Concepts of Seed Science and Technology

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Cambridge Scholars Publishing

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This book first published 2024

Cambridge Scholars Publishing

Lady Stephenson Library, Newcastle upon Tyne, NE6 2PA, UK

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN: 978-1-0364-1494-8
ISBN (Ebook): 978-1-0364-1495-5

TABLE OF CONTENTS

ABBREVIATIONS

AA: Appellate Authority
Air Screen Machine: ASM
Air Separator: AS
ASA: Appeal Against Seed Certification Agency
B: Bajra
BAS - Bagging Automatic Scale
BCP: Brief Cultural Practices
BH - Bagging Handling
BMS - Bagging Manual Scale
BMS: Breakdown of Male Sterility
BS: Breeder Seed
BSS - Bagging Semi-Automatic Scale
BT: Breeder Techniques
BW - Bagger-Weigher
CE: Chemical Emasculants
CE: Cultural Manipulation for Nicking
CPA: Crop Production Area
CPT: Control Plot Testing
CS: Certified Seed
CSA: Central Seed Committee
CSCB: Central Seed Certification Board
CSP: Certified Seed Program
CSTL: Central Seed Testing Laboratory
DBD: Differential Blooming Dates
DCSP/CHSP: Double Cross Seed Production/Commercial Hybrid Seed Production
DCV: Developmental Variation
DH: Development of Hybrids
DRT: Direct Treater
Electric Color Sorters: ECS
EP: Electrophoresis
EVT: Evaporation
F&I: Fungicides and Insecticides
F: Female
FAD: Forced Air Drying

FAO: Food and Agriculture Organization
FCP: Final Cultural Practices
FFYP: First Five-Year Plan
FI: Field Inspections
FLC: Flag Leaf Clipping
FR: Field Requirement
FSI: Field Inspection
FSP: Foundation Seed Program
G.B. Pant University: G.B. Pant University of Agriculture & Technology
GA: Grain Auger
GA_3A: GA_3 Application
GCS: Grant of Certificate, Tagging, and Sealing
GD: Genetic Drift
GOT: Grow-Out Test
Gravity Separator: GS
HDS: Harvesting, Drying, and Shelling
HP: Hand Pollination
HPD: Heated Air Drying
HSP: Hybrid Seed Production
HT: Harvesting and Threshing
HVAC: Heating, Ventilation, and Air Conditioning
HYV: High Yielding Variety
ICAR: Indian Council of Agricultural Research
ID: Isolation Distance
IMC: Initial Moisture Content
IMSCS: Indian Minimum Seed Certification Standards
INM: Inorganic Non-Mercurials
IP: Isolation Practices
IPR: Intellectual Property Rights
IR: Inspection and Roughing
ISC: Improper/Defective Seed Certification System
ISST: Indian Society of Seed Technology
ISTA - International Seed Testing Association
Layout Planning: LP
LD: Land Requirements
M: Maize
M: Mutations
Magnetic Separator: MS
MC: Moisture Content
MGV: Minor Genetic Variation
MICOR: Methods of Increasing Cross-Pollination Rate

MM: Mechanical Mixtures
Moisture Content: MC
MP: Maintenance of Parental Lines
MPBS: Maintenance of Breeder seed
MPGP: Maintenance of Genetic Purity during Seed Production
MPL: Maintenance of Parental Lines
MPN: Maintenance of Nucleus seed
NAF: Natural Air Drying
NARP: National Agricultural Project
NC: Natural Crossing
NCA: National Commission on Agriculture
NS: Nucleus Seed
NSP: National Seeds Programme
ONM: Organic Non-Mercurials
OPV: Open-Pollinated Varieties
PBR: Plant Breeder Rights
PE: Platform Elevator
PH: Seed Packing and Handling
PHD: Post-Harvest Drying
PHI: Post-Harvest Inspection
PIST: Precautions in Seed Treatment
PL: Portable Lifter
PPV&FR: Protection of Plant Varieties and Farmers' Rights Act
PR: Planting Ratio
R: Rice
RC: Revocation of Certificate
RD: Relative Humidity
RFI: Receipt and Scrutiny of the Application
Rou: Rouging
RP: Rope Pulling
RR: Rouging in Hybrid Seed Production
S&NPD: Systemic and Non-systemic Plant Diseases
S: Sorghum
SA: Seed Act
SA: Seed Inspector
SA: Seeds Act
SC: Seed Certification
SCA: Seed Certification Agency
SCD: Seed Drying
SCSP: Single Cross Seed Production
SD: Seed Disinfection

