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Lean Philosophy in Agricultural Production: A Literature Review on Türkiye

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ABSTRACT
This study is a review article that addresses the potential of lean production philosophy to reduce waste and increase process efficiency in the manufacturing processes of agricultural products. Lean production is widely applied, especially in the manufacturing sector, as an approach that aims to eliminate waste, optimize processes, and increase value-added processes. Techniques such as Value Stream Mapping, Kaizen, 5S, and Kanban are among the basic tools of this philosophy and have produced important results such as reducing costs and increasing customer satisfaction in businesses. The application of lean production techniques in agricultural production is a relatively new field of research. In this study, studies in the literature on lean production techniques used in the production process of agricultural products are focused, and the results are evaluated. As a result of the examinations, it has been seen that lean production techniques can be successfully applied in the production process of agricultural products and provide significant improvements in processes. However, it has been determined that the studies conducted on using these techniques in agricultural production are limited. There is a serious lack of research on this subject, especially in Türkiye. This situation has brought to the agenda the need to reveal the potential of lean production techniques in agricultural production and to raise awareness to eliminate the deficiency in this field. The study aims to contribute to the literature on increasing process efficiency in agricultural production, reducing waste, and spreading lean production practices in the agricultural sector. Considering Türkiye's agricultural potential, it is evaluated that sustainable development can be achieved in the sector using lean production techniques.

Keywords: Lean, Agriculture, Waste, Production

1. Introduction

Agricultural production has become more critical than ever in line with the increasing population and global food demand (Hiywotu 2025). The pandemic period has revealed how vital agricultural production is not only for economic development but also for ensuring food security in societies (Hussain et al. 2025). Disruptions in food supply chains have led countries to increase the efficiency of agricultural processes and minimize waste in this area (Wang et al. 2024). Topics such as integrating IoT (Internet of Things) technology into the process, using UAV (unmanned aerial vehicle), and using artificial intelligence technologies such as remote sensing have been addressed to increase productivity, resource efficiency and sustainability in agricultural practices (Alexopoulos et al. 2023; Pandey & Mishra 2024). It is thought that eliminating existing waste should be a priority before using these technologies that require investment (Imai 2012).

Waste in production processes leads to economic losses and unnecessary use of natural resources. Especially in agricultural production, the efficient use of scarce resources such as land, water and energy is of great importance. Eliminating waste and optimising processes reduces costs and contributes to environmental sustainability. Therefore, approaches to increase efficiency in production processes are becoming more prominent in the agricultural sector.

The lean manufacturing philosophy is developed to eliminate waste in production processes, minimize non-value-creating activities, and use resources more effectively. This philosophy, which was first implemented in the automotive sector under the name of the Toyota Production System (Dave 2020), is now used in different sectors (Paladugu & Grau 2020). Lean manufacturing techniques provide a competitive advantage to businesses with tools such as Value Stream Mapping (VSM) (Chen & Meng 2010), Kaizen (Brunet & New 2003), and 5S (Omogbai & Salonitis 2017). As can be seen in the literature section, the fact that most of the studies were conducted in the last decade shows that lean production practices have become popular and have begun to be implemented in agricultural production.

The purpose of this study is to examine, analyse and interpret existing studies in the literature on the application of lean production techniques in the agricultural sector. In the study, after addressing the lean production philosophy and agricultural

production processes, literature examples on the use of lean production techniques in the production process of agricultural products were analysed. Statistical evaluations were made on the frequency of the methods used and the results obtained. In the conclusion section, suggestions were made in line with the findings obtained and the necessity of new studies on lean production applications in the agricultural sector was emphasized.

2. Lean Manufacturing

Lean manufacturing is a production management philosophy that began with the Toyota Production System. This philosophy was developed by the Japanese automobile manufacturer Toyota and was later widely adopted in many industries and sectors. It is an approach whose primary purpose is to increase efficiency, minimize waste and continuously improve processes. Lean manufacturing philosophy has identified 7 basic types of waste: Overproduction, Waiting, Transport, Processing, Inventory, Motion and Rejects (Ohno 1990). Lean manufacturing techniques have basic principles. These are value, value stream, continuous flow, pull and perfection. The common goal of these principles is to reveal and eliminate waste. These principles are value, value stream, continuous flow, pull and perfection (Womack & Jones 2003).

Value refers to any activity that creates value for the customer by changing the product during the production process, while activities that do not meet this criterion are considered waste. The first step is determining what the customer wants and focusing on activities that add value. Value stream refers to identifying value-added and non-value-added activities by laying out the product's production process step by step. VSM is used to identify and eliminate waste in the process. Continuous flow refers to optimizing the steps in the process and eliminating bottlenecks to ensure the uninterrupted flow of the product. Pull refers to manufacturing based on customer demands, meaning that production is aligned with the demand from the previous step, thereby minimizing stock levels. Perfection refers to always working for the best and maintaining a constant focus on excellence.

