Current Lean production tool use in arable crop production

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Executive summary

The New Zealand arable industry is faced with an ever-increasing problem of maintaining a competitive and profitable advantage, that still provides for its consumers. These challenges are compounded by increasing environmental compliance. Lean theory offers an ever-evolving group of practices, both theoretical and managerial, that create a problem-solving culture, that could help the New Zealand arable industry face these challenges. Critical to Lean is continuous improvement, learning, waste elimination, and customer satisfaction. Lean tools have been explored in the wider agricultural industry, with literature indicating benefits of improved product quality, yield optimisation, enhance personnel management, waste reduction, and product value creation. Other than financial benefits, both psychosocial and environment can be improved with Lean use. When considering arable agriculture very little information is available regarding Lean. To identify any current use of Lean tools or active Lean theory in New Zealand arable industry, five managers from the New Zealand arable agriculture industry were interviewed. Interview questions helped identify any Lean management practice use, or any currently used management practices that fit with Lean. Interviewees showed several underlying managerial ideas that fit loosely with Lean theory, these include standardised work procedures, Jidoka, continuous improvement, learning, error detection, waste, and value definition. Using these existing managerial ideas as smaller localised steps of change, could offer a pathway for increasing the use of Lean in New Zealand arable agriculture. Lean flow can be considered to fit well with New Zealand arable production, but Lean customer pull is expected to be difficult to adopt with current production programmes. Difficultly with Lean pull, is primarily due to the complicated biological system that drives arable production, rather than customer requirement as the driver for Lean pull. Pull is expected to be a primary challenge with further adoption of Lean into New Zealand arable agriculture.

Recommendations include:

- further research is required to interpret Lean customer pull and the interaction with the arable biological system.
- Identify any New Zealand arable producers that operate under a Lean business model.
- Use Lean in a trial adoption, i.e., from the start to finish of one arable crop.
- Using some of the underlying Lean ideas to help enhance management if full Lean system adoption cannot occur.

Key words: New Zealand, Arable, Agriculture, Lean, Continuous, Improvement, Waste, Learning, Customer.

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Table of Contents

List of Tables

1. Introduction

Providing value to customers, while maintaining both a competitive, and profitable advantage are persistent concerns of the manufacturing industry (Andersson et al., 2020). Likewise, the New Zealand's (NZ) arable agricultural industry, is faced with these exact some concerns, but compounded by an additional tidal wave of environmental compliance (Callaghan, 2021). A pathway to help manage both profitability, customer value, and potentially environmental compliance is via the use of Lean. Lean theory, and Lean tools offer concepts that rely on quality and productivity that reduce costs, and improve productivity, offering significant industry benefits (Alves et al., 2014; Andersson et al., 2020). Lean is well proven in line based automotive manufacturing industry, and has been successfully implemented in almost all forms of manufacturing and service industries, including: healthcare, schools, electrical manufacturing, software services, and government (Alves et al., 2014).

While the NZ arable agricultural and the wider NZ agricultural industry have a strong reputation for delivering high quality products, and remaining competitive, there are both opportunities and risks that can both enhance and disadvantage the industry (Callaghan, 2021; Proudfoot et al., 2021). The works of Dora, Lambrecht, Gellynck, & Van Goubergen (2015), and Melin & Barth (2018), considered that the agricultural industry could benefit from the utilisation of Lean, to enhance financial success. Further works by Belhadi et al. (2018), and Andersson et al. (2020) indicate respectively that the environmental, and labour dimension of a Lean industry can also be of benefit. With profitability, environment, and labour, presented as both opportunities and risks to the wider NZ agricultural industry as well as the NZ arable industry, Lean utilisation could offer significant advantages.