SC: Seed Cleaning
SL: Seed Lots
SP: Seed Processing
SQ: Seed Quality
SU: Seed Upgrading
SID: Selective Influence of Diseases
SLE: Seed Law Enforcement
SLT: Slurry Treater
SoS: Source of Seed
SP: Seed Production
SP: Seed Protection MC: Mercurial Compounds
SPH - Seed Packing and Handling
SPS: Seed Production of Sorghum
SQE: Seed Quality Enhancement
SR&SB: Seed Rot and Seedling Blights MI: Mechanical Injuries
SSC: State Seed Corporation
SSCA: State Seed Certification Agencies
SST: Seed Sampling and Testing
SSTL: State Seed Testing Laboratories
ST: Seed Technology
ST: Seed Treatment
STC: Selfing and Sibling Pollination
SWD: Sun Drying
SY: Seed Yield
TL: Two-Line System
TLS: Three-Line System
TLS: Truthfully Labeled Seed
TLS-AxR: Three-Line System Hybrid Seed Production (AxR)
TLS-CHSP: Commercial Hybrid Seed Production in Three-Line System
TLS-HSP: Three-Line System Hybrid Seed Production
TLS-MPL: Maintenance of Parental Lines in Three-Line System
TMP: Temperature
TRIPs: Trade-Related Aspects of Intellectual Property Right
TTS: Two-Line System
Types of Seed Cleaning Stages: TSCS
Unwanted Materials: UM
UPOV: International Union for the Protection of New Varieties of Plants
VP: Validity Period
VSSCR: Verification of Seed Source, Class, and Requirements
Y: Yield

CHAPTER 1

CONCEPT AND GOALS OF SEED TECHNOLOGY

Introduction

The history of agricultural progress from the early days of man has been the history of seeds of new crops and crop varieties brought under cultivation. In the early days it was achieved through the cultivation of indigenous but useful plants and those taken through introductions. Later, through the well-known techniques of selection, hybridization, mutation, polyploidization, and plant biotechnology the scientists made available many new and better varieties. However, to the farmer all this scientific research would be of little value unless he gets seeds which are genetically pure, high germination percentage and have vigor, high purity, sound health etc., When the farmers do not get seeds possessing these qualities the yields they obtain may not be as expected. The pace of progress in production, therefore, will largely depend upon the speed with which we are able to multiply and market good quality seeds of high yielding varieties.

Definitions of Seed Technology

Cowan (1973) identified seed technology as "that discipline of study having to do with seed production, maintenance, quality and preservation".

Feistritzer (1975) provided a definition for seed technology, describing it as the set of methods used to enhance the genetic and physical attributes of seeds. These methods involve various tasks, including creating new varieties, assessing and approving them, producing seeds, processing, storing, and certifying them.

In essence, seed technology represents a multidisciplinary field that covers a wide array of subjects. In its broadest context, it encompasses the advancement of superior crop varieties, their evaluation and release, seed production, processing, storage, testing, certification, quality control, marketing, distribution, as well as research into seed physiology, production, and handling. These activities are grounded in modern botanical and agricultural sciences.

Concept of seed technology

The differentiation between seed and grain holds immense significance within agriculture. In its strict definition, a seed is essentially an "embryo," a living organism enclosed within supporting or food storage tissue. It refers to material—be it seed, fruit, or vegetative propagating material—intended for preservation specifically for planting, serving the fundamental purpose of reproduction. Scientifically produced seeds (e.g., under seed certification) stand out notably due to their superior seed quality, including aspects like enhanced variety, varietal purity, absence of weed, and other crop seed mixtures, good seed health, high germination rates, and vigor, appropriate seed treatment, and safe moisture content. On the contrary, grains encompass cereals and pulses primarily meant for human consumption.

Differences between scientifically produced seed and the grain (used as seed)

	(Scientifically produced) seed	**Grain (used as seed)**
1.	It is the result of well-planned seed programme.	This refers to a portion of the harvest specifically reserved for sowing or planting in future agricultural cycles for commercial purposes.
2.	This outcome is the culmination of a meticulously designed seed program. It stems from a foundation of robust scientific knowledge, systematic efforts, and investments in processing, storage, and marketing infrastructure.	Knowledge is not required.
3.	The pedigree of the seed is ensured. It can be related to the initial breeder’s seed.	Its varietal purity is not known.