To sustain these principles, some techniques and approaches have been developed within the scope of lean production. In this section, only the lean techniques employed in the studies presented in Section 4, which contains the literature review, are explained.

VSM visualizes all steps of a production process and enables the identification of waste. A four-step procedure can be applied for VSM analysis: Selection of the product family, drawing of the current state map, drawing of the future state map, and reaching the future state. In VSM application, waste is tried to be eliminated by making improvements in the production process to reach the target. These changes are shown in the future state map (Birgün et al. 2006; Shou et al. 2017).

Total Productive Maintenance (TPM) is a method that increases the performance of machinery and equipment used in production and minimizes malfunctions. At the same time, TPM improves business performance in many ways, such as efficiency, occupational safety, cleanliness, employee morale and customer satisfaction (Brah & Chong 2007).

The word *Kaizen* is of Japanese origin and means continuous improvement. The primary purpose of Kaizen is to eliminate waste, encourage innovation, increase productivity and ensure that employees participate in production not only physically but also mentally. This technique takes measures to reduce inefficiencies while continuously improving (Kumar et al. 2022).

The *5S* method takes its name from the initials of the essential elements of the system: Seiri (sorting), Seiton (order), Seiso (cleanliness), Seiketsu (standardization), and Shitsuke (discipline). It maintains order in the work environment and encourages employees to participate actively. Osada and Hirano revealed different visions of this approach. While Osada evaluates 5S as a development process to improve productivity and working conditions in the workplace, Hirano sees 5S as a tool developed specifically to eliminate waste (Jaca et al. 2014).

First introduced to Toyota by Taiichi Ohno in 1950, *Kanban* is defined as a Material Flow Control mechanism that controls the production of the required product in the correct quantity and at the right time. Kanban application provides many benefits, such as reducing companies' stocks, reducing storage space, preventing material shortages, and preventing damaged and expired goods (Triana & Beatrix 2019; Yuniar et al. 2023).

Just-in-Time Manufacturing (JIT) was first developed in Japan by Taiichi Ohno in the early 1970s. JIT is a philosophy that prepares materials and parts exactly when they are needed in the production process. For the technique to be implemented, many factors must be realised, such as the support of senior managers, the participation of employees in decision-making processes, and the smoothness of parts received from suppliers (Pourasiabi & Pourasiabi 2012).

Heijunka is a Japanese term that means balancing, and it is a method that tries to balance production and product mix. It collects customer orders in a certain period, divides them into small batches, creates a product mix, and organizes a standardized production schedule. This way, it provides balanced demand management by preventing excessive workload on operators and machines (Boutbagha & Abbadı 2022; Gerger 2019).

Jidoka is both a technique and a system. As a technique, Jidoka is an automation principle that allows operators to monitor multiple machines. As a system, Jidoka is a system that detects problems in a machine and takes precautions against problems in production through visual and audible alarms (Baudin 2007; Romero et al. 2019).

Single Minute Mold Changeover (SMED) was developed by Shigeo Shingo in Japan in the 1950s to analyse the mould changeover process to switch to the production of a new product. Changeover time is the time between the last good part of a product and the first good part of the following product. This time is spent cleaning, changing machine parts, and preparing and trial production (Karam et al. 2018; Hasabe et al. 2019).

Poka-Yoke or Mistake Proofing is a method developed by Shigeo Shingo in the early 1960s that attempts to minimize the possibility of product mistakes. Poka-Yoke devices are used to minimize mistakes. With these devices, mistakes can be detected before or after and prevented without causing further negative consequences (Al-Araidah et al. 2010).

3. Production Processes of Agricultural Products

Agriculture is a branch of science that consists of two basic branches of production, making products suitable for human consumption and marketing them. Agricultural activities are divided into two fundamental branches: plant and animal production. Plant farming includes products such as grain, vegetables, and fruits, while animal farming includes products obtained from cattle, poultry, and small cattle (Harris & Fuller 2014; Bhavikatti 2010). A detailed scheme of agricultural activities is given in Figure 1.

