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On Driving Operational Excellence, How Continuous Improvement Culture Minimizes the Effect of Seasonality in the Agricultural Seed Industry: A Literature Review

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ABSTRACT

The hybrid seed industry operates under extreme seasonality, where fixed biological planting and harvesting windows contrast with the need for consistent industrial processing. In a CI (Continuous Improvement) culture, this creates a unique tension: how do you maintain "continuous" progress when the plant oscillates between 0% and 200% capacity?

This article examines related literatures that emphasizes and studied Continuous improvement (Kaizen) in the agricultural manufacturing industry Continuous Improvement (CI) has been extensively studied in manufacturing and is widely recognized for enhancing productivity, profitability, and operational performance (Turovski, 2024). However, its application within the agricultural sector remains limited, with existing studies often focusing on isolated stages rather than the entire value chain.

This study aims to bridge this gap by examining how CI can be integrated from field operations to plant processing within the hybrid seed industry. This will try to integrate established discipline in Continuous Improvement and create/propose a framework that might be adopted by various organizations in these industries.

Based on the review of related literature, it was concluded that there are 4 major principles of Continuous Improvement that can be implemented to addressed the seasonality of this industry. These include: (1) leveling the biological load (Heijunka), (2) managing seasonal workforce through standardized work, (3) shifting focus from production to maintenance using Total Productive Maintenance (TPM), and (4) managing quality variability through Six Sigma.

It is also found out that no specific Continuous Improvement principle can singlehandedly resolve the issue but rather it was discovered the Elasticity logic of the proposed framework. The unique contribution of the framework is the concept of Continuous Improvement elasticity. Specifically, during high-load periods (100–200%), CI becomes rigid, emphasizing strict adherence to standard work and implementation are rapid and continuous to avoid delays and downtime, especially on the single line's operations. In contrast, during low-load periods (0–20%), CI becomes more flexible, encouraging innovation and process redesign.

Having in place the Continuous improvement principles in the industry, this will increase profitability, efficiency, reduce cost, achieve optimum quality, retained skilled personnel and others. The proposed framework moves the hybrid seed industry from a Crisis-Response model to a Proactive-Sync model, where the off-season builds the capability that the peak season implements.

Keywords: Continuous Improvement, Agricultural Industry, Seasonal crops, Operational Excellence, Productivity

INTRODUCTION

Seasonality of Agricultural Industry

As defined, (Peter et al, 2022) volatility refers to the degree and speed of variability like the commodity prices that changes overtime encompassing predictable variation and uncertainty. Agricultural production is inherently seasonal, largely determined by climatic patterns and biological growth cycles. In the high valued crops such as corn and rice and in the Philippines during two distinct seasons—the dry and the wet season. The dry season, from January to April, tends to produce higher yields than the wet season, from July to October (Rice Today, 2025). These production cycles directly influence post-harvest operations, as processing facilities must align their activities with harvesting periods, often resulting in idle or "lean" operational phases.

One major factor of the seasonality of agricultural industry is the climate variability that disrupts the cropping season. Sometimes it stretches and compresses the planting season that poses challenges in this industry, thereby affecting the sustainability and the productivity of the crops (Ajiere et al., 2021). Valuable crops such as corn, rice, sorghum and others are dependent to the climate, high temperature seasons reduce crop yield while increased in rainfall enhances its yields (Osman et al., 2021). This climate variability pushes farmers to delay their planting thus, disrupting the cropping season. Main factors that climate affects the cropping season are due to La nino, La nina, excessive and short rainfall and others. El Niño conditions generally lead to reduced yields for several major crops. For instance, El Niño tends to decrease the global-mean yields of maize, rice, and wheat by up to 4.3 %, although it can improve soybean yields by 2.1–5.4 %. In contrast, La Niña often results in lower global yields for most crops, with a decline in maize, rice, and wheat production during La Niña years (Nizamani et. al, 2025)

This compounded factors and effects to the agricultural industry must be accepted and understand to further improve the crop yield, timing and other important consideration to alleviate the agricultural industry. Due to this seasonality, the entire process is affected not just the crops. The quality of the crops must be maintained and optimum value must be delivered from the harvested crops.