Published work on the benefits of Lean to the NZ arable agricultural industry are limited, with the work of Hocken and Hocken (2019) notable in the wider NZ agriculture industry, and Grigg et al. (2018) notable in NZ horticulture industry. Indicated in the work of Melin and Barth (2018), Lean uptake by farm industries can be difficult, this may not be the realty. Farmers are very good at solving problems and adopting new strategies to improve business. Examples in NZ agriculture can be freely found, such as: Adoption of tractor guidance with global positioning system (GPS), to reduce overlap, and increase repeatability (Mitchell, 2009). Livestock bred to be more suited to a specific farming system, e.g. Wiltshire sheep requiring no shearing (Mangapiri downs organic stud farm, 2021). Utilizing new plant varieties that give improved forage yields (Stewart, 2018). These examples led to farm business reducing costs, and improving productivity, via quality and productivity manipulation consistent with concepts of Lean. Supporting these examples Melin and Barth (2018), indicate that Lean may incorporate well into small, isolated components of the agricultural system, where results are obviously seen.

1.1. Objectives

This report helps explore any current Lean involvement, that NZ arable farmers may have in their system.

Objectives of the research:

- Identify current use of Lean tools in NZ arable agriculture.
- Interpret any active Lean theory in NZ arable agriculture.

2. Literature review

The objective of the literature review is to assess what Lean tools are available, and what could be expected to occur by implementing them into an agricultural production system. This review is not intended to be a complete account of all available literature, rather an indication of what has been performed.

2.1. Lean

There is no standard theoretical framework for defining "Lean production" to that of "Total quality management (TQM)" (Pettersen, 2009). Rather Lean can be considered the banner for a combination of adopted practices, that meet an organization's needs, sharing common assumptions with TQM, where practices are ever evolving (Pettersen, 2009). For simplicity, this report uses both Lean and TQM practices as one and is termed as Lean. As a suggested definition by Murti (2009), this report considers the underlying concept of Lean to be a problem-solving culture that relies on continuous improvement (CI) and learning, where waste elimination, and customer preference are critical underlying themes (Alves et al., 2014; Pereira et al., 2016).

The "Toyota production system" is considered the precursor to the development of Lean theory (Murti, 2009). After the end of World War II, for Toyota to meet a rapidly changing manufacturing environment, its capacity to learn needed to exceed the rate of environment change (Murti, 2009). This developed the culture of Toyota to exceed customer expectation, by following two core principles of "Continuous improvement" and "respect for people", developing the now core Lean principles (Murti, 2009; Toyota New Zealand, 2021).

With origins in the automotive industry, Lean is now found to be implemented in a large range of industries, that include insurance, electronic manufactures, school operations, health care, textiles, software development, banking, and courts of law (Alves et al., 2014). The primary benefits of Lean for these industries has been reduced costs, and improved productivity, allowing for improved profit without increasing resources, or redundancy of employees (Alves et al., 2014).

2.2. Concepts and tools of Lean

Summarised by Murti (2009) there is no one way of doing Lean, but multiple ways of achieving the desired Lean result. To create a sustainable Lean culture, many authors have created different systems, and theoretical models that fit with multiple industries, these include: P4 Model, lean management systems, and the Lean iceberg model (Murti, 2009).

Listed below are a range of common Lean tools that could be of interest in an arable agriculture production system or the wider agriculture industry:

2.2.1. Value stream mapping

Visual representation of both the flow of material and information through a production cycle from customer order to product receival (Grewal, 2008). Value stream mapping (VSM) shows all steps in the production cycle including, adding value and non-value to the product (Grewal, 2008). Seeing the current VSM allows for the development of innovative VSM that further meets the requirements of Lean. Value stream map creates a road map of changes, identifies waste, and waste source, and can help disseminate information (Grewal, 2008).

2.2.2. Five "S" of Lean

The five "S" represent the Japanese concept of good maintenance establishing the operational stability required to make CI, essential for a Lean workplace (Filip & Marascu-Klein, 2015). The five

"S" as described by Filip and Marascu-Klein (2015) are represented below, with Japanese translation in brackets:

Sort (Seiri) - Remove unnecessary things.

Set in order (Seiton) – Logically arrange things into standardised locations.

Shine (Seison) – Quality production is achieved in clean workplaces.

Standardize (Seiketsu) – Create standards that reduce mistakes, and search time.

Sustain (Shitsuke) – Evaluate, and continual improve all activities.

The five "S" primarily help to create a visual workplace, that is self-developing (Filip & Marascu-Klein, 2015).