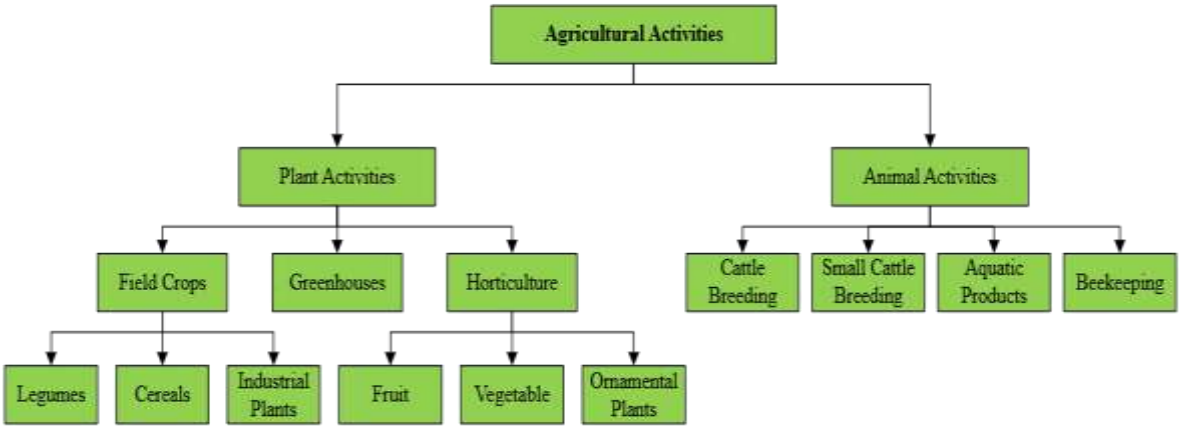


Figure 1-Agricultural activities schema

Agricultural production ensures the sustainable existence of food, seeds, and other essential plant products for human life. This production process includes various stages, from seed sowing to harvesting pieces, and each stage is critical regarding product quality. Seed quality is the cornerstone of sustainable agriculture, and high-quality seeds directly affect product yield. In agricultural processes, the seed's journey begins with its development and maturation in the plant. At this stage, nutrients accumulate in the seed, and its durability increases. Harvesting mature seeds at the right time is important for them to be of the best quality. Correct harvesting after maturation is critical for the seed to reach the highest germination capacity. Harvested seeds are separated according to size and quality, and defective ones are cleaned. Then, the seeds are stored at low temperatures and humidity to prevent deterioration. The controls made during this process guarantee the seeds' germination power and genetic purity (Sundareswaran et al. 2023). The process flow chart of agricultural production is given in Figure 2.

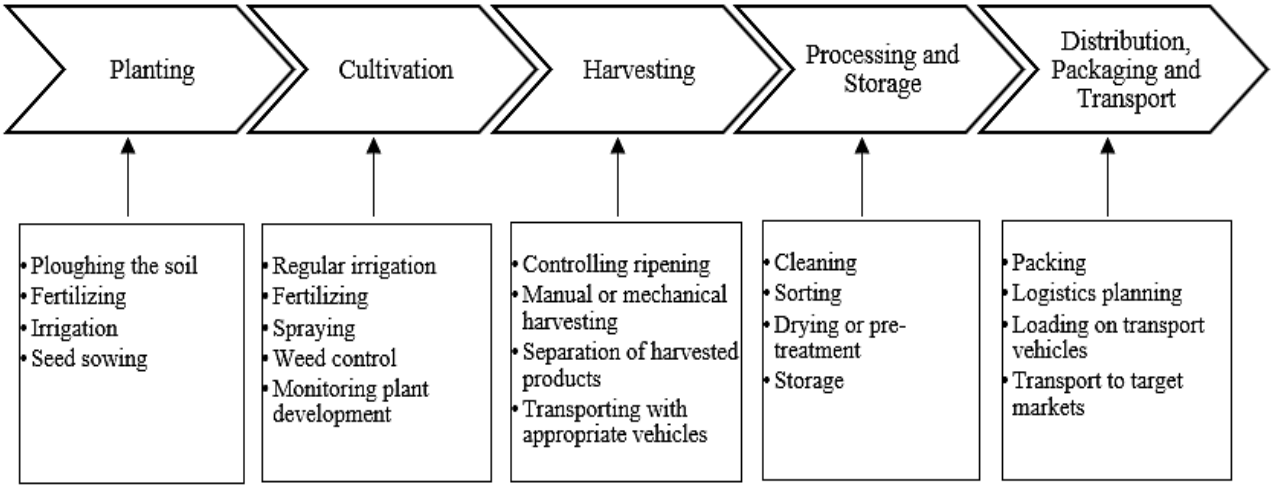


Figure 2-Agricultural production process diagram (Solano et al. 2020; Plà et al. 2017)