To synthesize above effect of the seasonality of the agricultural industry, major effects are but not limited to crop yield during harvest season, variability and vulnerability in the prices of harvested crops and the farm implements, artificial peak that drives manpower cost increase, job security of personnel in this industry, food security due to crop season failures and others that affect the operation of agricultural industry both in the field and plant operations and also on the food security.

Application of Continuous Improvement in the Agricultural Industry

Continuous Improvement (CI) philosophy though establishes its roots from industrial manufacturing can play a pivotal role in the advancement and productivity of the agriculture industry. Kaizen as part of CI philosophy is a systematic approach in establishing small and significant improvements that are continuously improve to enhance productivity, reduce wastes and create a culture of discipline across the entire organizations (Moradi, 2025).

In agricultural manufacturing, research highlights challenges such as equipment variability, post-harvest losses, batch inconsistencies, and logistics inefficiencies.

The main driver of CI is the cost, delivery and quality to improve operational competitiveness. This is implemented while balancing the above elements while ensuring that cost cutting doesn't compromise the quality and the productivity of the organization or the process (Olamide et al., 2022).

Objective Of The Study

The researchers will try to understand various continuous improvements programs that will reduce if not eliminate the effect of seasonality of the agricultural industry through literature review of various articles, studies and journals that pertains to this topic. From this review, the researcher will tailor a framework in which will be adoptable in every stage of this industry.

Specifically, this literature review will try to focus on this objective;

A. To create a continuous improvement framework based on the literature review that will minimize the effect of the seasonality in the agricultural industry

METHODOLOGY

This study employs a Systematic Literature Review (SLR) approach to investigate the integration of Continuous Improvement (CI) methodologies within the hybrid seed industry. As established from the previous chapter on the seasonality and biological constraints unique to agriculture, the methodology was designed to identify principles of Continuous Improvement that could be adapted to the agricultural supply chain.

Search Strategy and Data Sources

In ensuring comprehensive review of this journal a systematic selection of related literature from academic databases, google scholar and others that was published between 2021 and 2025 related to the developments and implementation of CI in the agricultural industry.

The criteria of inclusion and exclusion of related literatures

To establish direction of framework in this study, specific criteria were considered to filter related literature regarding the subject matter

Inclusion criteria: Reviewed related literatures that was published from 2021 to recent and deemed significant for this study are included

Exclusion criteria: Literature that are not significantly related to the study and literatures that was published 2021 and below

Data Extraction and Synthesis

A thematic synthesis approach was used to analyze the collected data. Instead of a chronological summary, the literature was categorized based on its application to the four stages of the hybrid seed lifecycle: Pre-Harvest, Peak Harvest, Processing, and Off-Season.

Framework Development

The final stage of the methodology involved the development of a Hybridized Continuous Improvement Framework. This is after thorough review of the related literatures that the proposed framework will be created. Since this is general framework, each organization must create a specific Continuous Improvement project related to the principle. This must be implemented, reviewed, adjust and re-implement again.

RESULTS AND DISCUSSIONS

After the literature review, the researcher analyzes 4 major items that will tackle the issue of the seasonality of agricultural industry. From these major observations, a general framework is created and discussed as a result of the analysis for these 4 major action items. This is expounded in the latter part. Below are the related literature's that discusses and utilizes these related principles of Continuous Improvement.

1. Leveling the "Biological Load" (Heijunka)

In Lean manufacturing, Heijunka refers to load leveling to stabilize production flow. In the seed industry, this concept is adapted through geographic diversification and staggered crop maturity. This process will

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streamline the harvesting season thus addressing the artificial peak in the harvest and plant operations. Also, this will allow the organization and the management to produce requirement of the customers timely and rapidly. This is important as the agriculture product market had a diversified requirements but needed a rapid availability of products.

