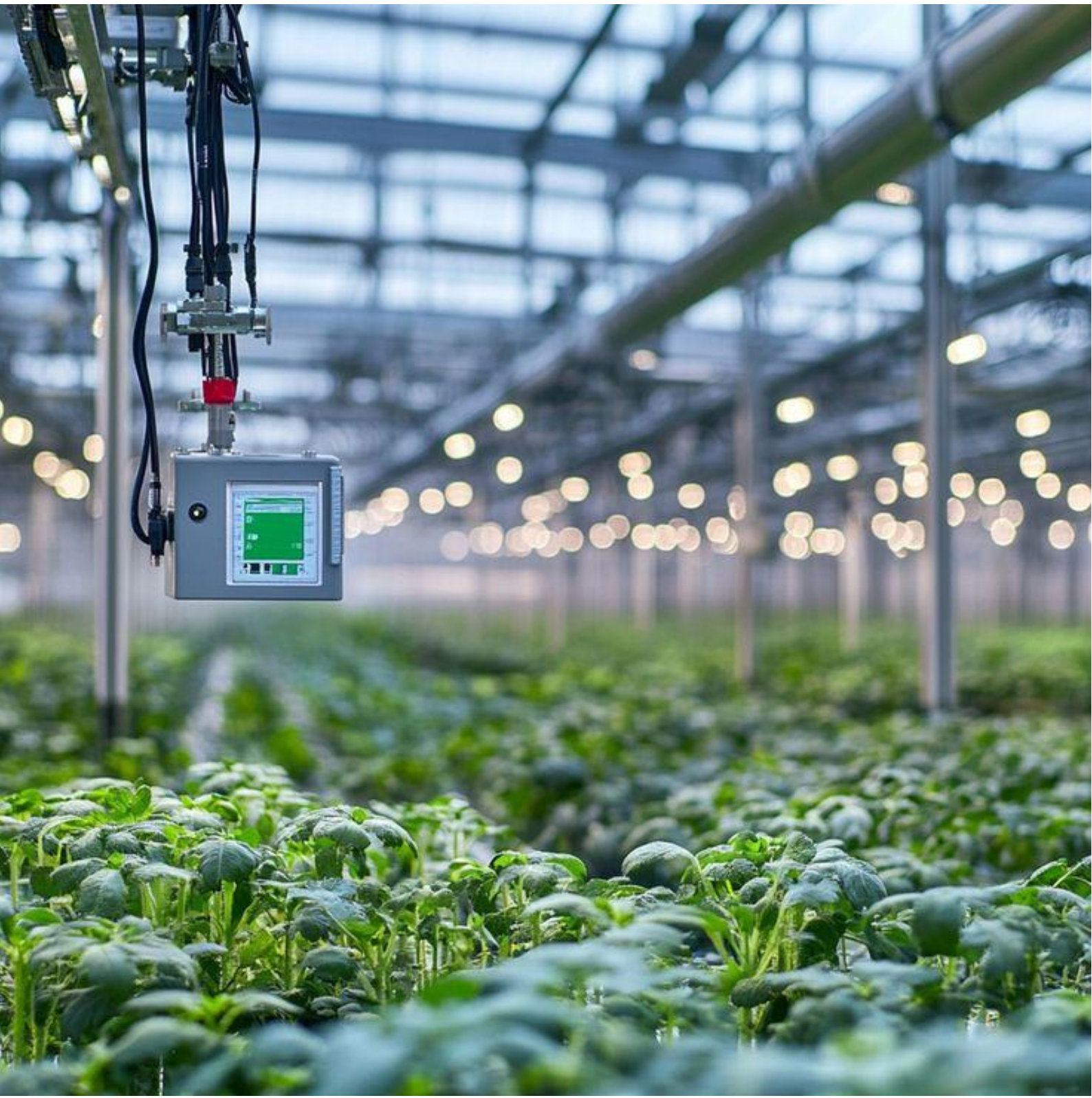
Monitoring within Wholesale Plant Nurseries

Investigating how Success Rate can be improved through better Monitoring Techniques and Tools

By Cameron Hastie n11960469



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Word Count - 4415

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Executive Summary

This research report investigates a specific problem area within Wholesale Nurseries. The aim of the report was to develop a comprehensive understanding of the problem within the topic area through benchmarking, causes of the problem and opportunities for design led improvement. This was performed through the combination of primary and secondary sources, which together will provide an evidence based foundation.

Firstly, the introduction introduced the topic, purpose and scope of the research report in greater detail, while providing readers with definitions and context surrounding the identified problem and direction of the project to ultimately creating a design solution product. Leading on from the introduction, the background section of the report allowed for the establishment of existing issues/aspects of the topic that were factors contributing to the problem.

Benchmarking was then conducted on a wide range of products and categories currently existing around the topic/issue. This is where common benchmarking criteria was carried out on each product with reference to a propagation phase, to form a product report. However, the benchmarking products were scrutinisingly chosen to ensure they matched up against the propagation phases identified. Analysis and findings led evaluation allowed for the identification of gaps in the market and design opportunities.

The research for the report was collated using a combination of primary and secondary research methods that as a whole aimed to deliver a comprehensive understanding and identification of the topic, problems and design opportunities that were both data and existing product driven. Primary research sources were then collected through surveys sent to various Wholesale Nurseries around SEQ. Secondary research sources were also collected through Archival research of academic and literature sources including, articles, studies and videos.

The analysis and findings section of the report allowed for critical evaluation and interpretation to be conducted on the collected data in the varying forms of images, graphs and statistics. By identifying trends, themes, relationships and significant insights from the range of data sources, in the findings section then allowed for the discussion section to follow suit. Critically examining and evaluating primary data against secondary data and existing products in the discussion section allowed for better understanding of the significance and implications on the problem the findings had. The evaluation and justification lead to the design implications section being constructed around design opportunity outcomes from the primary and secondary research data that were placed into 5 categories. Finally the conclusion section of the report summarises all of the key findings and takeaways presented through all the methods of research to reinforce the importance of the identified opportunities and an overall justified direction for the project as a whole.

Authenticity Statement/AI Statement

Authenticity Statement

This is to certify that to the best of my knowledge, the content of this report is my own work. This report has not been submitted for any subject or for other purposes. I certify that the intellectual content of this report is the product of my own work and that all the assistance received in preparing this report and sources have been acknowledged.

Your name: Cameron Hastie

Student number: 11960469

Date: 11/09/2026

AI Use Statement

I have utilised Generative AI in this report in the form of ChatGPT to assist in various ways. The way I have used AI includes brainstorming and research collection, refinement of ideas and analysis techniques.

Introduction:

AI was only used in this section of the report to narrow the scope of the investigation where the issue topic of Success Rate was picked

Background:

Ai was only used in this section to define key terms and to gauge a quick understanding of how these aspects influence the topic and issue

Benchmarking:

AI was only used in this section of to brainstorm a selection of criteria that was used to assess each benchmarking product against and displaying on Radar Graphs

Analysis and Findings:

Ai was only used in this section to gauge an understanding of how the "coding" table might be set out for archival research and how the temporal event method of "coding" could be modified for survey qualitative analysis

Your name: Cameron Hastie

Student number: 11960469

Date: 11/09/2026

Cameron Hastie n11960469

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Section One

Introduction

The nursery industry particularly wholesale nurseries play a crucial and fundamental role in the production of plants on a large scale for the eventual use in landscaping, environmental and horticultural applications. The process of producing these plants involves, multiple large processes with many sub-processes, to help the plants through phases of early propagation and growth, then through growing-on and quality assessment phases before being supplied to a variety of different contexts. The use of monitoring techniques and tools throughout the phases of plant propagation and growth allow for the ability to observe and monitor plant health and growth through factors such as soil moisture, temperature, humidity and pH crucial to ensure that plant development and overall quality are adequate.