Agriculture has undergone significant changes from the past to the present while meeting people's basic needs. Agriculture, which dates back 10,000 years, has evolved alongside population growth and the interaction of diverse societies. As shown in Figure 3, the development of agriculture has continued with multiple revolutions to the present day. First, with the beginning of the Green Revolution in the mid-1960s, the increase in diversity and fertilizer applications, and the more widespread use of irrigation methods, yields of staple grains in the Global South, especially rice and wheat in Asia, increased. In 1960-1962, 30 million people died of starvation in China, while Vietnam experienced serious food shortages. These shortages were caused using collectivized farms, and both countries saved people from famine by switching to the family farm model. 1989, the Berlin Wall fell, and significant agricultural reforms were implemented in Central and Eastern Europe. With the livestock revolution, there was an increase in demand for various food products. Later, products that increased diversity were developed. With the expansion of the supply chain of agricultural food, retail sales, and processing have made a remarkable difference. The increase in income per person, easier access to food, and increased variety and quality have changed how households buy and shop for food. With technological advancements, genetically modified organisms have been introduced, significantly enhancing food production by improving product efficiency and durability (Fuglie et al. 2024).

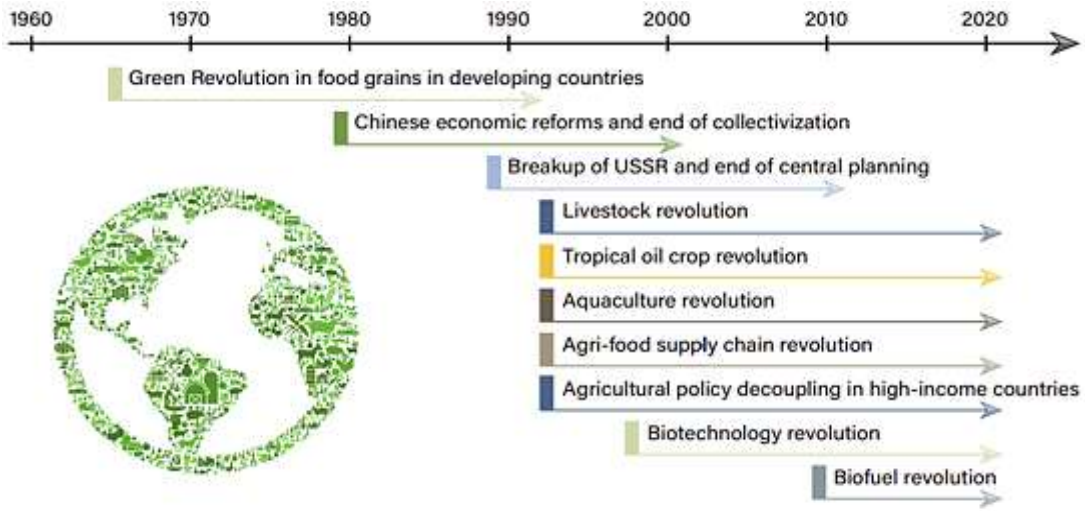


Figure 3- Important developments affecting world agriculture (Fuglie et al. 2024)

The world population increased from 3.0 billion to 7.8 billion between 1961 and 2020, driven by growth in food demand and, thus, agricultural expansion. More than 90 percent of these 4.8 billion increases occurred in the Global South (developing countries). From 1961 to 2020, global agricultural production grew at an average annual rate of 2.3%. However, this growth has slowed in the past decade. From 2011 to 2020, agricultural production grew at an annual rate of 1.93%, compared with 2.72% from 2001 to 2010. The slowdown is largely attributable to the decline in total factor productivity growth. Annual total factor productivity growth nearly halved from 1.99% to 1.12% between the 2001–10 and 2011–20 decades. The rate of land expansion has also increased over this period. Overall, world agricultural land use has increased by 7.6% between 1961 and 2020 and today covers approximately 32% of the world's land area (Fuglie et al. 2024).

Türkiye has been an important agricultural country, with agricultural activities going from past to present. Türkiye, which has a share of 0.8% of the world's agricultural lands, realizes more than 1.29% of global production. It is expected that it will increase its share to over 3% with new technological works that can be done in the future. From 2002 to 2020, $70 billion in support was provided to the agricultural sector, and this resource transfer created an economic activity of more than $1 trillion. It is estimated that the production value, which was $58 billion in 2022, will decrease to $42 billion in 2030 because of the analysis (Merdan 2024).

A decrease in agricultural production due to the increasing population in Türkiye may have important economic and social consequences. The inability of food production to meet demand may negatively affect the foreign trade balance of countries by increasing import dependency. At the same time, supply shortages in basic foodstuffs may lead to an increase in food prices and an increase in inflation. This situation may deepen social inequalities by causing a decrease in food security, especially in low-income households. In addition, a decrease in agricultural production may lead to increased unemployment in rural areas and the migration of the population earning their living from agriculture to large cities, thus causing deterioration in the socio-economic structure. To prevent this decrease, it is thought that using lean production techniques that do not require serious costs in the production phase of agricultural products will also provide positive developments for Türkiye, based on studies conducted worldwide.