2.2.3. Gemba walk

Refers to the process of observing, and interacting with the people at the work site, while they perform their duties (Dalton, 2019). Gemba is a Japanese term meaning real place. The objective of the Gemba walk is to get detailed first-hand insight into production, allowing for improvement as well as system checking (Dalton, 2019).

2.2.4. Jidoka

Intelligent or autonomous automation is referred to by the Japanese word Jidoka (Deuse et al., 2020). Jidoka is used without human interaction to monitor production process, and detect problems with production (Deuse et al., 2020). Jidoka allows for early detection, enabling production to be stopped autonomously, and abnormalities rectified (Deuse et al., 2020).

2.2.5. Hoshin Kanri

Hoshin Kanri, is a Japanese term that is commonly related to companywide policy management (Witcher, 2003). Hoshin Kanri is used as a system for managing companywide effort, helping to achieve company strategy (Witcher, 2003).

2.2.6. Kaizen

Gradual or CI made over time are referred to by the Japanese term Kaizen, with a Kaizen event considered to be a rapid improvement (Manos, 2007). Continuous improvement can also be considered to be the pursuit of perfection (Sundar et al., 2014). Continuous improvements under pin Lean theory and create qualitative and quantitative benefits, that help drive organisation competition without major investment (Manos, 2007).To achieve Kaizen, a suitable business culture is required to develop over time, that relies on never settling for the status quo or the pursuit of perfection (Al Smadi, 2009; Sundar et al., 2014).

2.2.7. Muda

Waste is termed in Japanese as Muda, and in Lean is anything within the production cycle that does not have value, and should consequently be removed (Arunagiri & Gnanavelbabu, 2014). Suggested by Domingo (2015), there are seven primary wastes: processing waste, transport waste, overproduction waste, waiting time waste, inventory waste, motion waste, and defects. Domingo (2015) further indicates that waste, can be hidden or visible, with hidden waste of a larger issue to production. Critical to producing more from less in lean production, waste is conceded to be a key component to achieving Lean (Arunagiri & Gnanavelbabu, 2014).

2.2.8. Root cause analysis

Root cause analysis (RCA) covers a range of methods that help to identify the primary underlying causes of problems within the production system, not just obvious problems (Hubbard, 2010). Commonly the five "whys" method is used for RCA, it follows a systematic investigative approach (Hubbard, 2010). Identifying the root cause, allows for curative actions to be put in place that prevent the problem from recurring, this is considered to be a continuous improvement typical of Lean (Hubbard, 2010).

2.2.9. Standardized work

Standardised work is the best method for every situation, that maximises the principles of Lean (Pereira et al., 2016). Standardised work ensures knowledge is maintained, and shared, but also gives a base activity where continuous improvements can built upon, maintaining Lean (Pereira et al., 2016).

2.2.10. Poke- Yoke

Poke- Yoke (PY) also termed mistake proofing, refers to a control system that detects errors arising within the production system, that can be actively or passively prevented (Lazarevic et al., 2019). As well as identifying mistakes from human or automatic production, PY also helps to identify failings in management, training, and design (Lazarevic et al., 2019). While PY ensures customers receive error free production, it also further offers that ability to apply other lean theories, such as Muda to the production system (Lazarevic et al., 2019).

2.2.11. Value Definition

In Lean, the value of a product is defined via the customer, not via the businesses vertical chain of production (Setijono & Dahlgaard, 2007). In this case a business will attempt to acknowledge customer value of a product and then supply the value (Setijono & Dahlgaard, 2007).

2.2.12. Flow

The movement of operations through a system is termed flow (Kettering global, 2018). Consistent flow allows for a reduced chance of waste accumulation, and enhanced efficiency of the system (Kettering global, 2018). Obstructions of flow can be considered to be both physical and intangible (Kettering global, 2018).

2.2.13. Pull

Rather than production being pushed downstream, pull production relies on an upstream pull (Powell et al., 2013). With pull, no proceeding steps in the system are completed until the customer downstream askes for it (Powell et al., 2013).