Nursery Production and Propagation	
Phase	**Process**
1.	Selection of Healthy Mother (stock) Plants Seed Propagation Initiated
2.	Collection of Cuttings for both Cutting and Tissue Culture Propagation
3.	Preparing Cuttings for Propagation (leaf removal, hormone application)
4.	Planting into Propagation Media for either Cutting or Tissue Culture Propagation
5.	Placement into Controlled Propagation/Greenhouse Environment (misting, humidity, temperature)
6.	Root Initiation in Controlled Environments
7.	Root Development and Propagation Shoot Growth
8.	Monitoring factors including (disease, irrigation, nutrition and environmental conditions)
9.	Potting of Successful Propagated Plants into Pots (cutting propagation) and small tubes (tissue culture propagation)
10.	Hardening-off/Acclimatisation of Developing Plants in less Controlled Environments
11.	Quality/Pre-Sale Inspection through aspect including (leaf growth, disease, overall health)
12.	Dispatch and Transport to Independent Site

Figure 1: Table Representing Key Propagation Phases with the corresponding process (Greenlife Industry, 2025)

The effectiveness and results from monitoring plant development are vital when considering the aspect of success rate of a plant once it leaves the nursery space and is implemented into the different final contexts. Success rate in this context can be defined as the proportion/number of plants that successfully establish or establish following planting or any propagation stage (Accentis, 2020).

Unsuccessful establishment or propagation thus impacts success rate and can result in the additional need for resources, plants and labour to achieve a successful outcome. The issue of success rate is not only a problem at a large scale but also when analysing the impacts that it has on plants that are transferred into a new growing environment. Therefore, investigating the monitoring techniques and tools and judging their effectiveness is a crucial element in understanding their effectiveness as a whole these aspects have towards the larger underlying issue of success rate.



Figure 2: Representation of Low Success Rate in a Nursery (Greenlife Industry, 2025)



Figure 3: Representation of Possible Wasted Resources from Low Success Rate (Thompson, 2022)

Research Question

The aim of this project is through the use various research and analysis methods, how can monitoring techniques and tools throughout wholesale nurseries can be improved to resultingly help improve success rate within the key propagation phases.

Background

Managing plant growth and quality throughout early propagation and development in wholesale nurseries is a crucial element that is primarily conducted through monitoring techniques, tools and systems (Kaptein et al., 2019). These conduction methods as a whole involve the measuring and collection of data through a range of tested elements including soil moisture, temperature, electrical conductivity, pH, humidity, visual assessment and overall environmental conditions (Hunt, 2021). The monitoring of these element's influences and changes habits and practices within nurseries. For example, information that is collected around temperature and humidity levels influences watering habits, while pH and EC data influences nutrient and chemical regulations given to plants (Incrocci et al., 2018). However, the propagation phases as represented by (Figure 28 in the Appendix), also regulates and influences how a plant is monitored and managed. These monitoring elements by themselves or combined through a system or multifunction tool, provide nurseries with critical information about the conditions the plants are currently in and through analysis of data, improving the plants situation or conditions.



Figure 4: Representation of the Monitoring Tools (Temperature/Humidity Reader) and (Pest Identifier), being used within Nurseries (ST19023 Applied Horticultural Research, 2020), (Gabriella Plants. (2020, April 17).

Resultingly, the propagation phases as represented in (Figure 28 in the Appendix), must be adequately met in order for the plant to be at a level of development and readiness to be sold to independent organisations. This is also known as the quality assessment/inspection phase where it can be defined as the process of checking, measuring, and evaluating plants, growing media, and production steps against preset health and regulatory standards to approve, reject, or grade stock (Marritz, 2017). Further, the monitoring elements and quality standards need to be met at each propagation phase in order for success rate to be at an adequate level throughout all phases. If success rate levels are too low they can impact both nursery and independent businesses through increased labour costs, maintenance costs and transport costs (Greening Australia, 2022).

The balance between the above monitored elements helps build the determinacy of whether a plant passes quality assessment and thus being successful (success rate). A study by the Western Sydney University in 2018 analysed more than 13,800 trees across 23 nurseries finding that the balance between root development and shoot development is a critical factor in the potential survival of plants (WSU, 2018). However, it also highlighted the factor that although success rate is primarily determined once plants are developed (matured), success rate is determined and analysed in each process phase of development (Figure 28 in the Appendix). This further creates the importance of monitoring within nurseries to ensure success rate is achieved both before, during and after development.



Figure 5: Representation of how Quality Assessments are typically conducted within a Wholesale Nursery (Workpower, 2026)

However, current research also shows there is great deal of uncertainty that surrounds the link between success rate of a plant and monitoring that occurs whilst the plant is moving through the propagation phases (Mari J. Maja & Robbins, 2018). Although many monitoring aspects are already explored both as individual tools and systems, investigating aspects of each phase of plant propagation through primary and secondary research must be conducted in order for concepts to be created in support of improving success rate.



Figure 6: Representation of the need for greater investigation between Root and Shoot development to improve Success Rate (Innovatek, 2026)

Benchmarking

The purpose of this section is to evaluate existing monitoring systems and tools used within nursery production against the different phases of propagation to as a whole understand the positive impact they have on success rate. However, some tools or systems may be used throughout many different phases in this case the tool or system was allocated to the phases they best fit into. Each benchmarking product was assessed against the criteria on a scale from 0 – 10 (Figure 30 in the Appendix), where a 5 was classified as a par score.

The benchmarking analysis was further strengthened by the splitting of the propagation phases as represented in Figure 9, 10 and 11. Through this approach 1 monitoring system and 2 monitoring tools were allocated to each section (Figure 29 in the Appendix). Radar graphs were then constructed for each section of phases, where the allocated monitoring system and tools were assessed through the aspects of accuracy, suitability, usability, practicality and finally the impact they had towards success rate as a whole.

Figure 7:

Section 1 allocated Propagation Phases and Products

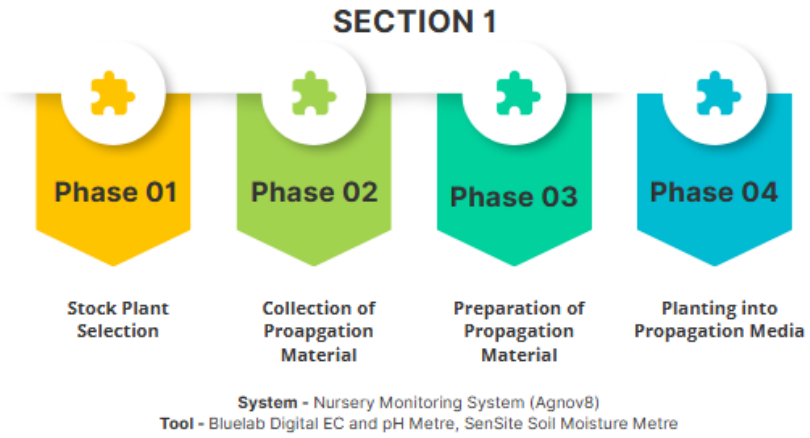


Figure 8:

Section 2 allocated Propagation Phases and Products

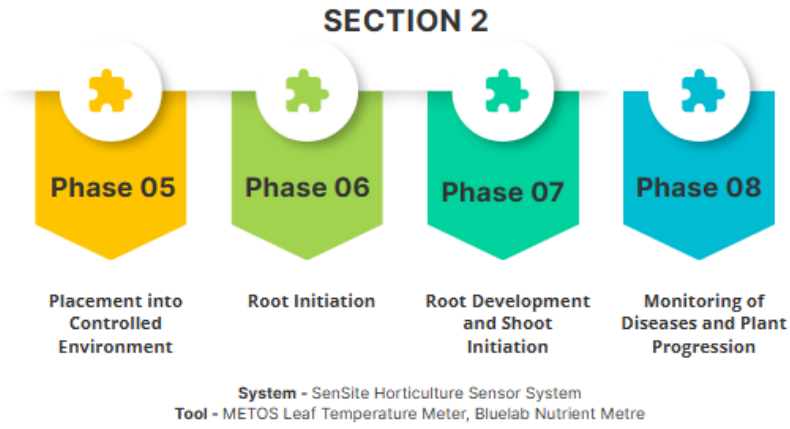
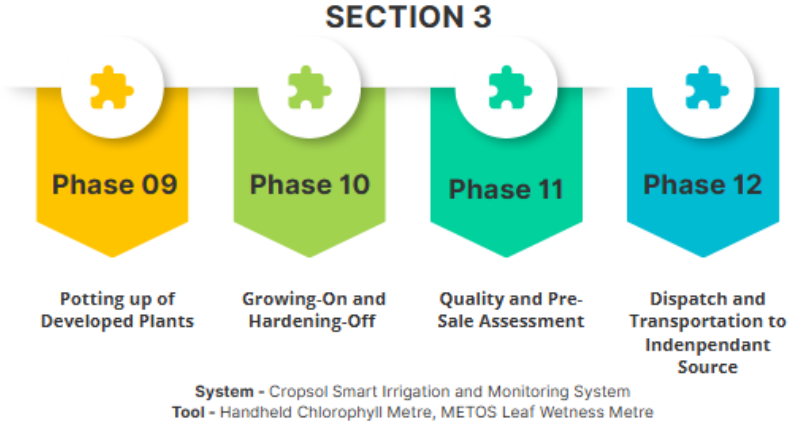


Figure 9:

Section 3 allocated Propagation Phases and Products



Section One

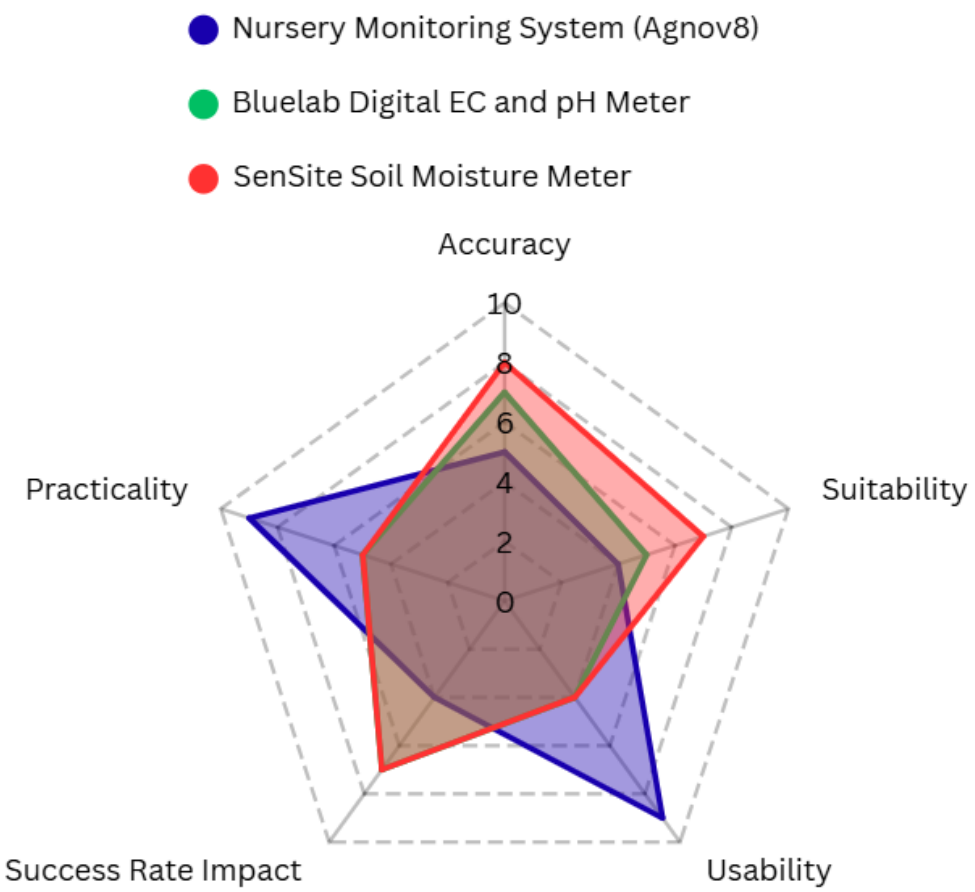


Figure 10: Representation of Benchmarked Products against criteria for Propagation Phases 1 – 4 (Figure 29 in the Appendix – NMS, 2026, Bluelab, 2026a, SenSite, 2022)

The system and 2 tools allocated to Section 1 were represented on a radar graph and graded upon each assessed criteria (Figure 12), where critical takeaways and opportunities were then identifiable. The main point that was highlighted in the map was that between all 3 products, each had their own different criteria elements that they excelled within. The graph represented that the monitoring system (blue) was more focused towards practicality and usability for users rather than accuracy, suitability and overall success rate impact. While for both of the monitoring tools (green and red), there was a greater focus towards accuracy, suitability and overall success rate impact rather than user practicality and usability.

Design Opportunities from Opportunities and Gaps in the Market

Analysing the findings, suitability and usability directed approaches through better ergonomics would greatly benefit monitoring in the propagation phases 1 – 4, through specifically and appropriately targeted tools. Further, design opportunities also emerged around the improvement of tools that heavily focus on the monitoring of early plant development, (Full List – Figure 40 in Appendix).

