labour for the nursery, and a need to attract backpackers and other transitory staff was developing. The retention of skilled nursery workers was still possible at this nursery, but automation was a seen as a potential long-term future requirement.

Overall, labour availability is considered to be the dominant issue in nursery productivity. Many nurseries could be producing significantly greater volumes of crops, but cannot commit to this due to uncertainty around the ability to actually harvest the crop within the appropriate window of time for the clients. One nursery manager commented that with their current staffing, the nursery could plant, top, undercut and maintain 14 million seedlings in a given season, but can only contract production of 5 – 6 million due to uncertainty around the availability of staff to lift the stock during the harvesting window. Given that these labour issues appear to be getting worse, a step change to automated systems is largely considered to be not just advantageous, but essential.

## Licence to operate

The current range and extent of chemical use within nurseries is creating concerns amongst Regional Council entities regarding the “environmental footprint” associated with operational practices. This issue is most relevant to the use of nitrogenous fertilisers, which is currently a key concern in industrial land use in New Zealand. Automated systems, appropriately linked to sensor networks, are seen as an opportunity to improve the precision of treatment applications, enabling managers to move away from large scale broadcasting with the potential to create considerable nutrient loss, and instead utilise small scale, area specific treatments.

With regards to the use of herbicides, insecticides and fungicides, improved precision in utilisation is desirable not only for environmental reasons, but also because it will slow the development of resistance amongst target pests. Given that disease, weeds and insect pests are all substantial issues in nursery productivity, improved management of treatment resistance is a key issue for future viability within regulatory constraints.

Associated with both staffing and licence to operate issues are health and safety requirements around the chemicals used within the nursery environment. Chemicals are needed throughout the year, and ensuring compliance with Health and Safety regulations can be challenging at the best of times. Exposure to copper, which is a key ingredient in various fungicides, is seen as particular issue. This risk is exacerbated at harvest due to the influx of largely inexperienced staff, but is also offset to some extent as most treatments cease at this time – but certain operations such as cutting set are still taking place, which is associated with significant chemical use.

Overall, automation is seen as a potential pathway to manage these issues by improving the precision of chemical applications and reducing the numbers of staff involved in chemical handling. Furthermore, if future regulations force a transition away from certain chemicals used in pest control, automation may provide a physical solution for some issues.

# Proposed Automation Systems

## Physical management

For several decades various automated lifting system have been trialled in New Zealand radiata pine bare root nurseries with various levels of success in terms of physically removing the seedling. However, all essentially failed due to the lack of appropriate sensor technology with respect to seedling position in the beds, and an inability to account for the needs to trim and grade the stock.

Research and investment within the New Zealand nursery sector is currently supporting the development of two types of comprehensive automation systems targeted at bare root radiata pine stock production. This has effort has been revitalised by developments in on-board computing capacity, sensor technology and machine learning, which suggest that the previous limitations to lifting may be able to be overcome. In addition, a number of subsidiary systems are being implemented to support specific aspects of stock management.

The first of these comprehensive systems follows the overarching principle that increased accuracy in tractor based sowing in seed beds will enable the efficient and effective automation of other practices – essentially, if you can put the seeds into the ground very precisely, this enables all the other physical treatments to be accurately applied (e.g. undercutting/wrenching, topping, and lifting). This system also requires a range of on board packages to locate seedlings accurately not only in the horizontal planes, but also vertically to ensure topping / undercutting is done correctly. Therefore, accurate elevation sensing is also a requirement. A modular approach is being taken in the development of this equipment, enabling the prospect of tractor units that can cultivate, sow and apply treatments in a single pass over the bed, providing considerable savings in machine hours and fuel costs.

***Figure 1*** *Example of a tractor equipped with a GPS / radar driven unit that enables precision planting in the seed beds. Although currently occupied, the tractor can operate autonomously.*


***Figure 2*** *The leading module (obscured) forms the bed, while the modules following the tractor plant the seed, with additional options to add a treatment at planting. All modules are mounted on lateral actuators that precisely maintain the position of the modules relative to the seed bed being formed.*

The modules that will perform lifting and grading at operational scales are currently under development, but follow the same concept that accuracy in seedling location will simplify later operations. Return on investment in this machinery is anticipated to manifest from increased annual production, which would transition to being limited by nursery space rather than staff availability. This would also open opportunities for expansion, which cannot currently be considered due to staffing concerns.