2.3. Lean in agriculture

Lean was characteristically developed and implemented in industry that has strong standardised production, with the application of Lean into more diverse industries now occurring (Alves et al., 2014; Dora et al., 2015). Not dissimilar, agricultural industries follow some form of standardised production, that characterises a typical industry that would utilise Lean (Grigg et al., 2018). Published work that explores or adopts Lean into agriculture is available, with some notable authors Dora et al. (2015), Grigg et al. (2018), Melin and Barth (2018), and Voskuilen (2010) having produced work that is or can be applicable to NZ agriculture. Advisory available that directly helps implement Lean into agriculture production is limited, but still existent, with Jana Hocken, and Tim McLean both offering Lean consulting and information services in NZ (Hocken, 2021; Hocken & Hocken, 2019; TXM Lean solutions, 2021).

As with other industries, Lean offers similar advantages to production in agriculture. In the NZ horticulture industry, that shares similarities to the NZ agriculture industry, Grigg et al. (2018) identified advantages with the use of Lean tools: value definition, flow, Pull, perfection, and value stream mapping. Lean tools identified by Grigg et al. (2018) were constant to those identified by Dora et al. (2015), where a more broad agriculture industry approach was considered. Primary advantages found within literature relating to Lean tool implementation in agriculture include but not limited to: improved product quality, yield optimisation, improved facility layout, enhanced personal management, understanding of competitors, waste reduction (Including over production, time loss, reducing costs), anticipation or mitigation of external shock (e.g. weather, and marketing), and product value creation (Dora et al., 2015; Grigg et al., 2018; Melin & Barth, 2018).

The commonalities between agriculture production and more standardised manufacturing production, make agriculture a good candidate for Lean, but the difference between the two can hinder Lean adoption (Dora et al., 2015; Melin & Barth, 2018). The table produced by Dora et al. (2015) shown below as Table 1, gives example of where manufacturing sector and agriculture industry sector divergence can occur, when considering Lean. Both Dora et al. (2015), and Melin and Barth (2018) entertain the idea that agriculture production has unique attributes over the manufacturing sector that included: short shelf-life, seasonality, biological production processes, long lead times, low product variability, highly repetitive environment, and characteristics of the farm (e.g. business size, inter-generational, family). Consistently, published work indicates that for Lean advantages, and Lean tool implementation to occur in the agriculture sector, the sectors unique attributes need to be considered (Andersson et al., 2020; Dora et al., 2015; Grigg et al., 2018; Melin & Barth, 2018).

Table 1 *Differences between manufacturing and the agriculture sector, reproduced from Dora et al. (2015).*

Manufacturing sector	Agriculture sector
Generally non-perishable products	Highly perishable products
Standardized raw materials	Variation in quality of raw materials, supply, and price
Relatively limited number of designs	High variation of composition, products and farming techniques, variable yield and duration, variable product structure
Processing equipment is not necessarily sequence-dependent	Highly sequence-dependent
Mostly independent of external factors (e.g., weather) influence	Mostly dependent of external factor (e.g., weather) influence

Though advantages of Lean as a concept being utilised in agriculture are promising, actual industry up take is considered to be low (Grigg et al., 2018). Found by Grigg et al. (2018), close to one percent of the NZ horticultural industry (in this case a similar relationship may be expected for the NZ agricultural industry) was considered to be under taking by definition Lean management, importantly management was cited to be a primary barrier to Lean uptake. Interestingly in line with Grigg et al. (2018), Melin and Barth (2018) found a similar up take of Lean with Swedish farmers, that were supplied directly with Lean coaching, with management also a primary barrier to uptake. Managements understanding of Lean philosophy, realistic Lean results and success time frame is suggested in the works of Andersson et al. (2020), Grigg et al. (2018), and Melin and Barth (2018) to be the primary driver of low Lean up take in agriculture.

2.4. Implementation of Lean

The education strategy for incorporating Lean into the agriculture industry can have a primary bearing on the level of Lean result achieved (Andersson et al., 2020; Grigg et al., 2018; Melin & Barth, 2018). Suggested by the work of Melin and Barth (2018), teaching Lean tools rather than Lean theory, where farmers achieved quick wins tended to show farmers being less resistant to Lean implementation. Opposing Melin and Barth (2018), Andersson et al. (2020) that looked at the same trial, indicated famers that adopted a stronger philosophy of Lean rather than a quick win mentality tended to have longer term increases in desirable Lean results, out surpassing the farmers focusing on the quick wins. Focusing on teaching the philosophy of Lean for integrating into the system is supported both by Grigg et al. (2018) in the NZ horticulture industry, and Murti (2009) assessing a range of in NZ company's. Targeted teaching of Lean tools to give some quick wins, for a new system could lead to reducing resistance to Lean adoption (Melin & Barth, 2018). Following up the initial quick wins by focusing on developing Lean theory, could lead to much better long-term results and adoption of Lean (Andersson et al., 2020; Melin & Barth, 2018; Murti, 2009).