Staggered Maturity – (Gade, 2025) and (Kan et al., 2023) discuss using "Speed Breeding" and genomic markers to develop hybrids with slightly different maturity windows. This allows the processing plant to extend its peak season, preventing the "bottleneck" effect that usually degrades seed quality during a single massive harvest.

Buffer Management - Literature suggests that CI plants use the "off-season" to optimize silo management and drying protocols, ensuring that when the peak hits, the "standardized work" is so robust that it can handle high-volume variability (Raj, 2024).

2. Seasonal Workforce and Standardized Work

A major challenge in CI culture is maintaining quality when 60–80% of the workforce is seasonal/temporary. Executing these programs is important in the organization to ensure continuity of the operations and to maintain optimum processing output and quality.

Poka-Yoke (Error Proofing) – (Saad, 2024) highlights that high-performing seed plants implement visual controls and physical "fail-safes" (Poka-Yoke) to prevent variety cross-contamination. Because seasonal workers have less training time, processes must be designed to minimize human error through built-in controls and simplified procedures.

Training Kaizen - Recent case studies (Alhosani et al., 2020) indicate that successful plants treat the induction of seasonal staff as a Kaizen event itself constantly refining the 2-day training period to ensure maximum "Standard Work" adherence from day one.

3. Shift of focus from Production to Maintenance (TPM)

This concept plays a critical role in the implementation of (CI) Continuous Improvement principle in the organization as this period where the off season occurs and personnel needed to be re-aligned to optimize their responsibility. Total Productive Maintenance (TPM) recognizes dual phase of continuous improvement culture;

Peak Season (Execution) – Focuses on quick response on downtimes and significantly monitoring the OEE (Overall Equipment Effectiveness) of the machines and the plant

Off-Season (Improvement) - This phase represents the core of continuous improvement, where in-depth analysis and system enhancements are conducted. (Aquino-Rojas et al., 2022) found that the off-season is used for "Deep-Dive Kaizens" where permanent staff analyze the previous season’s data to re-engineer machines for the next cycle.

4. Managing the Quality Variability (Six Sigma)

The variability in raw materials impacts the quality output on the crops in hybrid seed industry which relies on the processing and classification process. If in this part of the industry if mismanage can create unnecessary cost and inventories that will negatively impact the organization.

DMAIC in Real-Time – (Wahyuni et al., 2024) case study shows how Six Sigma (specifically the Measure and Analyze phases) is used during peak season to adjust machine calibrations for each unique batch of corn cobs. This Adaptive CI culture allows the plant to maintain a 3.4 Sigma level even under the stress of high-volume seasonal inflow.

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With the above analysis of the major action items that will tackle the seasonality of the agricultural industry, below is the proposed general framework that might be adopted by the organizations in this industry. To minimize if not to eliminate the effect of seasonality in their operations.

Table 1. Proposed Continuous Improvement Framework

The Continuous Improvement Matrix/Framework				
Seasonal Phase	**Operational State**	**CI Strategic Pillar**	**Core Tool/Action**	**Objective**
Pre-Harvest	Preparation (The Ramp-Up)	**Standardized Work Procedure** **QMS**	Poka-Yoke & Rapid Induction Pre-start up season review Work Instruction / Procedure	Zero-defect start despite unskilled labor.
Peak Harvest	Execution (The Sprint)	**Heijunka & Flow** **Quality Control** **QMS**	Muda elimination (Waiting, rejects etc.) Process standardization	Maximizing throughput in the biological window.
Processing	Refinement (The Sorting)	**Six Sigma** **Value Stream Mapping** **Root Cause Analysis** **Lean** **Quality Control** **QMS**	DMAIC / Quality Control VSM board SOP's	Reducing rejects, damages and ensure optimum processing recovery and quality
Off-Season	Evolution (The Reset)	**Total Productive Maintenance** **PDCA** **Performance Management** **QMS**	Deep-Dive Kaizen Post season review Planning	Re-engineering the system for the next cycle. Equipment overhaul and process re-design

Table 1, is the proposed general continuous improvement framework as an output of this literature review. Each organization must plan and strategize base on the framework a streamlined CI projects to be implemented in the organizations. In creating the CI team, management must strategically select technical and direct support employee in each phase of operations. This will streamline and approach head-on common issues and concerns that might be addressed by the CI projects implementations. Also, these projects must be documented, reviewed, assessed, audited and discussed the effectiveness and the efficiency in the process. Once needed to be revised, adjust or stop upon the result of assessment this must be also documented. Continuous Improvement cycle must be implemented and assessed continuously. Document cost savings, safety and other related output, closed and kept a monitoring for the implemented projects.