4.	During production, effort is made to rogue out	
	off-types, diseased plants, objectionable weeds, and other crop plants at appropriate stages of crop growth which ensures satisfactory seed purity and health.	Purity and health status is inferior
5.	The seed undergoes scientific processing, treatment, and meticulous packaging, complete with accurate lot identification labels.	The grain used as seed may be manually cleaned. In some cases, prior to sowing seed, treatment is done.
6.	The seed undergoes rigorous testing to ensure its planting quality. Assessments cover germination rates, purity, presence of weed, or other crop seeds, seed health, and moisture content.	Routine seed testing is not used.
7.	The supervision of seed quality is typically conducted by an independent agency not involved in the production process, often referred to as the seed certification agency.	There is no provision for quality control.
8.	Seed must adhere to established quality standards, ensuring a recognized level of quality. The labels and certification tags affixed to the seed containers act as clear indicators of its quality standards.	No seed quality standards are applied. The quality is non-descript and not known.

Role of seed technology:

Feistritzer (1975) outlined the following roles of improved seed.

1. Improved seed – a carrier of new technologies.

The strategic introduction of quality seeds, especially new varieties coupled with other essential inputs, has proven to be a catalyst in substantially boosting yield levels. In India, the adoption of high-yielding varieties has played a pivotal role in elevating food production from 52 million tonnes to nearly 180 million tonnes over a span of 40 years**.**

2. **Improved seed – a basic tool for secured food supply.**

India's effective execution of the high-yielding varieties program has resulted in a remarkable surge in production. Moreover, despite a rapid population increase, the country has managed to reduce its dependency on food imports from other nations**.**

3. Improved seed – the principal means to secure crop yields in less favorable areas of production.

Providing high-quality seeds of improved varieties tailored to specific regions stands as a crucial contribution toward achieving higher crop yields in those areas. Improved seeds are a medium for rapid rehabilitation of agriculture in cases of natural disaster. During instances of floods or droughts impacting agricultural areas, the government intervenes by supplying improved seeds from national seed reserves. This initiative aims to rehabilitate and revive food grain production within the country's affected regions.

Goals of Seed Technology:

The major goal of seed technology is to increase agricultural production through the spread of good quality seeds of high yielding varieties. It aims at the following:

1. Rapid multiplication: Enhancing agricultural production by rapidly disseminating newly developed plant varieties is key: The efficiency and sufficiency of seed technology in a country should be measured by the speed at which significant quantities of seeds of improved varieties reach farmers.
2. Timely supply: It’s crucial to ensure timely availability of improved seeds of new varieties, allowing farmers to maintain their planting schedules without disruption and enabling them to utilize superior seeds for planting purposes.
3. Assured high quality of seeds: This is necessary to obtain the expected dividends from the use of seeds of improved varieties.
4. Reasonable price: The cost of high-quality seed should be cheap so that it can be in reach of the average farmer.

CHAPTER 2

HISTORY OF SEED INDUSTRY IN INDIA

History and development of seed Industry in India can be discussed under two headers:

1. Pre-independence development
2. Post- independence development

Pre-independence development:

1. In the initial years of the 20th century, endeavors were undertaken to create enhanced varieties of cotton, wheat, groundnut, and sugarcane. The state department of agriculture embraced two methods for reproducing and disseminating these improved varieties: The strategy involved the multiplication of seeds of improved varieties at a single location, followed by distribution across a wide geographical area to replace the existing local varieties.
2. Small packets of seeds were distributed to numerous farmers, with the expectation that these farmers would multiply the seeds themselves, contributing to the expansion of the improved varieties.

In Bengal, efforts to implement the second method, which aimed at distributing better strains of jute and paddy among farmers for multiplication, did not yield favourable results. As a result, the state returned to the initial approach of centralized multiplication and subsequent distribution of these improved varieties. In 1925 the Royal Commission on Agriculture put forth specific recommendations regarding the introduction and dissemination of improved varieties.

1. They proposed the creation of a specialized entity within the agricultural domain solely focused on the examination and dissemination of seeds.

2. Their suggestion involved utilizing cooperative societies, the Department of Agriculture, and certified seed growers as the principal avenues for distributing seeds.