Management and personnel are the primary drivers of effective lean implementation into a system (Alves et al., 2014; Andersson et al., 2020; Melin & Barth, 2018; Murti, 2009). Found by Melin and Barth (2018) in agriculture, and Murti (2009) in NZ company's, failure with Lean implementation, can be related to resistance to change, and lack of suitable understanding, predominantly driven by management. Suggested further by Melin and Barth (2018) managers that had a poor attitude to adopting lean tended to drive other employees to adopt similar feelings further restricting Lean. Additionally Murti (2009) indicates that poor attitude, can be related to inherent short term thinking culture of the current system. Poor attitude can also be driven by: discouraging lack of long term gain, hesitancy to change, education, market analysis, and work delegation (Murti, 2009). Increasing strong top-down leadership, and reducing conflict between adopters, and non-adopters, and promoting longer term thinking, could lead to improved implementation of Lean (Melin & Barth, 2018; Murti, 2009). Importantly to consider, Murti (2009) indicates NZ businesses are very good at adopting quick win approaches. Inherit industry adopting strategy's, could lead to difficulties with implementing Lean into NZ agriculture. Adopting Lean into smaller more isolated components of the system, though slowing down Lean implementation could offer a way to combat management attitude (Melin & Barth, 2018).

2.5. Unintended consequences of Lean

Maintaining the current work force is a primary object to Lean, the workplace environment can be impacted by Lean (Alves et al., 2014; Andersson et al., 2020; Womack, 2007). Indicated by Andersson et al. (2020) both the psychosocial and physical work environment was improved for farmers utilising Lean in their study, this was supported by the work of Womack (2007) regarding the manufacturing sector. Improved workplace environment can be attributed to enhanced health and safety monitoring and problem solving, reduced fatigue (Physical and mental), improved communication, improved co-operation, better work structure, and reduced injury's (Andersson et al., 2020; Womack, 2007). Contrary to these improvements, Womack (2007) identified in their literature review, but not supported by their research, that lean production can negatively impact worker health. Negative impacts that have been suggested from Lean to employees include: work related musculoskeletal disorders, increased workloads, decreased autonomy, increased fatigue, and awkward postures (Womack, 2007). New Zealand agricultural industry relays heavily on the personnel component, and is currently struggling to fill job roles (Kelly, 2021). Understanding how Lean could enhance or disadvantage people in the work environment should be an important consideration for adopting Lean, to help fill job vacancies and maintain current personnel.

Underlying concepts in achieving Lean can lead to unintended or intended ecological environmental consequences (Abreu et al., 2017). Key tools in achieving Lean, increasing efficiency, and reducing waste, can lead to a subsidiary complementary effect of improving environmental impact of production (Abreu et al., 2017; Belhadi et al., 2018; King & Lenox, 2001). This can be seen in the work by King and Lenox (2001) where businesses in their study that implemented Lean had a reduction in total toxic polluting emissions, increased relative environmental performance, and increased voluntary adoption of environmental management systems. On the other hand, Lean systems drive consumer value, if consumers value requires a lower environmental impact, the Lean systems will supply (Abreu et al., 2017). Agricultural production in NZ is coming under increasing scrutiny by the public and regulatory regarding negative environmental outputs (Mitchell, 2017). Lean adoption into the NZ agricultural systems could offer another strategy to reduced negative environmental output.

