



Quality Seed Production Process According to Standards

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Abstract

Quality seed is a fundamental input in agricultural production, directly influencing crop yield, resilience, and uniformity across farming systems. However, many seed production systems in developing regions still rely on informal practices that do not fully comply with established seed quality standards, resulting in low genetic purity, high contamination, and variable germination performance. This study develops a conceptual framework for the Quality Seed Production Process According to Standards by synthesizing principles from international seed certification schemes, national regulations, and best practices in field and post harvest management. The framework integrates four key layers genetic and varietal integrity, field production and isolation, post harvest handling and quality testing, and certification and traceability to illustrate how seed producers can systematically meet physical, physiological, and genetic quality requirements. The findings highlight that adherence to seed production standards can increase productivity, reduce the risk of seed-borne diseases, and improve farmers' confidence in formal seed systems, while policy implications include strengthening certification institutions, promoting producer training, and developing digital traceability tools for seed lot monitoring.

Keywords: Quality Seed, Seed Production, Seed Certification, Genetic Purity, Traceability and Productivity

1. Introduction

Seed is widely recognized as the most critical input in agriculture because it determines the upper limit of crop productivity and responsiveness to management. In a marine or coastal context, a similar principle applies to aquaculture and coastal agro maritime systems: the "seed" (for example, fish fry, shrimp post-larvae, seaweed propagules, or mangrove seedlings) sets the biological potential of production in ponds, cages, sea farms, and coastal rehabilitation projects. High quality seed with verified genetic purity, high survival potential, and robustness to environmental stress enables farmers or coastal producers to achieve better yields even under limited feed, fluctuating water quality, or modest infrastructure, whereas poor quality seed can negate investments in feed, aeration, water treatment, and infrastructure, just as poor crop seed can waste fertilizer and irrigation on land. High quality seed with verified genetic purity, high germination, and vigor enables farmers to achieve better yields even under resource constrained conditions, while poor quality seed can negate the benefits of fertilizers, irrigation, and crop

protection. In the context of marine and coastal production systems, the same logic holds for hatchery produced seed: robust, disease free fry or post larvae allow more efficient use of feed, energy, and infrastructure, whereas weak or infected seed leads to higher mortality, poor feed conversion, and increased treatment costs. For both agriculture and aquaculture, this creates a strong incentive for regulators and industry to adopt standards and certification systems that define what “quality seed” means in measurable terms and how it should be produced [1].

In response, international organizations and national regulatory agencies have developed seed standards and certification schemes to ensure that marketed seed meets minimum quality thresholds for purity, moisture, health, and germination. This regulatory logic is mirrored in many coastal and marine sectors, where standards for hatchery management, broodstock quality, biosecurity, and water quality are used to ensure that aquaculture seed (fish, shrimp, shellfish, seaweed) meets minimum health and performance criteria before stocking. These standards define not only laboratory parameters but also field or facility level procedures for maintaining identity (specific strain or species), controlling off types or unwanted species, and preventing contamination during production and handling. In aquaculture hatcheries, for example, this includes protocols for water intake and treatment, disinfection routines, stock density, feeding regimes, and health screening functionally analogous to field inspection, isolation distances, and rouging in seed crops. Nevertheless, in many developing economies, the seed sector remains dualistic, with a coexistence of formal and informal systems; smallholder farmers frequently rely on saved seed or local markets where quality control is weak or absent. A comparable dualism often exists in coastal and marine resource use: alongside formal hatcheries and regulated farms, there are small scale or informal operations sourcing seed from unregulated suppliers or wild capture without health screening. This can lead to production units stocked with mixed or low quality seed, increasing disease risk and reducing productivity, just as unregulated crop seed can contain mixtures of varieties, weed seeds, and pathogens. The result in both cases is limited adoption of improved, high performing genetic material and reduced effectiveness of sectoral development programs meant to raise yields and incomes [2].

Seed quality is a multidimensional concept encompassing genetic, physical, physiological, and health attributes. In a marine or aquaculture setting, similar dimensions can be identified for seed: genetic quality relates to the strain or line (for example, fast growing or disease-resistant fish lines), physical quality relates to size uniformity and absence of deformities or foreign organisms, physiological quality relates to survival, stress resistance, and growth potential, and health quality concerns freedom from pathogens and parasites. Genetic quality refers to the maintenance of varietal identity and purity; physical quality relates to the proportion of pure seed and the absence of inert matter and contaminants; physiological quality concerns germination and vigor; and health quality pertains to the presence or absence of seed-borne diseases and pests. An effective seed production process must therefore integrate these dimensions from the earliest stages of breeder seed preparation to the final packaging and distribution of certified seed, and in marine contexts, an analogous process must integrate broodstock management, spawning, larval rearing, grading, health checks, and transport to farms. This paper proposes a structured Quality Seed Production Process According to Standards that synthesizes key principles from regulations, international guidelines, and practical experience in seed multiplication systems. The same systems-thinking approach can be translated into marine engineering related domains that support aquaculture and coastal production for instance, designing hatchery water treatment systems, nursery infrastructure, or offshore aquaculture facilities that enable consistent application of biological quality standards. By organizing the process into clear stages variety selection, field isolation, rouging, harvesting, conditioning, laboratory testing, and certification the



study provides a normative guide for seed producers, extension agents, and policymakers who seek to uplift seed quality along the entire value chain. In a marine or coastal context, engineers and planners can apply a similar staged, standards based logic to the design and operation of marine infrastructure: ensuring that facility design, water intake and circulation, biosecurity systems, handling equipment, and monitoring protocols are all aligned with biological quality requirements for aquaculture seed and stock. Although primarily focused on terrestrial agriculture, this layered quality system concept can be modified to support the governance and engineering of marine facilities related to the production and supply of seeds (seedlings) for aquaculture and coastal rehabilitation [3].