3. There should be proactive support and encouragement provided to private individuals or entities involved in seed cultivation.

Following the suggestions of Royal commission, the Govt. of India established the Research Institutes, however the seed multiplication and distribution was not encouraging. Later on several committees were made, notably including:

1. **Sir John Russell Committee in 1937**
2. **ICAR committee in 1940**
3. **Dr. Burns committee in 1944**
4. **Famine enquiry committee in 1944**
5. **Food Grain Policy committee in 1944**

Following are the points which were revealed by the review commission. Review commissions revealed that:

- Crop botanists should actively participate in the creation, testing, and showcasing of enhanced varieties.
- The government farms should initially undertake the multiplication of seeds, followed by subsequent multiplication in the fields of registered growers.
- The government ought to buy seeds from registered growers at a higher price and subsequently distribute them to farmers at subsidized rates.

Till 1939 vegetable seeds were imported from other countries and, due to the second world war in 1939, the supply of veg. Seeds were completely ended and by 1945 private Seed companies of vegetable had developed facilities for producing vegetable seed at **Quetta** in Pakistan and Kashmir valley. In 1946, The All-India Seed Growers, Merchants, and Nurserymen's Association was established with the aim of swiftly advancing the vegetable seed industry.

Seed Industry after Independence

1948 - 17 Agricultural colleges were under the department of Agriculture
1948-49 - Dr S. Radha Krishnan recommended the formation of Agricultural Universities and called them rural Universities. Until 1951, agriculture was neglected and, not until after the formation of Agricultural University and Research Institutes, did agriculture development start in India.

First Five-Year Plan (1951-56)

During this era, considerable importance was placed on utilizing enhanced seeds. These improved varieties were formulated, and the initial breeder seed was cultivated on government farms. Subsequently, it underwent multiplication in 2 or 3 stages through different classes of cultivators referred to as A, B, and C. The purity of the seed decreased as the number of intermediate stages increased.

1952 - Grow More Food Enquiry Committee

Upon establishment, they proposed schemes for seed multiplication and distribution. However, the progress achieved during the FFYP was unsatisfactory, and seeds were primarily distributed with subsidies.

Second five -year Plan (1956-61)

This era is widely considered a golden age for Agricultural Development and Research. In 1957, the All India Coordinated Maize Improvement Project was initiated in partnership with the Rockefeller Foundation of the USA, employing a multidisciplinary approach. Within just four years of its inception, four maize hybrids were introduced and made available.

In 1961 four maize hybrids were released as: [1] Deccan Hybrid Makka-Hyd; [2] Ranjit from New Delhi; [3] Ganga -1 from G.B.Pant Agril. Univ.; [4] U.P Ganga -101 from G.B. Pant Agril. Univ., U.P.

Observing the advancements achieved, the Government of India initiated analogous projects for Sorghum and Bajra in 1961. The initial sorghum hybrid CSH-1 was released from New Delhi in 1964, followed by the first bajra hybrid HB-1 from Punjab in 1965. Subsequently, the Government of India expanded this initiative to encompass all crops of significant economic importance.

During this period, there was a significant emphasis on multiplying foundation seeds from breeder seeds at the block level. To achieve this, a policy was formulated requiring each National Extension Service Block to possess a seed farm and a seed store. As per this plan, 4328 seed farms, each spanning 10 hectares, were proposed. However, by the conclusion of the second planned period, only 2551 seed farms were operational.

In 1959, the first Indo-American Agriculture Production Team was formed to assess India's food production challenges. The team, led by Dr. Sherman

E. Johnson of the Ford Foundation, put forward the following recommendations:

- Extension workers at the village, block, and district levels should take responsibility for educating farmers on the utilization of improved seeds.
- State Agriculture Department to be made responsible for seed certification. Co-operatives and private seed growers need to take accountability for ensuring seed supply.
- Establishment of seed testing laboratories.
- Formulation of uniform seed certification standards and enactment of seed laws for regulation.
- The expected progress during the SFYP couldn't be attained due to several reasons:
- Insufficient availability of necessary quantities of breeder seed.
- Limited inclusion of crucial cereals like hybrid maize and bajra in seed programs.
- Inadequate organization of the Foundation Seed Program (FSP) at the block level, leading to incomplete utilization of foundation seed in some blocks.
- Lack of timely inspections to remove undesirable plants.
- Predominantly leaving the marketing of improved seed to seed producers.
- Unsatisfactory seed procurement due to insufficient funds.
- Defective seed processing resulting in numerous complaints about seed purity and germination.