2.6. Conclusion

Lean is an ever-evolving group of adopted practices, both theoretical and managerial, that creates a problem-solving culture (Pettersen, 2009). Critical to lean is CI, learning, waste elimination, and customer satisfaction (Pereira et al., 2016; Pettersen, 2009). Lean tools have been explored in the agricultural industry, with literature signaling similar benefits to more traditional manufacturing industry's (Andersson et al., 2020; Hocken, 2021). Benefits that can be expected in agriculture include Improved product quality, yield optimisation, enhance personnel management, waste reduction, and product value creation (Dora et al., 2015; Grigg et al., 2018; Melin & Barth, 2018). When implementing Lean into agriculture, resistance can be expected, consider when initially implementing Lean, target components that are in isolation that can give quick wins, then developing Lean more widely for longer term gains (Andersson et al., 2020; Melin & Barth, 2018; Murti, 2009). When implementing and considering lean, other than the financial benefits, both psychosocial, and environment can also be benefited (Abreu et al., 2017; Andersson et al., 2020). Lean offers some strong advantages to the agricultural industry, but care needs to be taken in the implementation phase.

3. Materials and Methods

Utilising recommendations from Melin and Barth (2018) and insights gained via literature review, a small subset of five NZ arable farmers are considered for investigation.

Case study methodology consistent with that outlined by Tellis (1997) was used to construct the investigation method. Key information was supplied via personal interviews with a select group of five arable farmers. Interviewees were asked a range of engaging questions, to identify any existing Lean tools or Lean theory they currently use. Questions, and question process was constructed to help mitigate questioner leading interviewees answers. Questions that were used in the interview process are given in Appendix one, Table 2. Interviewees were given a brief introduction into Lean, and the background for this research at the start of the question session.

Interviewees were selected on a primary bases, that each farm system was similar allowing for differences in interviewee management and ideas to be the focus. Interviewees were selected via the following criteria: primary business income from arable production, primary manager of the business, all aspects of the production can be undertaken in house (e.g., no full reliance on contractors or sub leasing land), land class of each interviewees land is similar.

On completion of interviews, data from each interview was considered qualitatively on both intrinsic, and instrumental values. Thematic analysis, out lined by Braun and Clarke (2006) was used to compare and contrast the data collected, and interpret in accordance with the literature review.

4. Results and Discussion

Of the interviewees, none had any prior experience with Lean use in their business, although some had a rudimentary idea of Lean. This is consistent with Grigg et al. (2018) in the NZ horticultural industry, and Murti (2009) in NZ manufacturing industry, both suggesting a lack of managerial, and operation understanding of Lean in NZ organisations. Though lack of Lean understanding is of no consequences in the case of this research project, it is an important aspect to consider if Lean is to be introduced into a NZ arable agricultural business. Murti (2009) suggests that where knowledge of Lean is low, the lean implementation tends to follow a more proscribed linear step by step process, giving some short-term Lean wins, that is good for gaining initial Lean business buy in. Murti (2009) as well as Melin and Barth (2018) in Swedish agriculture, implied that business challengers don't normally present themselves in simplified linear nature, making Lean taught linearly of little long term benefit. Learning of Lean needs to target a flexible, and evolutionary process, that is crucial to allowing a Lean business to meet external and internal challenges (Melin & Barth, 2018; Murti, 2009). Through the Interview process, it was clear NZ arable agriculture businesses do not follow a simple path of challenges, and are required to be flexible, and resilient to meet environment (natural and economic), and biological system challenges. For a successful incorporation of Lean into the NZ arable agriculture industry, a high level of education is required.

As expected during the interview process, interviewees indicated that several primary lean concepts and Lean tools had strong resemblances to their currently used business processes. Although guiding Lean principles, and a lean tool-based approach was not apparent, the underlying ideas were similar. For example, when considering standard work process, almost all interviewees had a standard process for combine harvester, and drilling operation, but not considered formally as such. Similar, Jidoka with automation of both task operation and error detection was very common in use, this was frequently seen with the use of semi-autonomous GPS tractor and irrigation guidance, as well as with sectional control for irrigation, drilling, spraying and fertiliser application. Semi-autonomous enabled the interviewees enhanced control that improved product and implement placement, to reduce wastage of time, and inputs. Considering present processes that share similarities to Lean, could offer a pathway of reduced resistance when implementing Lean into a NZ arable agricultural business. Both the works of Melin and Barth (2018) and Murti (2009) suggested, overcoming manager resistance to change is a primary issue for Lean implementation. Using the current operations undertaken by managers but modified to align more to Lean principles could offer smaller steps towards change, that could minimise initial manager resistance. Small effective steps with quick wins gives evidence to managers the benefits of Lean. Through the interview process, interviewees were relatively risk adverse, and conservative when new opportunities present. Taking smaller steps to change, that allows for lower risk to exposure or reversable operation, may offer a conservative approach that fits better for initial Lean adoption into NZ arable agricultural business.