Section Two

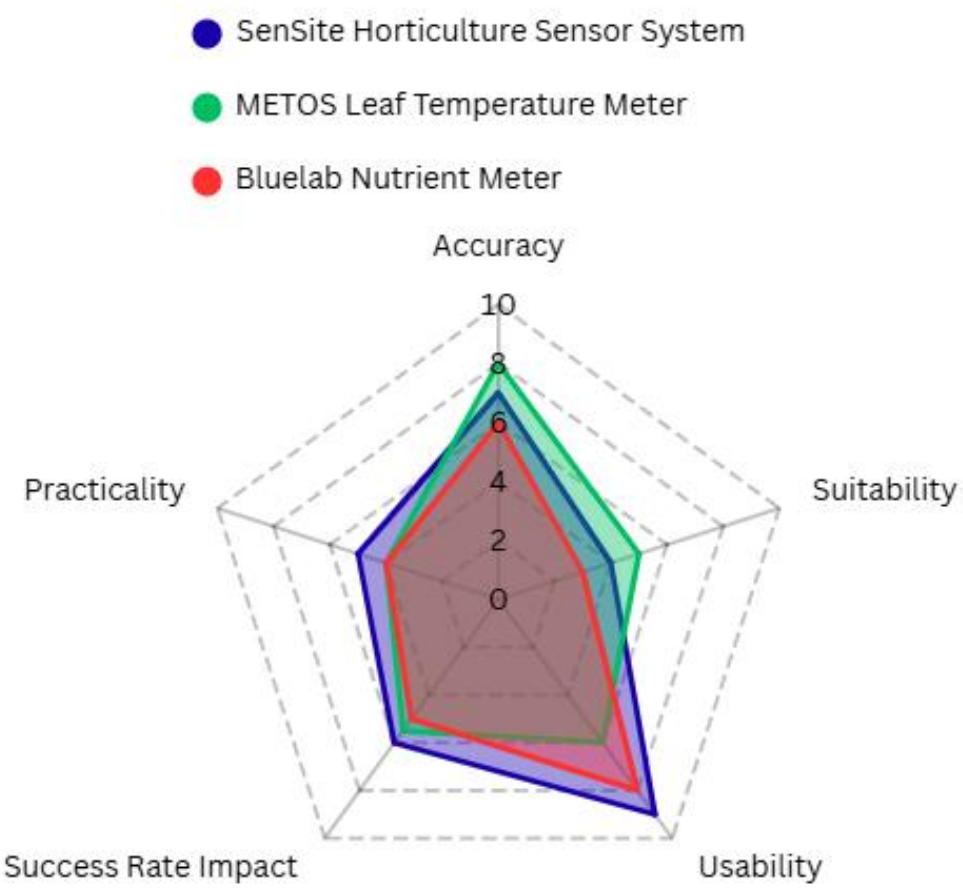


Figure 11: Representation of Benchmarked Products against criteria for Propagation Phases 5 – 8 (Figure 29 in the Appendix – SenSite, 2022, METOS, 2022, Bluelab, 2026b)

The system and 2 tools allocated to Section 2 were represented on a radar graph and graded upon each assessed criteria (Figure 13), where critical takeaways and opportunities were then identifiable. The radar graph clearly highlighted the main point that across all monitoring techniques there was a clear lack of alignment towards practicality and suitability which as a result flowed into negatively affecting success rate as a whole. This was pin pointed towards all 3 monitoring products being targeted towards a larger range of phases outside of the Section 2 phases (5 – 8) as seen in (Figure 29 in the Appendix). However, positive takeaways identified when analysing all the assessed monitoring products, was the importance around usability, and as explicitly pointed by the graph, its relatedness to accuracy.

Design Opportunities from Opportunities and Gaps in the Market

Analysing the findings, directed approaches that target the propagation phases of 5 – 8 through environmental conditions would help the monitoring of early and developing roots and shoots. Further, design opportunities also emerged around the monitoring aspects of plants below the surface, (Full List – Figure 40 in the Appendix).

Section Three

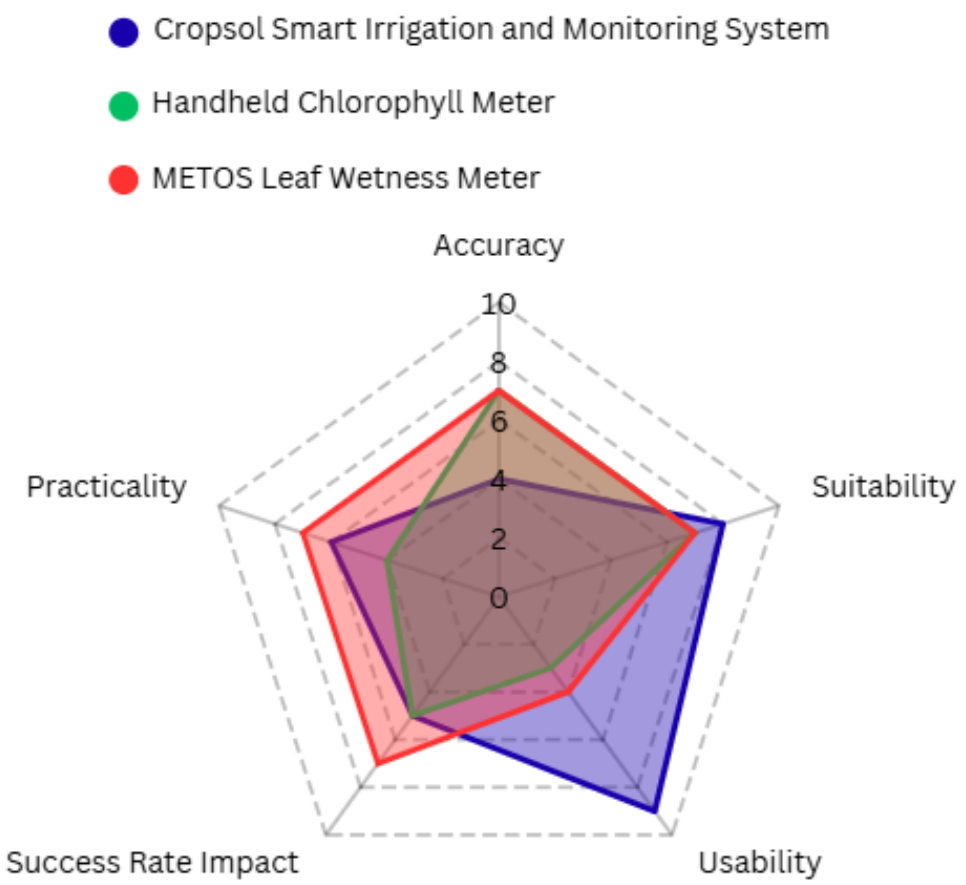


Figure 12: Representation of Benchmarked Products against criteria for Propagation Phases 9 – 12 (Figure 29 in the Appendix – Cropsol Irrigation and Management Control, 2026, KONICA MINOLTA, 2026, METOS, 2022)

The system and 2 tools allocated to Section 3 were represented on a radar graph and graded upon each assessed criteria (Figure 14), where critical takeaways and opportunities were then identifiable. The radar graphs presented that among all 3 of the monitoring products there was a different overall score against all 5 assessed criteria. However there was a difference between the monitoring system and tools in the criterions of accuracy and usability where the monitoring system had a high usability score and a low accuracy score, while both monitoring tools were found to be the complete opposite. This analysis was linked to information that is presented in (Figure 29 in the Appendix), about the monitoring system where it was targeted towards a larger group of phases, rather than just those in Section 3. Further, the system itself was not focused on accuracy due to it being an irrigation monitoring system where no actual information is collected directly from it, rather information is implemented into it.

Design Opportunities from Opportunities and Gaps in the Market

Analysing the findings, directed approaches that surround the propagation phases of hardening off and plant quality assessments were identified to exist through the combination of many monitoring aspects. Design opportunities also emerged around the transportation/dispatch and related health monitoring, (Full List – Figure 40 in the Appendix)

Benchmarking Overview

As seen through Figure 29 in the Appendix, across all 12 propagation phases there were some phases that had either 1 or 2 products from the entire 9 benchmarked products that fit them to some extend while other phases had no products that monitor them. Although this may be seen as a limitation of existing product collection, each benchmarked product that was selected had a minimum of 5 phases the tool or system helped monitor, with some monitoring tools reaching 8 of the total 12 propagation phases.

Specifically the phases where no benchmarked product was identified, was in Section 2, phases 6 and 7 which were described as Root Initiation in Controlled Environments and Root Development and Propagation Shoot Growth. Although there were highlighted specific monitoring systems and tools that directly partner with propagation phases 10 and 11, they were only partially monitoring the phases.

Design Opportunities from Opportunities and Gaps in the Market from Overview

Analysing the findings, design opportunities emerged around propagation phases 6 and 7 that have no monitoring representation, and an individual and system based monitoring product that allows for wider range of monitoring, (Full List – Figure 40 in the Appendix).