The first Agricultural University in the country was established at Pantnagar in Uttar Pradesh. During the Third Five Year Plan (1961-66), the introduction of the initial four maize hybrids in 1961 prompted the need for a dedicated organization to facilitate seed production, thus leading to the establishment of the Central Seeds Corporation (CSC) in 1963. The primary objectives behind the establishment of CSC were:

1. Establishing foundation and certified seed production.
2. Assisting in the development and marketing of seeds.
3. Encouraging and aiding in the development of seed certification programs, seed laws, and enforcement programs.
4. Training personnel engaged in seed programs.
5. Coordinating improved seed programs.

This signified the initiation of a structured seed production program grounded in scientific principles. NSC's primary establishment was for foundation seed production. However, due to the absence of other organizations, NSC assumed the responsibility for managing FSP, CSP, seed certification, and seed marketing. Additionally, it played a role in facilitating the establishment of seed processing plants, aiding private seed producers, and conducting training programs for individuals involved in seed production. NSC's most notable accomplishments in advancing the seed industry include:

1. Creating a scientific seed industry within the nation.
2. Supporting and motivating Indian manufacturers to produce seed processing equipment.
3. Creating field inspection techniques and seed standards for seed certification and labelling.
4. Multiplying pre-released varieties of national importance.
5. Implementing Foundation Seed Programs for varieties significant at a national level.
6. Offering expert services to the Food and Agriculture Organization (FAO) for designing high-capacity processing plants in Iran and constructing seed storage facilities in Malaysia.

1966-69-Annual Plans

In 1966, the Indian government initiated the High Yielding Variety (HYV) program, aiming to cover 9.2 million hectares of food crop area by 1968-69 and 25 million hectares by 1973-74, specifically targeting crops like bajra, maize, sorghum, paddy, and wheat. The Parliament introduced the Seed Act Bill on December 29, 1966. Then, on October 2, 1969, this bill came into effect nationwide. During 1968, the Indian government established a seed review team, which addressed various topics and proposed 101 recommendations.

ICAR establish standards to enhance the quality of breeder seed.

1. During the Fourth Five-Year Plan (1969-74), the Tarai Development Corporation was founded in 1969 with support from the World Bank. The project's primary goal was the comprehensive agricultural development of the Tarai region, emphasizing the production of high-quality seeds. Subsequently, on July 1, 1978, it was rebranded as U.P. Seeds and Tarai Development Corporation Ltd. The unique features of this corporation were: The G.B. Pant University of

Agriculture & Technology staff actively participated in the project, offering technical guidance and supervision to seed growers to enhance the production of substantial quantities of Foundation and Certified seeds necessary for the entire project area. Employing an integrated development approach, the project prioritized activities such as land levelling, farm mechanization, irrigation development, electrification, and ensuring sufficient availability of essential inputs to foster superior crop growth, along with facilitating credit facilities.

2. Seed growers were encouraged to become shareholders of the corporation, contrasting the conventional contact system of seed production.
3. Implementation of the Compact Area Approach: Technical supervision, guidance, and certification tasks, crucial but time-consuming, were efficiently managed in compact regions. This approach facilitated collective plant protection measures, training programs, and streamlined the arrangement of credit facilities.
4. Emphasis on stringent quality control measures: Besides inspections conducted by the Seed Certification Agency (SCA), the corporation, in collaboration with the G.B. Pant University, undertook inspections during all stages of seed production, marketing, and distribution. Introducing laboratory testing for the first time, substandard seed lots were rejected.
5. Money-Back Guarantee: The corporation offered refunds if any seed lot was deemed substandard by their assessments.
6. Integrated seed marketing approach: The Corporation exclusively appointed dealers engaged in marketing fertilizers, pesticides, etc., simultaneously. This strategy aimed to provide consumers with easy access to multiple inputs in one location.

In 1971, the **Indian Society of Seed Technology (ISST)** was established, offering a platform for individuals involved in the seed industry to share experiences and scientific knowledge. The ISST publishes the Seed Research and Seed Technology Newsletter and convenes annually.