Pre-harvest phase, in this part of framework in which the plant operations start, its main objective is to have all personnel/s either old or new to be onboard with common language and understands the flow of operations. This will also address over complacency from the case of old employee. The standardized and documented work instructions, procedures and SOPs will fast track the learnings of the employee specially the newcomer, that is rapid induction of employee. Pre-start up season review or the PSSR is also a powerful lean tool that will guide personnels in the operation. This is focus on the review of machineries operations and the totality of the last season operations. In this phase, Continuous Improvement tools implementation will help both the operations in preparing for the incoming peak and also for the personnel to retain their jobs. This will protect the operation in its seasonality to prevent error, operational slow down, equipment breakdowns and others.

Peak Harvest phase, heijunka or load levelling is very important during in-season operations. This planning will start from the field operations in the planting pattern and choosing of right materials for planting. Management can select early maturing hybrids, regular hybrids and sturdy to environments hybrids. This is to planned out evenness in the harvest season while not missing out with the planting season. This is where seasonality of cropping season during harvest phase are manage. Early maturing hybrids will be harvested and arrived early in the plant, then followed by the regular hybrids and the harsh environment resistance hybrid. This will even out be processing in the plant and will resolve the artificial peak that are being introduced by peak harvests. This continuous improvement integration must start from research and development in developing suitable hybrid that will fit against the identified issues. Significant CI tool that is helpful in this scenario is the root cause analysis tools, benchmarking to competitors and performance management review for hybrid and production performance.

Processing phase, or the plant operation activities. This play a crucial part on this industry as processing are compressed unlike with the field operations. This will also determine the optimum quality that a crop can achieved and also will play a significant role in the company expenses. As reflected in the table 1, the ultimate objectives in this phase in implementing Continuous Improvement is to reduce if cannot eliminate wastes and damages and to achieved optimum processing recovery and the crop quality. Since processing phase can be mapped out based on the field operations status, means that management can plan out implementations and projects that are suitable and can addressed the objectives. Certain Continuous Improvement tools that can be implemented in this phase are the projects coming from 5S, Kaizen, Kanban, PDCA (Plan-Do-Check-Act), one page problem solving tools, Gemba, VSM (Visual Stream Mapping) and others. One page problem solving tool is an effective tool from the Root Cause Analysis principle since plant operations must be agile and rapidly resolve any issues arise along the operations. 5S, Kanban, PDCA, Gemba and VSM methodology that the management can introduce projects to streamline operations and create a culture of Continuous improvement in the operations. Kaizen is the best avenue also for the management to engage personnel and to create a culture of ownership in the process line. This will connect the management with their personnel up to the shop floor level.

Off Season Phase, in this phase, the seasonality majority takes place. This is the period that no field operations and plant operations are done in this industry. The main goal of implementing continuous improvements projects is to minimize this period thus minimizing also the effect on the organization and also with the employees. In this period, continuous improvement plays a significant role to ensure continuity of the operations and to preserve talent on the organization. One best example of CI that can be implemented are the TPM (Total Productive Maintenance) in which management can establish projects related to this principle. Instead of having 3rd party provider of the autonomous, predictive and corrective maintenance management can utilize its own personnel with just a proper training. This will start from the hiring process of HR to put technical personnel in the operation with the same value and cost. In this method, if off season occurs the same personnel can be utilized in the maintenance programs which can retain talents and ensure continuity of the process. In the field operations, technical personnels can perform off season activities also such as land sourcing, personnel and farmer growers training, field process developments and others. This is also a season for the management to review its entire process and the implementation of the CI projects following the principle of PDCA and the continuous improvement cycle. Once this will be a culture in the organization, not just that seasonality can be resolved this will also bring positive impact and develop personnel capability. There is lot mathematical model that can support this implementation in the agricultural industry (Caicedo Solano et al., 2020)