2. Materials and Methods

This study relies on secondary data drawn from three main categories of sources: international seed standards and testing rules, national regulatory frameworks, and peer reviewed scientific literature in the field of seed science. International standards, such as the OECD seed schemes and the ISTA (International Seed Testing Association) rules, are used to understand globally accepted definitions of seed quality, including how parameters like germination, purity, and moisture should be measured, and under what conditions tests must be conducted to ensure reliability and comparability across laboratories. These documents also describe in detail how seed samples should be taken from bulk lots, how large the samples must be for different seed sizes, and how test results should be interpreted and reported to maintain statistical validity. National seed laws, implementing regulations, and technical guidelines issued by ministries of agriculture and official seed certification agencies complement this international framework by specifying country specific requirements for seed classes (such as breeder, foundation, and certified seed), legal obligations of seed producers, and the roles and responsibilities of inspectors, analysts, and regulatory authorities in monitoring compliance. They typically outline step by step procedures for field inspection (including the number and timing of visits, traits to be observed, and allowable levels of off types and diseased plants), as well as conditions under which a seed lot can be approved, downgraded, or rejected [4].

In parallel, scholarly publications on seed technology, seed system development, and seed quality management provide empirical evidence and conceptual insights that help interpret and operationalize these standards in real production environments. Research articles and technical reviews document how specific practices such as isolation distances, rouging intensity, harvesting time, drying methods, and storage conditions affect key seed quality traits, and they often compare the performance of formal and informal seed channels under different agro ecological and socio economic contexts. From these studies, the present work extracts lessons on critical control points, common failure modes, and cost effectiveness of various quality assurance measures, which are then integrated into the proposed process framework [5].

All of these documents together provide both quantitative benchmarks and qualitative procedures. Quantitative benchmarks include, for example, minimum germination percentages required for certified seed of particular crops, maximum allowable proportions of inert matter, weed seeds, and other crop seeds, as well as acceptable ranges for seed moisture content to ensure safe storage without rapid viability loss. Qualitative procedures detail how these targets should be achieved and verified: they describe field inspection protocols (what traits to observe, sampling patterns within fields, documentation requirements), isolation requirements based on pollination biology and landscape context, and recommended methods for cleaning and conditioning seed to remove contaminants without damaging seed viability. In addition, official manuals and internal standard operating procedures from accredited seed testing laboratories are



used to ensure that the conceptual model aligns with how tests are actually performed in practice. These manuals specify, for each test type, the apparatus needed, environmental conditions (such as temperature, light, and substrate) for germination tests, counting rules for normal and abnormal seedlings, methods for purity analysis and separation of seed fractions, techniques for moisture determination (e.g., oven drying or rapid methods), and diagnostic procedures for detecting seed borne pathogens. By basing the framework on these well established, codified procedures, the study ensures that the described Quality Seed Production Process is technically sound, reproducible, and directly compatible with existing regulatory and laboratory systems, so that it can be adopted or adapted by seed producers, inspectors, and policymakers without contradicting current standards [6].

3. Results

Standard compliant seed production is a continuous chain that begins with choosing the correct variety and obtaining authentic breeder or foundation seed, then establishing well isolated seed fields where cross pollination and physical mixing are minimized. During crop growth, good agronomic management is combined with scheduled field inspections and rouging to remove off types, volunteer plants, and diseased individuals before they contribute to the seed lot. Harvest is conducted at true physiological maturity with clean equipment to protect viability and avoid mixing among different lots. After harvest, seed is dried carefully to safe moisture levels to maintain germination and storability, then cleaned and graded to remove inert matter, weed seeds, and other crop seeds and to improve uniformity. Where appropriate, seed treatments are applied under controlled conditions to protect against pests and diseases. Representative samples are then taken using standardized procedures and sent to accredited laboratories, where purity, germination, moisture, and, when necessary, seed health are tested under defined conditions so that results accurately reflect the quality of the bulk lot [7].

These operations can be organized into four interactive layers. The genetic and varietal integrity layer ensures the correct variety and seed class are used and properly documented, preventing genetic drift across multiplication cycles. The field production and isolation layer covers site selection, isolation design, crop establishment, inspections, and rouging, translating genetic intentions into field practice and protecting against contamination. The post harvest handling and quality testing layer links harvesting, threshing, drying, cleaning, grading, treatment, storage, sampling, and laboratory testing to the physical, physiological, and health attributes of the seed. Finally, the certification, labeling, and traceability layer uses all process records and test data to make formal certification decisions, issue labels, and maintain batch level tracking from field to farmer [8].