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Section 2

Research

The research that was conducted for the report used a range of data and other written information from a combination of both primary and secondary research in partnership with the triangulation technique. These methods were both utilised in the collation of research to formulate a better understanding of monitoring systems, tools and how they are implemented and used within early plant production nurseries. Further, the methods allowed for the gathering of both academic and industry knowledge and the influence all aspects of plant production and monitoring have of plant success rate overall.

Primary research was collected through the implementation and construction of a survey on Google Forms that was send to a large selection of wholesale nurseries across SEQ, that specialise in early and late plant production (Figure 31 in the Appendix). However, to gather further research, within the workplace the survey was attempted by a range of departments ranging from managers to horticulturalists. The survey was structured to ask questions that ranged in intensity from role within the nursery, to current monitoring systems and tools, to finally aspects of propagation monitoring that require improvement. These types of questions and their wording was understood through the lecture content presented in Week 4, (Gomez Rafael, (2026). The primary use of questions that were either multiple choice, yes/no and rating/scale questions was to collect quantitative data, (Figure 15 and 16).

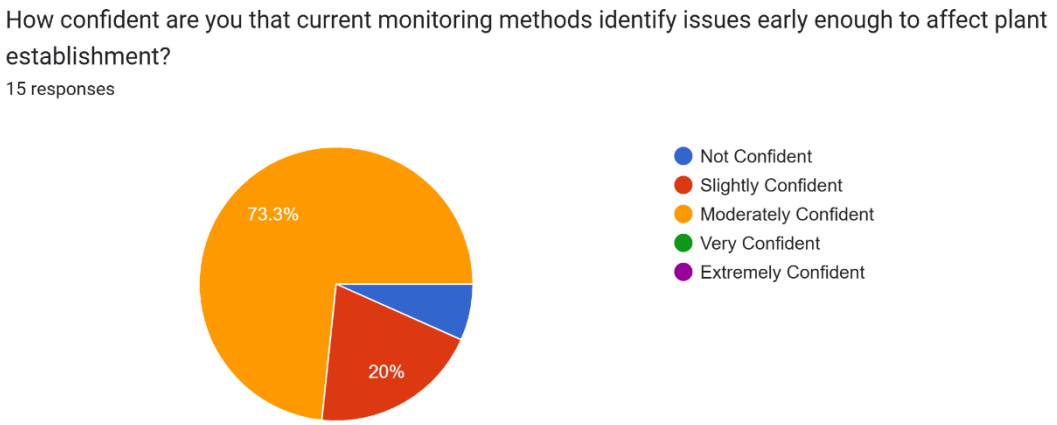
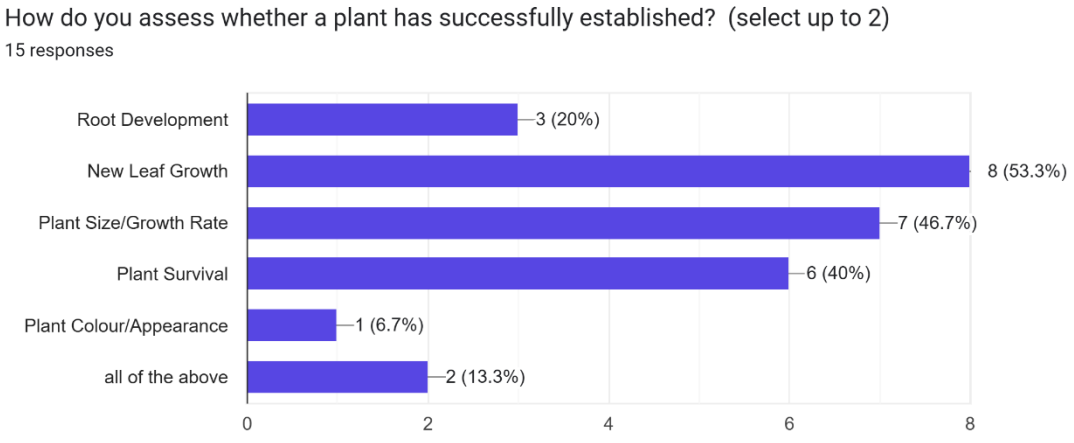


Figure 13:

Representation of Survey Results for a Single and Multiple Choice Question that allows for a Correlation



However, towards the end of the survey the questions changed to short and long response answers, allowing that allowed for the collection of qualitative data. Qualitative data questions were constructed to explore a wider and more complex range of aspects surrounding monitoring tools and systems, the propagation phases themselves and where complex problems arise. These types of questions were deliberately worded in a way that allowed for multiple themes and conclusions to be identified through analysis. Furthermore, all questions were constructed to allow for conclusions to be drawn from responses that surround the relationship between monitoring within the propagation phases and impacts towards success rate. As a result of the conduction methods of primary data unlike secondary research, primary research in the form of surveys allowed for a greater depth of understanding in aspects of practical knowledge and first hand common experiences from professionals in the field.

Archival research was the other method of research used in conjunction with surveys as part of the triangulation technique to collect research to analyse and interpret and draw design opportunities besides benchmarking research. This form of secondary research was used collected through vigorous researching of videos that clearly depicted monitoring within a nursery being conducted. Researching for relevant and in-depth videos was initially conducted by researching specific phases of plant propagation and development, however, the videos in the end depicted monitoring across many propagation phases. This was actually a benefit as it allowed for a larger analysis to be then conducted, thus allowing for a greater number of design opportunities.



Figure 14: Direct image from Archival Research that shows and explains monitoring from cutting to growing-on phase

The combination of both primary and secondary research and the analysis and evaluation of each research category helped to identifying opportunities and gaps in the market and progress towards design opportunities. Individually analysing and evaluating the data and information in the benchmarking, archival research and surveys, helped to initially construct several design directions for each from opportunities and gaps in the market that were identified. All design directions were then analysed for similarities and differences where narrowed and more concise design directions were then constructed.

Analysis and Findings

The analysis and findings section was where data and information collected through the research methods of archival research and surveys was firstly analysed through various techniques, where the information that was drawn from this process was stated as findings with reference to broader aspects of the research question. Further, the examination techniques allowed for design opportunities to be initially constructed from the findings presented.

Analysis

Archival Research

Archival research was conducted to find relevant video sources that depicted monitoring within nurseries taking place. These sources were analysed initially through a table that identified important timestamps and relevant comments (Figure 32 and Figure 33 in the Appendix), where a temporal event coding method was then conducted. This process was greatly beneficial in helping to identify key and relevant findings as well as opportunities and gaps in the market. Temporal event coding method involves the identification of key important timestamps throughout a process or task. Key aspects that were seen throughout the entire video were then collated, those became the "code". The "codes" were then highlighted on the table where they were found within the range of timestamps (Figure 20 and Figure 21). This method of research analysis allowed for correlations between codes to be identified as well as other crucial relationships and patterns to be identified.

Survey Research

Survey research was conducted to find data, information and statistics from real world representatives (primary data) where multiple choice and short answer questions were asked. The analysis method for those responses involved a mixture of graphs, charts and coding. The use of google forms for conducting the survey meant that any quantitative responses were automatically displaced in graphs and charts, where comparisons were made between the graphs and charts where needed. Similar to archival research, the temporal event coding method was used to analyse the short answer questions. However, instead of allocating tabs against a specific timestamps, they were allocated to anonymous participants – P1, P2, P3 etc, where an in-depth collation of codes from the short responses can be found in (Figure 38 and Figure 39 in the Appendix). This method of research analysis allowed for correlations between codes to be identified between the different participants instead of deciphering whole responses.