4. Systematic Review Methodology

This study employed a systematic literature review as its methodological approach, a critical process in scientific inquiry aimed at structuring existing knowledge and generating theoretical insights from the synthesized findings.

Step 1: Defining the Question and Conceptual Framework: Two research questions were identified for this systematic literature review: "Have studies been conducted utilizing lean production techniques in the production process of agricultural products? Are there any studies on agricultural product production in Türkiye?"

Step 2: Task Sharing: The research process will be conducted separately by two authors. In the final stage, both authors will conduct another literature review together.

Step 3: Search Strategy: The literature review was conducted in four academic databases: Web of Science, ScienceDirect, Google Scholar, and DergiPark to identify studies addressing lean production techniques in agricultural production. The search strategy was structured using topic-specific keywords. The keywords chosen were "Lean-Agriculture", "Lean-Agricultural", "Lean-Farm", "Lean-Agriculture" and “Yalın-Tarım” These keywords were selected to encompass both English and Turkish literature. The search was conducted using the conjunctions "OR" and "AND," aiming to cover all relevant studies. The search process was conducted at two different levels:

Title Search: Keywords were searched only in the article titles, yielding more specific results.

Topic Search: Keywords were searched within the keyword or topic tags of the articles.

This multi-stage search strategy enabled a comprehensive review of the relevant literature. Data collection was limited to a 15-year period between 2010 and 2024.

Step 4: Search and Relevance: The titles, then the abstracts and keywords of the articles found as a result of the search mentioned in Step 3 were examined. The scope of the search was limited to the production process of agricultural products. Subjects such as product storage, shipping, marketing, and supply chain establishment were excluded. The word "lean" is a term used individually outside the scope of "Lean Manufacturing." For example, studies using this term for the lean cut of meat were also excluded.

Step 5: Quality assessments: Conference papers were excluded from the review, and only articles published in scientific journals were included. The number of studies in the process described thus far is shown in Figure 4.

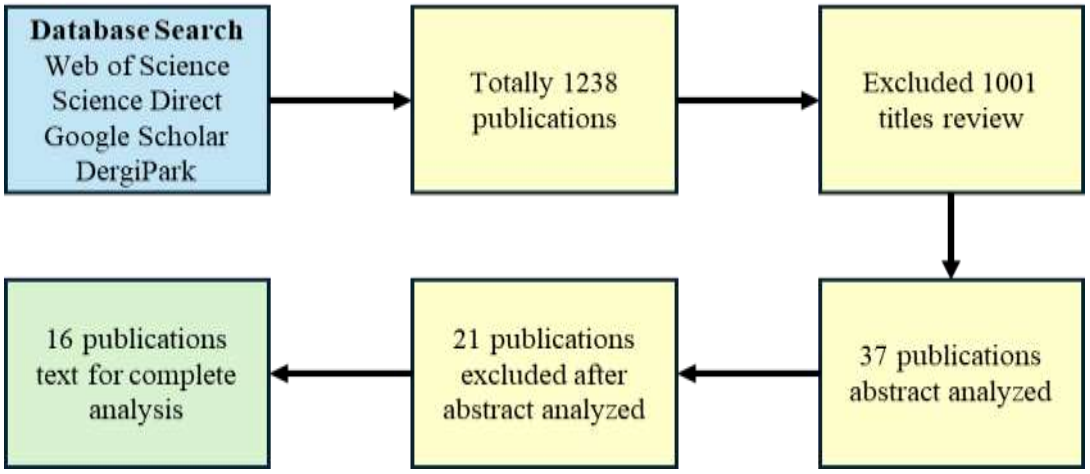


Figure 4-Results after inclusion and exclusion criteria were applied

Step 6: The systematic literature review yielded the studies listed in Table 2. These studies addressed a real-world problem and applied at least one lean technique to the production process of agricultural products.

5. Literature Review

This section examines 16 articles published so far that utilize lean techniques in agricultural production. It explains how lean techniques are used, what is considered in the process, and the resulting improvements.

The study, conducted in eight different agricultural enterprises in the Sao Paulo region, focused on the degree of compliance with the lean production philosophy, the impact of the lean production techniques used, and the examination of the production process. Data were collected through structured interviews, field visits, and document reviews. The results of the study show that the level of compliance with lean production varies among enterprises, with the strongest practices being long-term strategic planning and continuous improvement. The weakest areas are lean leader development and the spread of organizational culture. The most widely accepted lean production techniques include Continuous Flow, Jidoka, and VSM, while tools such as Kanban and 5S are used less (Satolo et al. 2017).