The integration of Continuous Improvement (CI) within the hybrid seed industry represents a departure from traditional "steady-state" manufacturing. Unlike automotive or electronic sectors where production levels are relatively linear, the hybrid seed "plant" operates within a binary cycle of dormancy and extreme peak demand. Literature suggests that a successful CI culture in this context is not defined by static adherence to rules, but by its elasticity.

Research by (Suárez-Barraza, 2024) and (Aquino-Rojas, 2022) indicates that the effect of CI is most visible in how a plant manages the transition periods between seasons. During the off season, CI culture shifts toward

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Total Productive Maintenance (TPM) and Kaizen, where permanent staff re-engineer processes based on the previous harvest's data. Conversely, during the "peak season," the focus pivots to Standardized Work and Poka-Yoke (error-proofing) to mitigate the risks associated with a high-volume, largely seasonal workforce.

Visual Diagram 1. Visual proposed framework

The visual diagram proposed framework reflects the recommended Continuous Improvements tools in each phase of the operations. This also clearly indicates in which phases are the high and low load happens which clearly indicates also the principle of elasticity in which CI tools will help reduce the effect of the industry seasonality

The synthesis of the literature review and the proposed framework, highlights three critical pillars for CI in this industry;

1. Process Stability amidst Biological Variability: Using Six Sigma (DMAIC) to standardize outputs (seed size, germination, and purity) despite the inherent noise of varying crop yields and weather impacted raw materials.

2. Workforce Resilience: Transforming the induction of temporary labor into a structured CI event, ensuring that Standard Work prevents varieties from cross contaminating a defect that is far more costly in seeds than in traditional manufacturing.

3. Optimization of the Biological Window: Implementing Heijunka (load leveling) through diversified maturity groups to prevent the drying and cleaning bottlenecks that lead to seed degradation.

Ultimately, the literature confirms that while seasonality acts as a significant barrier to traditional CI, a hybridized CI framework specifically tailored for agricultural manufacturing allows plants to move from a "reactive/crisis" mode to a "proactive/optimized" state. This transition is essential for maintaining the high genetic value and physical integrity required in the global hybrid seed market.

The proposed output framework is a general approach to reduce the effect of the industry seasonality in its operation.

Real Life Application of Continuous Improvement in Hybrid Seeds Industry

Continuous improvement is already long implemented in the hybrid seeds industry. Though not specifically to address the issue of seasonality of this industry but of various results that is necessary in their study and operation. CI improvement in the agricultural hybrid seeds industries varies implementation depending on their needs but this section will provide insights from related literature that CI are already implemented and being use in this industry.

To further discuss the positive effect of implementing Continuous Improvement, below are the related Literatures on the same industry and already implementing Continuous Improvement on their specific operation/s.

1. Lean Six Sigma Applications in the Rice Industry in Thailand, Australia and Indonesia

   Context & challenge – The study focuses in the rice processing frequent losses from breakage, packaging defects, bottlenecks from harvest and variability in drying. A series of implementations across Thailand, Australia, and Indonesia used Lean/Kaizen and Six Sigma to address these loss drivers.

   Interventions – In Thailand, through the DMAIC with Pareto Analysis, FMEA and DOE implemented the ready-rice packaging to reduce sealing and shape defects in the packaging line. In Australia, implementing Six Sigma that targets milling yield by cutting huller losses resulted into continuous improvement in the spanning drying accuracy and with the supply chain. Indonesia (rice milling defects): Cause-and-effect (Ishikawa), Pareto, and control of critical parameters to reduce defects across weekly production windows.