Findings

Archival Findings – Coding 1



Figure 15: Key Images from Video that helped to Identify Problem Areas "code"

Key Milestones Coded									
Timestamp	4.00	4.35	5.15	5.30	5.45	5.55	6.00	6.12	6.20
Damaged Root									
Visual Inspection Monitoring									
New Foliage									
Low Success Rate									
Growth Phases									

Figure 16: Table that Represents Coding Information for 1st Archival Research Video

Critically analysing (Figure 20) the coded temporal event table, there is a clear correlation between damaged roots in early propagation phases and the negative impact this has towards success rate when plants are ready for potting up. This strongly linked correlation is directly caused by the invasive monitoring technique of visual inspection damages and causes irreversible damages to newly developing roots. The coding also provides evidence that root and shoot development are not linked with only shoot development monitored as evidence of growth phases occurring.

Archival Findings – Coding 2



Figure 17: Key Images from Video that helped to Identify Problem Areas "code"

Key Milestones Coded									
Timestamp	0.40	1.00	1.20	1.40	1.55	2.10	2.40	2.55	3.15
Comparison Technique									
Biotic Factors									
Abiotic Factors									
Visual Inspection Monitoring									
Plant Removal/Tampering									

Figure 18: Table that Represents Coding Information for 1st Archival Research Video

Thoroughly analysing (Figure 22) the coded temporal event table, it can be seen that the comparison technique is used in direct partnership with the monitoring technique of visual inspection. This partnership that is identified between comparison technique and the monitoring technique of visual inspection is also shown to directly influence where plant removal/tampering occurs. However more specifically it can be said that the comparison technique was conducted via the monitoring method of visual inspection that was actioned through the removal/tampering of the plants. These techniques used either individually or combined have serious negative impacts towards success rate.

Survey Findings – Quantitative Data

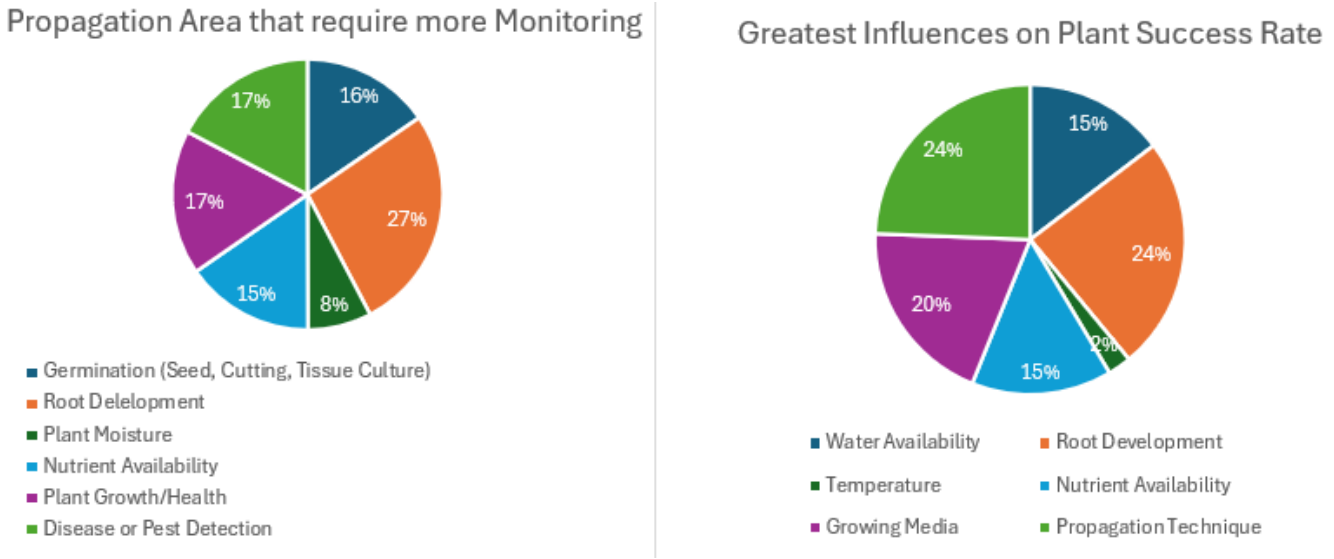


Figure 19: Correlation graph constructed with Two Pie Graphs from Raw Data (Figure 35 and Figure 36 in the Appendix)

The above graphs allowed for the identification of a key correlation between propagation areas that require more monitoring and the factors that influence plant success rate. Through the pie graphs it was identified that root development was the main propagation area that required more monitoring at 27%, where it was also identified as one of the biggest influences on plant success rate at 24%. However, the correlation also showed that the top 3 responses for both graphs are key aspects among many of the propagation phases.

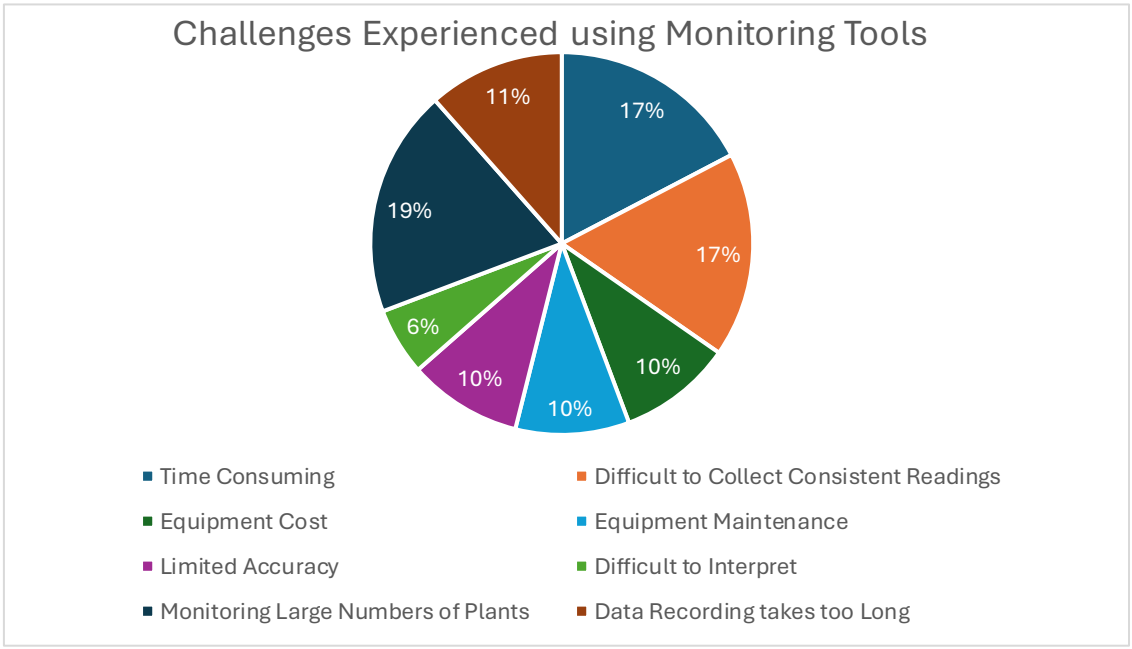


Figure 20: Pie graph constructed from Raw Data (Figure 37 in the Appendix)

The above pie graph shows that among the responses three main challenges associated with current monitoring tools can be identified. These challenges include;

- Monitoring Large Numbers of Plants = 19%

- Time Consuming = 17%
- Difficulty Collecting Consistent Readings = 17%

Although these results are not astronomically significant when compared to the other results presented on the pie graph, all three of these identified challenges directly relate back to the criteria of usability and suitability that was used to assess benchmarking criteria.