When the primary concepts of Lean are considered: CI, learning, waste, and customer preference, interviewees indicated that these were of current consideration, although not directly as a true Lean concept. General results for each of these concepts are summarised bellow:

4.1. Continuous improvement

Commonly the interviewees shared a somewhat perfectionist outlook of their business, where they strived to always improve their operations, neatly fitting Sundar et al. (2014) description of CI. Advocated by Manos (2007), Lean CI should be considered low cost, and a less dramatic shift to a business. In which case the interviewees indicated that a lack of capital was a primary restriction to business improvement, not neatly fitting Manos (2007) idea of CI. Although it must be conceded that

the interviewees showed a strong understanding on relative demising returns of input, as well a strong avoidance to risk, suggests that their underlying answer to this question may have been missed by the interview questions.

4.2. Learning

Interviewees showed a strong desire to learn, and somewhat unexpectedly strong openness to change. Interviewees used a wider range of learning resources including newspapers, and technical information, importantly the idea of discussion and seeing new things tended to be a more desired method for learning. Suggested by Murti (2009) literature review, learning in relation to Lean should follow a double loop process and not a more traditional single loop process. With a single loop process, an error is detected, but the activity of the business is not changed in any way to prevent the error reoccurring, whereas double loop learning the business modifies its process in some way using the error information to lead to improvement (Murti, 2009). Considering, Interviewees showed learning with RCA, where after an issue was found a change in procedure was made. A clear example of this occurrence occurred when an interviewee, found that hand turning seed during the drying process was costly in time, reduced quality, and reduced quantity of dried seed, this led to the development of a mechanical turner that reduced the labour time, maintained the original seed quality, and reduced the time required to dry the seed. This offers an example of double loop learning but also, one of CI. Simple changes to business operation are seen by the interviewees, but a more combined learning approach between single and double loop may be more normal for the NZ arable agricultural industry.

4.3. Waste

Of the primary Lean concepts, the interviewees had a very strong handle on the concept of waste, though not always put in practice. Similar to the types of wastes listed by Domingo (2015) the interviewees identified a number of wastes that can be considered hidden and visible waste. For example, one interviewee indicated that due to poor livestock handling facilities, livestock numbers were lower than the carrying compacity of their property, resulting in wasted potential and a hidden waste to the business. Visible wastes were also indicated by interviewees, for example over or under supply of fertiliser, resulting in inefficient agronomic and environmental gains, gives a visible production loss. Notable time and opportunity cost of time was considered by the interviewees to be a primary waste that they had difficulty in managing. When considering several farming practices and improvements undertaken or desired by the interviewees, e.g., tractor GPS guidance, irrigation, product application equipment, tractor size, these all relate directly to maximising efficiency. The work by Robertson (2010) shows that increased efficiency and therefore productivity, has been the long term driver of NZ agriculture growth, over the last 40 years. Focused productivity increases could suggest the concept of waste, not necessarily uniform to Lean theory, is already well established in the NZ arable agricultural industry.

4.4. Value definition

Interviewees indicated that the specification of their products was primarily dictated by the customer, where their ability to manipulate specification was low. The interviewees businesses meet the criteria of customer defined value, in accordance with the definition by Setijono and Dahlgaard (2007). Where the business acknowledges the specification set by the customer, and attempts to supply the specification (Setijono & Dahlgaard, 2007). For a true Lean supply chain, the value stream flow needs to allow the customer to pull the product from the producer (Setijono & Dahlgaard, 2007). With regards to the interviewees, their businesses have limited ability to manipulate flow and pull of the value stream. In arable production, there is some ability to manipulate the flow of production with agronomic practice, e.g., sowing date, agrichemicals, fertiliser etc. In most cases