In Sweden, consultants were assigned to thirty-four farm owners participating in the program within the scope of this study. Many lean production techniques were used to implement the lean farming approach. The study includes the benefits of a new business model for farmers with the techniques applied, the risks, and the training that should be received regarding these techniques. Interviews were recorded with the farms before, during, and after the program. The most used methods in the study were 5S and VSM. These methods were generally used for routine tasks. Process improvements were made on the farms, resources were managed more efficiently, and sustainable production methods were adopted. As a result, costs were reduced in the agricultural sector, environmental impacts were reduced, and the competitiveness of the farms increased (Barth & Melin 2018).

In Northumberland, a family-run farm applied VSM to see the production processes and identify waste. A current situation map was drawn, and waste was identified. Brainstorming meetings were held to identify waste, and ideas were suggested to minimize this waste. For example, the location of the fertilizer storage was changed to minimize transportation and increase efficiency in fertilization processes. A future situation map was prepared with the changes planned to be made. In the future situation map, improvements were made regarding seed sowing, transportation, and costs. As a result of the study, waste was reduced on the farm, and efficiency was increased (Colgan et al. 2013).

In fruit farms in South Africa, lean production techniques and their effects on sustainable performance were investigated. 15.9% of 132 farm owners were aware of lean production. At the end of the study, 59.1% of farmers were aware of lean production. The study made statistical calculations to see the effect of lean production techniques. Farms were divided into two groups: large and small-scale farms, according to their sizes. It was concluded that the lean production approach did not affect sustainable performance in small-scale farms and could be ignored for small-scale farms (Pearce et al. 2021).

The study implemented in a forest seedling company aimed to contribute to the lean agriculture philosophy by applying VSM, one of the lean production techniques, to the agricultural field. The data in Table 1 were obtained with the VSM applied to the planting and stocking of seedlings.

Table 1-Comparison of the current state with the future state (Forno et al. 2010)

ITEM	*CURRENT STATUS*	*FUTURE STATE*
Seed stock	365 days	30 days
Seeded trays	1.25 days	1 day
Germinated seedlings	1.5 days	1 day
Seedlings formed	1.5 days	1 day
Finished seedlings	1.5 days	1 day
Packaged seedlings	2 days	1.8 days
Biological growth	195 days	195 days
Production lead time	372.75 days	35.8 days
Stock size	8.5 million seedlings	4 million seedlings

In the company, the primary target of VSM is to reduce stocks. For this, it was stated that the current push system should be replaced by a pull system. For the pull system to be successfully implemented, switching to a supermarket application and renewing the agreements made with suppliers is suggested. In lean production, the supermarket is a controlled inventory area managed with kanban cards where certain materials or parts are stored; thus, the production line pulls the materials it needs, and the stocks are renewed only when consumed, thus minimizing waste. In addition to reducing stocks, the study aims to reduce total work time by reducing waste detected with VSM, thus increasing customer satisfaction. The study emphasizes that lean production is useful for increasing capacity, making customers feel valued, and standing out from the competition (Forno et al. 2010).

One of the lean production techniques, Kaizen, has been applied to the vertical farming model. As a result of Kaizen, two potential improvements were identified in the system. One is determining the ideal distance between the growing tray and the light source. The other is dividing the irrigation source into two and ensuring pressure balance in the system. As a suggestion, it was recommended to use simple robot arms to control the movements of the growing tray (Heng et al. 2020).

The Lembang Agriculture Incubation Center study focuses on the vegetable packaging process. This study aimed to reduce the total process time by eliminating non-value-added activities in vegetable packaging. The tool used in the study is VSM. As a result of the application of this method, a time saving of 25.68 minutes was achieved in value-added tasks, 145.78 minutes in non-value-added tasks, and 171.46 minutes in the vegetable packaging process. This saving increased process efficiency and customer satisfaction thanks to on-time delivery (Ariffien et al. 2021).

In Liverpool, a farm with vertical farming systems has been subjected to VSM, one of the lean production techniques. The farm has a monthly lettuce production capacity of 800 kilograms with mobile vertical tower growing systems. The aim of the study is to identify bottlenecks, reduce the duration of value-added and non-value-added processes, and improve production processes by making changes. When the current situation map was prepared, it was revealed that the desired material flow was not achieved due to incorrect layout. In addition, it was revealed that there was a bottleneck in the packaging process due to quality controls that led to product rejection. As a result of the application, production time was shortened, efficiency in energy and water use was achieved, and labor productivity was increased (Oliveira et al. 2020).