Survey Findings – Qualitative Data

Key Participant Notes Coded – Short Answer Response 1					
Participant					
	Environment	Monitoring	Growth	Assessment	Plant Health
Participant 1					
Participant 2					
Participant 3					
Participant 4					
Participant 5					
Participant 6					
Participant7					
Participant 8					
Participant 9					
Participant10					

Figure 21: Table that Represents Coding Information for 1st Short Response Answer

Analysing the above modified temporal event coded table it was seen that the "code" of environment was not linked through any participants comments to the other "codes" of monitoring and assessment. This suggested that factors surrounding environment are not considered when monitoring or assessing plants in relation to success rate. However across the rest of the table the same 2 "codes" (variables) are only found to link twice (participants 4 and 8) between all 10 participants.

Key Participant Notes Coded – Short Answer Response 2					
Participant					
	Early Growth	Development Growth	Monitoring	Root Development	Propagation Consistency
Participant 1					
Participant 2					
Participant 3					
Participant 4					
Participant 5					
Participant 6					
Participant7					
Participant 8					
Participant 9					
Participant10					

Figure 22: Table that Represents Coding Information for 2nd Short Response Answer

Analysing the above modified temporal event coded table it was seen that the "codes" of early growth and development growth were not linked through any participants comments, however between both codes they were only once liked to the "code" of monitoring. This suggested that monitoring is not adequately conducted throughout both early and developing growth.

Summary of Findings

Overall the analysis techniques that were used to analyse and interpret data for both the archival and survey research were greatly beneficial providing substantial and relevant findings to then be drawn from the data. The main finding from the archival research was the correlation between the comparison technique, and monitoring through visual inspection and the link these monitoring techniques had to plant success rate. The primary research survey gave in-depth insight into the challenges with using current monitoring tools and techniques and how some of the most crucial phases of plant propagation that were linked to success rate did not have adequate monitoring.

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Section 3

Discussion

Archival Research Coding

The archival research gave an understanding of opportunities surrounding the limitations of current monitoring techniques as it was found that throughout most nurseries there is a large reliance on visual inspection particularly throughout the stages of early propagation. The findings that followed this analysis suggested that although visual inspection is an accessible monitoring technique, it does not allow for adequate identification of developing issues in developing plants that resultingly impact success rate. Similarly the benchmarking research identified that through phases 5 – 9 where critical development occur, all products assessed in those phases did not adequately positively impact success rate (Figure 13). Design opportunities were then created for both benchmarking and archival research that covers monitoring approaches that provide adequate and analysable data during both root and shoot development, positively helping success rate.

Radar Graph 2:	
4.	- An approach that entails existing monitoring tools that redesigned and designed specifically towards aspects of propagation phases (5-8) rather than a wider range of phases.
5.	- An approach that focuses on monitoring environmental conditions that directly relate to early shoot and root development.

Archival Coding 1:	
11.	- An approach that investigates how success rate among early propagation can be better monitored before they reach the potting up phase of propagation, where negative impact to success rate are typically found.

Figure 23: Design Opportunities that fulfill the above Discussion (Full List Figure 40 Appendix)

The analysis also provided a key opportunity approach around the ability to monitor root development and health directly to provide an early identification of declining health below the surface rather than solely relying on above ground visual identification. The benchmarking research also identified issues surrounding health related monitoring. Although the elements were identified in later stages of product, it further justified that better health related monitoring is needed across the majority of plant production (Figure 14). These design opportunities are critical in relation to the research questions as they suggest that improving monitoring around early plant development will as a result help improve success rate.

Radar Graph 3:	
7.	- An approach that is directed towards monitoring within health inspection and transportation of plants where key aspects of possible diseases can be monitored and adequately adhered to either in storage or in truck transportation, placed within the plant batches themselves.

Archival Coding 2:	
13.	- An approach that develops a product that helps to monitor localised plant root-zones that specifically monitors a developing or maturing plants roots to help flag early detection of abiotic issues...potentially stopping it from becoming a biotic factor.

Figure 24: Design Opportunities that fulfill and above Discussion (Full List Figure 40 Appendix)

Survey Research

The quantitative survey research gave an understanding of opportunities surrounding the improvement of root development, usability, scalability and consistency of data collection through monitoring practises. The analysis found that root development was an area of significance for greater monitoring due to the influence it had on success rate. The analysis also identified challenges surrounding monitoring tools and techniques becoming less practical as production scale increases. The benchmarking research also identified issues surrounding root initiation and development, where it was found that suitability and usability were not adequately met by the products negatively affecting success rate (Figure 13). Information stated in both forms of research informed the basis for a design approach that provided practical information from a large quantity of plants.

Radar Graph 2:	
6.	- An approach that provides monitoring for gaps around below surface development such as root initiation and development.

Survey – Quantitative Data – Graphs:	
15.	- An approach that develops a monitoring method/tool that is specifically targeted towards initial root development that also helps to positively influence success rate.
16.	- An approach that develops tools that improve monitoring around the aspects of usability and suitability.

Figure 25: Design Opportunities that fulfill the above Discussion (Full List Figure 40 Appendix)

The qualitative data on the other hand through analysis gave insight into structuring design opportunities that surround strengthening environmental monitoring. However, similar to quantitative findings, qualitative findings also gave relevance for design opportunities for improved monitoring throughout early and developing roots and shoots, due to environmental influence. The benchmarking research also identified issues surrounding environmental influence of developing plants, where it was found that a lack of environmental monitoring in early initial development was further negatively affecting success rate (Figure 13).

Radar Graph 2:	
5.	- An approach that focuses on monitoring environmental conditions that directly relate to early shoot and root development.

Survey – Qualitative Data – Coding:	
20.	- An approach that allows for the incorporation of greater environmental monitoring and assessment into all plant propagation phases to strengthen the relationship between monitoring and success rate.

Figure 26: Design Opportunities that fulfill and above Discussion (Full List Figure 40 Appendix)

Interpretation and Relation to Literature

As a whole the research suggested that the issue of success rate related monitoring within nurseries was not due to a lack of monitoring tools or techniques, but the ability to gather the relevant information required to benefit plant success rate. Although the existing literature that was investigated within the background and benchmarking established the importance of aspects relevant to plant propagation, including environmental conditions and root development. The primary and secondary research provided a more specific view on the importance of monitoring these aspects. While these findings somewhat match with existing research, they further reinforced the importance of these aspects, where slight differences may have been due to individual responses or the scale of the nursery.

Knowledge Gained

Therefore all research combined reinforced the understanding that improving success rate within nurseries was only going to be achieved through greater propagation phases specific, objective and practical monitoring. This was as appose to simply increasing current monitoring techniques to fulfill monitoring needs for either large quantities of plants or an increased number of monitoring tools to reduce time conducting monitoring. Following this method for design was key to ensure a refined direction for the design concept process was established and to further create design criteria around the knowledge gained.

Design Implications

The analysis led findings and design opportunities created the basis for development and narrowing of a design direction. This process allowed for the establishment of limitations from the identified design opportunities and the affect they have on monitoring within wholesale nurseries and direct beneficial impact towards success rate. Instead of conceptualising concepts directly from one of the 21 identified design opportunities, 5 categories were created. The design opportunities identified from findings in the benchmarking, archival and survey research were allocated into one of the 5 categories. This approach allowed for design concepts to be influenced by a greater selection of key problem words from each design opportunity within a category.

The table below Figure 27 shows that across the 3 methods of research benchmarking, archival and survey, there was clear representation of the identified design opportunities across all 5 design categories. This shows that the issues that were relevant to the research question were prevalent through many forms of research, justifying the importance of these design categories.