interviewees consider the flow of production to be fixed by the seasonal and biological production system, e.g., plants will go to seed, regardless of farmer management, and they can only optimise this system with available management. The work of Grigg et al. (2018) in NZ horticulture, considers that Lean tools and methods that optimise the machine, in their case orchid trees, is flow management. This same idea can be considered in arable production, where the crop is considered the machine, therefore allowing Lean tools to optimise the crop, and flow. Furthermore, the biologically driven flow in the arable system resists any pull from the customer, leading to a significant challenge for Lean use. The interviewees indicated that they had no ability to manage pull. Some interviewees noted, conflict can arise where the biological system is not considered when product specifications are set, for example some crop types may not have the genetic potential to meet customer requirements, regardless of grower management. In similar accord, Grigg et al. (2018) observed the seasonality of production was a primary challenge for Lean adoption in NZ horticulture when customer pull is considered. Agriculture production in NZ, particularly arable crop production due to its seasonal and biologically driven nature struggles to meet the flow, and pull of a Lean system, offering a significant challenge for the implementation of Lean.

5. Conclusion

Lean offers several advantages to the NZ arable agriculture industry that includes improved product quality, yield optimisation, enhance personnel management, waste reduction, and product value creation. Additional benefits to psychosocial, and environment can also occur.

New Zealand arable agriculture producers tend to have several underlying managerial ideas that fit with Lean theory. Ideas include standardised work procedures, Jidoka, CI, learning, error detection, waste, and value definition. Though ideas are not strictly in accordance with lean business model, they offer initial smaller localised steps for targeted change, where Lean theories can be developed. Keeping initial steps small to show initial Lean benefits, fits well with the risk adverse and seeing is believing nature of NZ arable producers. Lean becomes difficult to implement and manage when the value stream flow and pull for NZ arable agriculture is considered. While NZ arable producers can manage some flow of production, the pull of production is dictated principally by the biologically driven agriculture system more than customer requirement, favoured with Lean management. This makes following Lean theory a challenge when customer pull is to be implemented.

5.1. Recommendations

- Further research, and interpretation of customer pull and the interaction with the biological system is required before a full system integration of Lean could occur in a NZ arable agricultural system.
- Identify any NZ arable producers that operate under a Lean business model. These producers could help to further identify the challenges of Lean adoption, but also indicate actual realised Lean benefits and disadvantages in NZ arable production.
- Use Lean in a trial adoption such as from the start to finish of one arable crop.
- Use some of the underlying Lean ideas in management if full Lean system adoption cannot occur.

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Appendix one

Table 2 *Questions asked of each interviewee during the interview process.*

Lean tools being considered	Questions
General questioning	Do you have a vision for your business? Are you improving as a business? Is there a timeline for improvement? What are the challenges you are facing with improvement? How are you coping with these?
CI and Kaizen	When improvements are sought, how do you approach these? Are you looking at big sift improvements or little shifts? Any justification? How do you determine the point to stop an improvement and move on?
Learning	How do you extend your understanding, relating to the business?
Gemba walk	How involved do you get with day-to-day operations? Do you feel you should be move involved or less involved? Why do you think this?
Jidoka	Is there any automation in your business? What is it? What would you like to automate or mechanise in the business? Why?
Hoshin Kanri	Do you have any business policy, ideas, or themes? What are they? Are these well known by those working or associated with the business? Why do you have these? Do you get any value from them?
Muda	Do you see any inefficacy's or wastes in your business? What are the primary ones? How are you approaching these?
Root Cause analysis	When you have had issues in production, how have you identified them? What did you do to fix them?
Standard work	Do you have any activities that have a standard process? How do you share this with operators? Do you see any value in standardisation?
Poke Yoke	How do you prevent problems or mistakes occurring? How did you find this effective?
Value definition	Do you have product specifications? how are these determined? What do you do to meet these specifications? Do you have any ability to manipulate product output? Are you driven by product specification? Why?
Flow	How is you production process driven? How do you keep things moving to the next stage?
Pull	How is the next step in production triggered? Why does it happen this way?
Five "S"	Is your workplace visual? Any examples? Is clean and tidy ever associated with your workplace? Any resining? Are there any standard locations for things used? Why do you do that?