Within this framework, it becomes clear that different stages primarily shape different quality traits: genetic purity depends on source seed and field isolation; physical purity is determined by cleaning, grading, and equipment hygiene; germination and vigor are highly sensitive to stress, harvest timing, drying, and storage; and seed health reflects both field disease management and post harvest sanitation. Because each step affects specific quality attributes, weaknesses at any stage can permanently compromise the final seed lot, so training, infrastructure investment, and policy support must focus on the most critical control points to consistently deliver high quality seed to farmers [9].

4. Discussion

4.1 Strategic Role of Standardized Seed Production



The findings indicate that standardized seed production processes serve as strategic levers for improving productivity and stability in farming systems. By ensuring that each stage from source seed to certification is governed by clear procedures and thresholds, producers can reliably deliver seed that meets farmers' expectations and legal requirements. This reliability reinforces trust in formal seed channels and encourages wider adoption of improved varieties, amplifying the impact of plant breeding and agronomic innovations. Moreover, alignment with recognized standards facilitates participation in regional and international seed markets, where buyers require documented proof of quality and provenance. Thus, investment in standard-compliant processes can open new commercial opportunities for seed producers and support the development of competitive seed industries [10].

4.2 Institutional Capacity and Implementation Challenges

Effective implementation of the proposed framework depends heavily on institutional capacity. Seed certification agencies need sufficient human resources, inspection protocols, and laboratory infrastructure to conduct timely and accurate evaluations. In many countries, limited budgets, inadequate training, and logistical constraints can slow certification processes or reduce inspection coverage. On the producer side, small and medium seed enterprises may face barriers such as limited access to processing equipment, storage facilities, and technical know-how. Tailored capacity-building programs, cost-sharing mechanisms for equipment, and simplified certification pathways for smaller producers could help bridge these gaps without compromising quality [11].

4.3 Digitalization and Traceability Opportunities

The framework suggests that digital tools can significantly strengthen the certification, labeling, and traceability layer. Digital platforms can record field inspection data, laboratory results, and seed lot movements in real time, allowing regulators, producers, and buyers to access up to date information on quality status. Technologies such as QR codes linked to online databases can enable farmers to verify the authenticity and certification details of seed bags at the point of purchase. Adopting such tools may require initial investment and training but can enhance transparency, reduce opportunities for fraud, and facilitate post-market surveillance and recall mechanisms when problems arise [12].

4.4 Implications for Smallholder-Oriented Seed Systems

For smallholder farmers, access to quality seed is crucial for increasing yields and reducing risk, yet formal seed supply often remains limited or geographically distant. Supporting farmer organizations, cooperatives, or community based seed enterprises to adopt standard compliant processes can localize the supply of quality seed while creating rural employment and entrepreneurship opportunities. Policies that combine rigorous quality requirements with flexible, context specific implementation such as phased certification, participatory guarantee systems, or decentralized testing facilities can help avoid excluding small actors from formal systems. Integrating gender and social inclusion considerations into training and support programs can further enhance equitable access to benefits [13].

5. Conclusion

The explanation underscores that quality seed is produced by an integrated system that



spans the entire seed value chain, rather than by a single point intervention such as a final laboratory test. The proposed framework brings structure to this system through four interrelated layers: genetic and varietal integrity, field production and isolation, post harvest handling and quality testing, and certification and traceability. Each layer has a distinct function starting from securing authentic breeder or foundation seed and preserving varietal identity, through managing how the seed crop is grown, harvested, and processed, and ending with how seed is tested, certified, labeled, and tracked in the market. When these layers work together coherently, they ensure that seed lots consistently meet requirements for genetic purity, physical purity, germination, and health, which in turn supports higher and more stable yields at farm level.

From an institutional and policy perspective, the framework shows that having written standards is not enough; the surrounding system must also be capable of enforcing and supporting them. Certification agencies need adequate human and financial resources, clear inspection and decision protocols, and coordination with accredited laboratories that can perform purity, germination, moisture, and health tests reliably. Seed producers and farmer groups require ongoing training to understand why each step such as isolation, rouging, drying, or proper storage is critical, and how to carry it out according to standards. At the same time, digital tools for data capture, certification records, and lot tracking can increase transparency and reduce the risk of fraud, making it easier for regulators and farmers to verify that a bag of seed truly meets its label claims.

The text also highlights priorities for future work and long term strategy. Because seed systems, crops, and regulatory environments vary widely, the framework should be adapted to specific crop country contexts, with local thresholds and procedures defined based on agro ecological conditions and institutional capacity. Research is needed to quantify how applying the framework affects yields, income, seed losses, and disease incidence, so that governments and private actors can see the concrete returns on investing in quality seed systems. Embedding this standardized, system based approach to seed production within broader agricultural development and climate resilience strategies is presented as essential: quality seed makes other interventions like improved agronomy, irrigation, and stress tolerant varieties more effective, thereby contributing to more productive, resilient, and sustainable farming systems overall.

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