Where the research question states; how can monitoring techniques and tools throughout wholesale nurseries can be improved to resultingly help improve success rate within the key propagation phases.

Design Categories from Design Opportunities			
Category	**Overall Approach**	**Design Opportunity Number**	**Research Area**
Category 1 – Root and Sub-Surface Development Monitoring			
	Key focus on tools and monitoring methods specifically targeted at underground growth, early root initiation and detecting root-zone related health issues	- 6	Radar Graph 2
		- 11	Archival Coding 1
		- 13	Archival Coding 2
		- 14	Archival Coding 2
		- 15	Survey – Quantitative
Category 2 – Data Collection, Scale and System Integration			
	Key focus on the ability to scale monitoring across large batches or multiple propagation phases to inform greater data consistency	- 7	Radar Graph 3
		- 9	Benchmarking Overview
		- 10	Benchmarking Overview
		- 17	Survey – Quantitative
		- 19	Survey – Quantitative
Category 3 – Usability, Ergonomics and Workflow Improvement			
	Key focus on a design that is user centred, and suitable for overall workflow optimisation	- 1	Radar Graph 1
		- 2	Radar Graph 1
		- 16	Survey – Quantitative
		- 18	Survey – Quantitative
Category 4 – Environmental and Media Quality Monitoring			
	Key focus on tracking external growth factors like preparing growth media and monitoring conditions	- 3	Radar Graph 1
		- 5	Radar Graph 2
		- 20	Survey – Qualitative

	during vulnerable early stages of propagation and development	- 21	Survey – Qualitative
Category 5 – Phase Transitions, Success Rates and Logistics			
	Key focus on managing large level outcomes around success rate like vulnerable transition periods and logistics/transportation	- 4	Radar Graph 2
		- 8	Radar Graph 3
		- 12	Archival Coding 1

Figure 27: Table representing the 21 identified design opportunities allocated into 5 categories with explanations of the key focus of each category.

The findings from the benchmarking, archival and survey research signal that whatever the final designs look like will prioritise the improvement of success rate throughout the propagation phases. Further, the designs will ensure that monitoring across both large and small quantities of plants are possible, where transitioning from one quantity to another does not mean an increase in monitoring time or labour requirements. The features of the design should ensure that aspects of ergonomics, interaction and accessibility are considered at all times. Lastly the design should allow for data collection and analysis that is easily actionable, further strengthening the interaction and accessibility for working to allow for early identification of issues that directly affect success rate.

The identification of design opportunities and their configuration within categories has directly influenced the above broad design criteria where establishing these criteria directly allows for initial concepts to be evaluated against them. The creation of multiple initial concepts for each category where evaluation against the design criteria will occur will ultimately ensure that the final initial concept picked for each category will have the best change of improving success rate.

Full List of Design Implications

Design Opportunities from Opportunities and Gaps in the Market:	
Benchmarking Research	
Number	**Design Opportunity**
Radar Graph 1:	
1.	- Through a usability led approach, developing products that are ergonomic or better suited to users in the specified phases where user case scenario would be needed to ensure relevance and intended use is met.
2.	- An approach that is led through the aspect of suitability, where instead of using larger monitoring tools for delicate tasks, developing a device that is better suited to developing cuttings that also incorporates the aspect of ergonomics and physical usability.
3.	- An approach that is specific towards monitoring preparation and environmental aspects of propagation media for quality propagation.
Radar Graph 2:	
4.	- An approach that entails existing monitoring tools that redesigned and designed specifically towards aspects of propagation phases (5-8) rather than a wider range of phases.
5.	- An approach that focuses on monitoring environmental conditions that directly relate to early shoot and root development.
6.	- An approach that provides monitoring for gaps around below surface development such as root initiation and development.
Radar Graph 3:	
7.	- An approach that that instead of using many monitoring products that are also relevant to other phases, incorporates main aspects relevant to the propagation phases in this section from each product into an overall plant assessment tool (hardening off phase – quality assessment phase).
8.	- An approach that is directed towards monitoring within dispatch and transportation of plants where key aspects of overall plant health can be monitored and adequately adhered to either in storage or in truck transportation, placed within the plant batches themselves.
Overview (Benchmarking Research)	
9.	- An approach that entails a monitoring system that specifically targeted towards the propagation phases that are not represented through the benchmarked products, in particular phases 6 and 7.

10.	- An approach that has the ability to be integrated within a monitoring system but also used independently to allow for monitoring to be conducted throughout a wider selection of propagation phases.
Archival Research	
Archival Coding 1:	
11.	- An approach that replaces the need for visual monitoring techniques that are frequently used throughout the initial root development phases, with a monitoring tool that provides more objective and analytical measurements to act upon.
12.	- An approach that investigates how success rate among early propagation can be better monitored before they reach the potting up phase of propagation, where negative impact to success rate are typically found.
Archival Coding 2:	
13.	- An approach that develops a product that helps to monitor localised plant root-zones that specifically monitors a developing or maturing plants roots to help flag early detection of abiotic issues…potentially stopping it from becoming a biotic factor.
14.	- An approach that incorporates a sensor or MRI style scanning tool that helps to monitor overall root health of plants in various phases of root and overall development.
Survey Research	
Survey – Quantitative Data – Graphs:	
15.	- An approach that develops a monitoring method/tool that is specifically targeted towards initial root development that also helps to positively influence success rate.
16.	- An approach that develops tools that improve monitoring around the aspects of usability and suitability.
17.	- An approach that allows for a large number of plants to be monitored more easily.
18.	- An approach that allows for improved time management and workflow usability when monitoring plants.
19.	- An approach that allows for improved consistent collection of data when monitoring plants.
Survey – Qualitative Data – Coding:	
20.	- An approach that allows for the incorporation of greater environmental monitoring and assessment into all plant propagation phases to strengthen the relationship between monitoring and success rate.

21.	- An approach that provides better monitoring to be conducted on propagation phases that include early and developing growth, to address the gap of monitoring developing plants.

Figure 28: List of all 21 Design Opportunities identified from the research methods = Benchmarking Research, Archival Research and Survey Research

Conclusion

The aim of the report was to investigate monitoring techniques, tools and systems within Wholesale Nurseries. After in-depth research into the topic was conducted and underlying problems and issues within the field were identified, a research question was constructed taking that took the form of; how can monitoring techniques and tools throughout wholesale nurseries can be improved to resultingly help improve success rate within the key propagation phases. The research methods of benchmarking, archival research and surveys were influential in identifying limitation and opportunities within current monitoring techniques and tools. The methods provided a range of findings with the benchmarking finding that among all products there was no consistency against the assessed criteria, no matter the propagation phase. Archival research found that monitoring technique of visual inspection was not only the most prominent monitoring technique, but it also had the greatest negative influence towards success rate, primarily in the early and later development phases. Lastly the survey research found that many monitoring techniques that were conducted in early development stages of plant propagation were not continued in later development, further impacting success rate.

The analysis methods used to analyse findings for each research method, allowed for findings to be identified, which influenced the establishment of 21 design opportunities, later organised into 5 key categories. The research suggested that issue of success rate related monitoring was not due to a lack of monitoring techniques or tools, but the ability to gather the relevant information required to analyse to then positively benefit plant success rate. Therefore, improving monitoring to positively influence plant success rate was identified as requiring greater propagation phases specific, objective and practical monitoring as appose to simply increasing current monitoring techniques to fulfill monitoring needs.

This understanding allowed for the establishment of a refined design direction and design criteria, providing a launch pad for concept development towards a refined design solution.

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