Additional revenue may be derived from licensing equipment designs to other nurseries and operators, which may have significant implications for the other nurseries. One option is that smaller nurseries unable to individually purchase automated systems could utilise a contractor that services multiple nurseries, or that nurseries own some of the modules individually, depending upon their needs, that are then used by the contractor on site. An operational model that has been discussed is the contractor providing the precision location modules, while the nurseries utilise their own modules for cultivation, sowing and treatment, in order to improve nursery hygiene.

The second comprehensive system that is being developed partners a tractor based planting and lifting system with a smaller autonomous robotic system that will conduct the day to day management of the seedlings. This smaller device, similar in concept to that illustrated in Fig. 3, is being developed to carry out various operations, such as topping, undercutting, and chemical applications to the seedlings, as well as performing growth data collection. The operation of this device in a nursery has not yet been observed.

***Figure 3*** *Example of an autonomous platform for conducting operations on plants within the seed bed level*

As with the wholly based tractor system, the principle goal is to be able to carry out multiple operations on one platform, greatly reducing the need for staff in the nursery itself. However, it is envisaged that the addition of the smaller robotic system will be able to deliver greater precision in treatment application than a tractor mounted system.

Applications of automation are also being developed for specific aspects of nursery management. To assist in the grading and preparation of clonal cutting stock, one nursery has developed and installed a conveyer belt system to enable the rate of processing to increase. While this is a comparatively small level of automation in a process that still relies largely on manual labour, it is hoped that it will support greater efficiency and higher quality.

Several nursery managers still see significant barriers to broader scale automations in their nurseries, which are unrelated to cost. Concerns around the layout of existing infrastructure, such as water lines, and variations in topography are cited as factors which complicate the use of autonomous systems. In addition, current research has focussed primarily on drilling seed – setting of cuttings is a more complex operation in terms of an automation process, so nursery managers that are establishing clonal crops would need to invest and develop a deeper level of automation technology to see the full benefits.

## Surveillance

The installation of enhanced surveillance technology in New Zealand nurseries is considered to be an important pairing with increased automation for two reasons. Firstly, greater levels of automation will reduce the physical presence of staff within the nursery, potential increasing the risk that disease, insect pest outbreaks, nutrient deficiencies or other occurrences will go unnoticed for longer. Secondly, increased surveillance capability will enable the potential of automation to be fully realised in terms of stock production and quality through greater accuracy in crop data collection and management. This last point was characterised by a nursery manager as follows:

*"there are two gates – the first is automation, which sets the target for production, and the second is surveillance, which allows you to reach that target"*

Improved nursery management through enhanced surveillance, and interpretation of the collected data, is seen as critical to improving seed efficiency, which the above statement directly refers to. Seed is a substantial cost, and little margin is provided in terms of the seed costs required to meet contracts – therefore, anything the increases confidence in the ability to convert seed into stock that meets client specifications provides a clear financial benefit. Improved surveillance capability is projected to enable the early identification of disease and other operational concerns such as weeds and insect activity, enabling pre-emptive or early treatment programs that will allow growth and survival rates to improve – although it is acknowledged that climatic conditions and other factors will influence the ability of managers to respond**.**

Sensor packages are already part of the design for the small robotic unit similar to that shown in Fig. 3, and drone overflights are also being considered for surveillance, particularly for the rapid identification of nutrient deficiencies.

*"we see the potential for managing nutrient deficiency to be a better fit for drone multispectral overflights to assess crop properties, in order to pick up precise areas for fertiliser treatments – deficiencies are slower to develop, and do not present anything like the kind of spread risk as disease and insect infestations"*

The potential for better surveillance to improve water use management was also raised, with particular regard to the health of cuttings. Cuttings initially require irrigation consistently during to help them establish, but this is then reduced as the stock matures to facilitate root development. By way of comparison, seedlings are only irrigated when moisture falls below critical levels. Soil moisture sensing systems may provide opportunities to be more precise around the timing of watering events for cuttings, as overwatering can facilitate disease.