   Results - Significant reductions in packaging defects via DOE-tuned sealing parameters (Thailand). Lower huller losses and improved whole-grain yield in the Australian mill (SunRice). Defect reduction trends validated with Pareto and line-level metrics in Indonesia.

2. Applying Lean Manufacturing to Enhance Operational Efficiency and Internal Logistics in Community Based Rice Mill

   Context & challenge - small community-based mills in Kalasin Province faced long cycle times, high broken-rice rates, and inefficient internal logistics.

   Interventions - Mixed-methods participatory action research combined classic Kaizen tools—5S, Value Stream Mapping, and ECRS (Eliminate-Combine-Rearrange-Simplify)—to optimize flows, standardize work, and improve changeovers/logistics.

   Results - Processing time reduce to 22.73%, operating cost reduce by 10–15%, broken rice reduce from 10–12% to 7–8%, and OEE increases from 59.94% to 80.47%.

3. The Art of the Kaizen Approach for Sugar Production in Ethiopia: Lessons from the Methara Sugar Factory

   Context & challenge - The Metehara Sugar Factory struggled with mismanagement, leaks, long repair delays, and cane cutting losses, depressing yield and efficiency.

   Interventions - Implement Kaizen program plantwide that emphasizes waste reduction, problem solving analysis, gemba, in-house maintenance and engaging employee in Kaizen projects.

   Results – With Kaizen application plant wide, sugarcane crops yielded 126.93 tons/hectare, increases production by 37% while 35% for the increase in plantation while dropping the cost at approximately 23birr/quintal.

4. Nestlé Continuous Excellence: Lessons for Driving Performance Improvement

Context & challenge - Nestlé built the Nestlé Continuous Excellence (NCE) system to accelerate performance improvements without compromising quality.

Interventions - NCE integrated Lean, TPM, DMAIC, goal deployment, and factory “gates” with assessments and audits—rolled out via pilots, then scaled across manufacturing and beyond.

Results - More than CHF 1.5B annual savings reported during early deployments; broad improvements in energy, water, GHG, and safety indicators; active spread to hundreds of factories.

5. How Cargill Achieves Sustainable Process Optimization - Rockwell Automation

Context & challenge - A flagship corn milling site saw KPI slippage due to competing priorities and weak project governance; more broadly, inconsistent control loop discipline diluted gains from optimization.

Interventions - Rapid Best Practice Deployment (daily management, visual management, 5S, focused improvement, governance for Kaizen projects). Process control Kaizen by standardizing and monitoring control loops globally (PlantESP rollout to 70+ plants). Results - Approximately US$700k realized in project savings within six months and a move from bottom to near-top divisional standings at the corn milling site; improved teamwork and DMAIC discipline. Sustained efficiencies from keeping loops in automatic with diagnostics/monitoring at scale.

CONCLUSIONS AND RECOMMENDATIONS

Continuous improvement (CI), when implemented systematically will not only enhance processes but also strengthens organizational culture, creating a resilient and competitive manufacturing environment. It offers standardized approach to achieve operational excellence and effectiveness by enhancing the consistency, adaptability and efficiency.

The proposed framework that is a product of the literature reviews is a significant guide for the organizations in this industry to implement. It is discussed in the previous chapter that implementing various principles of Continuous Improvement in specific projects or certain operations lead to a significant improvement that are both beneficial to the organizations and the manpower. As suggested from other studies, applying CI in operational level yielded significant improvements thus, implementing organizational wide can further improve the productivity and efficiency of the operations.

Given that the proposed CI framework is generalized, organizations are encouraged to establish dedicated Continuous Improvement teams to study and structure initiatives based on their specific operational contexts. Thorough selection of individuals that will comprise the team is a significant step to start.

To further streamline this study, the researchers recommending an in-depth study to categorize organizations in the agricultural industry. From that category a precise CI project might be adopted by each organization.

It is also recommended by the researcher to further study the involvement of financials in the project implementations. If the project generates ROI or profit to the organization, if the project are personnel friendly. All avenue and considerations in each project implementations must turn into financial value without compromising the personnel welfare and the environmental stewardship.

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