In a study conducted in Japan, the training process of farmers on lean production techniques was addressed, and at the end of the training, the application processes of lean production techniques on farms were investigated. The study included the application of the Heijunka method in a company. As a result of the study, customer satisfaction enhancement and loss visualization models were suggested. The success of these suggestions was evaluated through simulation (Katayama & Aoki 2016).

In the study conducted in the Indramayu District, VSM technique was applied to analyse the performance of rice production. As a result of the study, the waiting time after harvest was reduced from 68.41 hours to 65.65 hours. It was also observed that 99.87% of the total delivery time contributed to production, and only 0.13% of the loading process time was lost (Perdana et al. 2019).

In the study conducted by Aguiar et al. it was stated that some innovative lean practices were adopted in the production processes of family farms producing lettuce, which contributed to increasing production efficiency. With methods such as VSM, 5S, and Kaizen, labor efficiency was increased, and waste was reduced by identifying waste and inefficiencies in the production process. In addition, innovations such as standardization, labor efficiency, customer-oriented production, and operational improvements were implemented in production processes. The study showed that lean production principles provide advantages when used more consciously in family farms (Aguiar et al. 2020).

The selection and integration of lean manufacturing practices in the product development process was examined in a fruit farm in Parana, Brazil. This study provides a framework for selecting lean manufacturing methods. This framework improves processes by reducing waste, increasing efficiency, and ensuring environmental sustainability. Improvements include increasing labor productivity, reducing waste, and ensuring sustainable production by considering environmental impacts. The study

suggests that it is important to align lean manufacturing methods with environmental goals in the agricultural industry and that these methods support environmental sustainability while increasing efficiency (Lermen et al. 2018).

In a study conducted on a coffee farm, how VSM, one of the lean production techniques, was applied was examined. In the farm, problems such as inefficiency in processes, high costs, and the inability to prevent waste were addressed, and mapping processes with VSM minimized time losses and waste. However, the study addressed general efficiency improvements and process optimization instead of specific numerical results. As a result of the study, planning was suggested for more efficient use of invested capital. A roadmap was presented to farmers to manage their investments more effectively, and it was stated that resources should be used efficiently (Carrijo et al. 2024).

In the study conducted by Solano et al. a new operational model was developed in order to reduce costs and waste in agricultural production systems. The model includes a planning approach covering three basic agricultural processes: planting, product maintenance, and harvesting. A systematic solution proposal was presented by combining lean production principles and mixed integer nonlinear programming methods. The model was tested with data obtained from banana farms in the Caribbean region of Colombia. As a result of the study, up to 59% reductions in costs related to production waste were achieved, and more efficient use of teams, labor, and resources was made possible. It was suggested that the developed model be expanded to include different products, uncertainties, and supply chain stages (Solano et al. 2020).

The study conducted by Folinas et al. aimed to identify non-value-added processes and reduce waste by using the VSM technique to improve environmental performance in the agricultural food supply chain. In the study focusing on the supply chain of corn used in animal feed production, critical energy and water consumption processes such as drying and pelleting were analysed. As a result of the study, improvements were made, such as using takt time in production planning, integrating forecasting and material requirement planning modules into the ERP system, and using new corn hybrids that can be dried naturally. It also showed that lean philosophy can be an effective tool in operational processes and in line with sustainability goals (Folinas et al. 2014).

This article introduces a Lean-based methodological approach designed to reduce processing waste in agricultural systems—an area often overlooked in traditional Lean applications. VSM method was applied to a Colombian coffee farm to transform harvest and processing losses into compost. By integrating a parallel composting line, the farm achieved an 86% transformation rate of coffee by-products and reduced non-value-adding activity time by 30.3%, significantly improving efficiency and delivery times (Hualpa-Zúñiga et al. 2024).

In a study conducted in Sweden, it was stated that lean practices were effective not only in operational processes but also in areas such as strategic planning and workforce training, and that small and medium-sized farms could eliminate waste in both physical and information flow with the help of VSM (Melin & Barth 2018).

This study proposes a simplified Lean Six Sigma framework tailored for compound feed manufacturers to address rising costs and growing customer demands. Using a case study from an Irish feed producer, it combines VSM with Six Sigma's DMAIC approach. The findings suggest that the framework aligns well with the limited resources typical in this sector. While limited by a single case, the study offers a practical model for continuous improvement in agri-food SMEs (Trubetskaya et al. 2023).

There are two literature review articles. Mangini and his colleagues prepared this study as a literature review that showed how frequently lean production techniques are used in the agricultural sector. As a result, the first three most used techniques were as follows: Pull production and continuous flow, VSM, and TPM (Mangini et al. 2016). This review identifies lean tools applied in agro-pastoral production and their effects on reducing waste and increasing productivity. Tools like VSM, 5S, and SMED are commonly used across various agricultural contexts, showing positive outcomes. However, lean implementation is still at an early stage, with limited guidance and generalizability (Martins et al. 2023).