It is also envisaged that the data collection associated with improved surveillance will extend to the generation of automatic recording systems for both treatments and the response of the crop to those treatments. One manager indicated that he already has a difficult time collating the treatments currently used at large scales; if treatments were applied to specific sections of beds across differing timeframes he would need further support to ensure all interventions were properly recorded. This concept was already discussed at length with another manager who was interested in seeing the development of dynamic nursery mapping systems linked to the automated surveillance systems, and the automated physical systems that handled the treatments.

## Current Technology

An examination of the existing agricultural automation systems being developed for other sectors indicates that there is no critical technical barrier to obtaining the technology required to meet the needs of the nursery sector, as described above. The principle barriers are the economic justification for the time and costs required to adapt the systems to the specific needs of the New Zealand radiata pine nurseries (e.g. in terms of stock handling, ability to deliver the appropriate chemicals) and the development of recognition software of appropriate sophistication to manage

the post-lifting requirements (grading and trimming). To date, no such package appears to exist on the international market that puts all of the concepts discussed here together, so there may also be an opportunity for product development that extends beyond the New Zealand nursery market.

Drone based technology for treatment application was not discussed by any nursery manager in detail. This technology does exist and is being utilised widely internationally for plant production, and is currently being explored for various applications in the New Zealand planted forest estate.

***Figure 4*** *Precision application of agrochemicals using a drone delivery system*

# Summary

The interactions with various nursery staff that took place during the production of this report supports the initial position that the nursery industry will be unable continue operating under the current paradigm of intense outdoor labour demands during winter months at current pay scales. This, combined with increased concern of over chemical handling and exposure, is pushing a need for greater levels of automation. Although the projected timeline for investment in automation varied considerably from nursery to nursery, there was unanimous agreement that automation would play an increasingly important role in nursery operations. Some managers have already made the decision to invest heavily in customised projects, whereas others are developing systems that will potentially provide benefit to many nurseries, and are seeking to profit primarily from being early adopters.

Automation is also seen as a pathway to improve the status of nurseries as a place to work, and attract better employees to the industry. Discussions regarding what the workforce at a nursery might look like in ten years resulted in skillset descriptions encompassing a team with engineering and programming skills, combined with some horticultural knowledge.

Another viewpoint that was raised was the potential for automation in the nursery leading to advantageous changes further down the forestry value chain. These included:

- Improved ability to implement customised seedling production treatment recipes, to help the stock adapt more rapidly to particular forests
- redesigning the poly box and plastic bag system to something better and more sustainable, in order to support value chain credentials
- different packing modules to suit client needs
- lift more soil with stock to go directly in to the site and support microbial symbionts

Although not raised directly by any nursery manager, improved automation and surveillance systems may also play a role in reducing the impact of adverse environmental conditions on nursery production, such as out of season frosts and other events that may be associated with climate change. Better surveillance could provide early warning of such events, while automated systems may be able to help deliver the response during timeframes when staff availability is reduced.

It must be acknowledged that some nursery managers will need a considerable evidence base to switch from conventional disease and pest management treatment regimens that are based on timing and general climatic conditions to new strategies that are based on specific conditions in different parts of the nursery. This is a reasonable positon given the requirement of nursery managers to deliver on commercial contracts, and blanket chemical treatments have provided adequate levels of protection for several decades. However, this view must be counterbalanced by the increasing regulatory pressure on wide scale chemical use, so it is important to begin assembling this evidence base as rapidly as possible.

The level of investment in the scope and resolution of sensor networks and data processing systems is an important issue to resolve, as currently there is little information to identify the optimum package for nurseries of different size with different issues. The availability of external research and development funding is likely limited, as automation generally is a pathway to limit job opportunities, which is a poor fit for priorities around regional development in New Zealand. However, if it can be demonstrated that it is not possible to find staff within New Zealand, it may be possible to get funding on the basis that it will provide new technologies that have value on the international market, while also supporting a key New Zealand export industry.

In conclusion, enhanced automation in the nursery is primarily seen as a pathway to improve stock volumes, and the viability of the nursery sector as a while in the face of increasing labour and regulatory issues. Automation may enable enhanced stock quality, but this is not a primary concern at this stage. Given the importance of the reliable tree stock availability for the ongoing productivity of the planted forest estate, it is suggested that the wider forestry sector support nursery automation efforts. This support can manifest in multiple ways, including advocacy for research and development funding, facilitation of collaboration in nursery sector research efforts, engagement with managers around the risks of implementing new nursery systems, and the instigation of projects to track post-nursery impacts.

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