In the studies examined, it was observed that lean production techniques contributed significantly to improving production processes in the agricultural sector. These techniques improved the flow of agricultural processes, reduced waste, eliminated non-value-added activities, and provided significant improvements in critical issues such as customer satisfaction, productivity, quality, and on-time delivery. The rates related to lean production techniques used in the production process of agricultural products in the articles examined within the scope of this study are presented in Table 2.

Table 2-Lean techniques used in the production process of agricultural products

Lean Production Techniques	*Forno et al. (2010)*	*Colgan et al. (2013)*	*Folinas et al. (2014)*	*Katayama & Aoki (2016)*	*Satolo et al. (2017)*	*Barth & Melin (2018)*	*Melin & Barth (2018)*	*Perdana et al. (2019)*	*Aguiar et al. (2020)*	*Heng et al. (2020)*	*Oliveira et al. (2020)*	*Ariffien et al. (2021)*	*Pearce et al. (2021)*	*Trubetskaya et al. (2023)*	*Carrijo et al. (2024)*	*Hualpa-Zúñiga (2024)*	*RATE (%)*
VSM	✓	✓	✓		✓	✓	✓	✓	✓		✓	✓		✓	✓	✓	81.2
Kanban					✓	✓							✓				18.7
5S					✓	✓			✓								18.7
Kaizen					✓				✓	✓							18.7
Heijunka				✓	✓												12.5
TPM					✓								✓				12.5
SMED					✓												0.62
Jidoka					✓												0.62
JIT					✓												0.62
Poka-Yoke					✓												0.62

According to the findings presented in Table 2, the VSM technique was applied in most studies examined. This technique played an important role in the optimization of agricultural production processes. VSM allows the determination of waste sources in processes and the analysis of value-added and non-value-added activities. The fact that the technique provides multiple benefits, such as process improvement, productivity, and resource optimization, is why researchers widely prefer it.

Key concepts that prominently emerge in the reviewed literature include Agriculture, Farming, Lean, Flow, Value, and Waste. These terms reflect a common emphasis on improving efficiency, eliminating non-value-adding activities, and enhancing productivity within agro-industrial systems. Among the lean tools identified, VSM stands out as the most widely applied technique, underscoring its utility in detecting inefficiencies and optimizing production processes. Furthermore, the appearance of terms such as Pull, Standardization, and Continuous suggests an increasing adoption of lean principles across various stages of agricultural production.

6. Conclusions

Agricultural production worldwide needs to be made more efficient and sustainable with the increasing population and changing consumption habits. Lean production techniques play an important role in achieving this goal by reducing waste in the agricultural sector, using resources efficiently, and optimizing production processes. The dissemination of these techniques will contribute to the provision of higher quality and affordable products not only to farmers but also to consumers.

This study presents the results of the literature review on the applications of lean production techniques in the agricultural sector. The reviewed studies determined that lean production techniques provide significant benefits such as increased efficiency, reduced waste, and improved quality in agricultural production. In particular, the VSM technique is widely used to visualize and improve production processes.

Most studies observed that other lean tools, such as Kanban and 5S, were used with the VSM technique. Thanks to these tools, process times were shortened, waste was reduced, stock levels were reduced, and resources were used more effectively. However, there is no study on this subject specific to Türkiye.

Considering Türkiye's agricultural potential, it is important to spread lean production techniques in agricultural enterprises in our country. In this way, efficiency in agricultural production can be increased, product quality can be increased, and international competitiveness can be strengthened.

The following suggestions can be made for the future:

- Adoption of Lean Culture: Adopting the lean production philosophy in agricultural enterprises requires employee training and establishing a culture of continuous improvement.
- Use of Various Lean Tools: Besides VSM, other lean production tools such as TPM and Kaizen should be implemented in agricultural enterprises to achieve more comprehensive improvements.
- Technological Support: Productivity can be increased by investing in agricultural enterprises' modern irrigation systems, sensor technologies, and automation systems.
- Political Support: The state should create incentives and grant programs to support lean production practices in agricultural enterprises. Taking advantage of model factories, which were established and inspired by examples from around the world under the Ministry of Industry and Technology in Türkiye, and providing lean production consultancy to companies can provide faster results.
- Increasing Academic Studies: More academic studies should be conducted on lean production in the agricultural sector in Türkiye, and these studies should be disseminated.

The studies to be carried out in line with these recommendations will contribute significantly to Türkiye's agricultural sector becoming competitive at world standards and agricultural production worldwide becoming more efficient and sustainable.

Conflicts of interest

The authors declare that there is no conflict of interest to disclose.

Author Declarations

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