During the Fifth Five-Year Plan (1974-77), the National Commission on Agriculture conducted a review of the seed industry and presented recommendations in 1976. These recommendations included:

1. Expanding the seed industry along commercial lines and considering foreign involvement if necessary.

2. Developing a national registry of varieties by ICAR (Indian Council of Agricultural Research) and the Central Seeds Committee.
3. Encouraging small participants to form compact areas for seed production.
4. Offering promotional measures to seed growers, such as seed crop insurance and tax exemptions.
5. Facilitating the development and production of seed processing equipment.
6. Making seed processing compulsory.
7. Storing breeder seed and nucleus seed under controlled conditions.
8. Integrating grow-out tests into seed testing procedures.
9. Enforcing seed acts rigorously.
10. Considering the possibility of compulsory certification for seed material of hybrids and vegetatively propagated crops.
11. Introducing teaching programs on seed production technology in Agricultural Universities.
12. Dividing the Department of Agriculture into three distinct wings: handling input aspects, law enforcement, and seed certification.

The Government of India, in alignment with the recommendations of the National Commission on Agriculture (NCA), decided to set up seed production agencies across the country to ensure a reliable supply of seeds, thereby boosting agricultural production. Following the NCA's suggestions in 1976, the government launched the National Seeds Programme (NSP) in 1974, with financial assistance from the World Bank. NSP-I was initiated in 1975-76, but actual implementation began in 1976. Initially, State Seed Corporations (SSC) were established in four states: Punjab, Haryana, Maharashtra, and Andhra Pradesh. The program expanded in its second phase, establishing SSCs in an additional five states: Karnataka, Rajasthan, Uttar Pradesh, Bihar, and Orissa.

During the Sixth Five-Year Plan (1980-85), the Seed Control Order was enacted, designating seeds as an essential commodity. The Government of India initiated the National Agricultural Project (NARP), dividing the entire country into 127 Agro climatic zones and seven zones in Andhra Pradesh.

In the Seventh Five-Year Plan (1985-90), significant focus was placed on enhancing infrastructure and facilities to augment seed production in both the public and private sectors. Under NSP-III, SSCs were established in four more states: Assam, West Bengal, Madhya Pradesh, and Gujarat. This phase also emphasized bolstering seed technology research and training facilities.

A new policy on seed development was enacted on September 16, 1988, effective from October 1, 1988. This policy aimed to ensure Indian farmers' access to the finest seeds globally to maximize crop yields.

Key emphases of the policy included:

1. Importing high-quality seeds.
2. Implementing a time-bound program to enhance Plant Quarantine facilities.
3. Ensuring effective compliance with procedures for quarantine and post-quarantine measures.
4. Providing incentives to promote the growth of the domestic seed industry.
5. During the Eighth Five-Year Plan (1992-97), elevated seed production targets were set for this period.

The functions and responsibilities of a seed certification agency:

1. Certifying seeds of any notified kind or variety.
2. Outlining procedures for seed certification to ensure compliance with prescribed field and seed standards.
3. Verifying the eligibility of varieties for certification and validating the seed source.
4. Maintaining a registry of registered plant breeders.
5. Conducting field inspections at various crop growth stages to verify field standards and prevent genetic contamination.
6. Collecting samples from seed lots to confirm compliance with prescribed seed standards.
7. Inspecting seed processing plants to ensure avoidance of mechanical mixtures during processing.
8. Educating farmers about the benefits and proper use of certified seeds.
9. Issuing certificates, labels, and tags for certified seeds.

CHAPTER 3

DETERIORATION OF CROP VARIETIES AND VARIOUS METHODS TO PREVENT

The primary goal of seed production is to generate high-quality seeds that are genetically pure. However, it's important to understand why and how the genetic purity of a particular variety can decline or diminish during the process of seed multiplication. Kadam (1942) outlined various factors contributing to the loss of genetic purity in seed production, including:

Developmental Variation

1. Mechanical Mixtures
2. Mutations
3. Natural Crossing
4. Genetic drift
5. Minor Genetic Variation
6. Selective influence of Diseases
7. Techniques of the Breeder
8. Breakdown of male sterility
9. Improper / defective seed certification System

Developmental Variation: When a seed crop is cultivated in challenging environmental settings such as varied soil types and fertility, saline or alkaline conditions, diverse photoperiods, elevations, or stressful circumstances over several successive generations, it can lead to differences in growth patterns. To prevent or reduce such developmental discrepancies, it's crucial to always cultivate the variety in regions where it can adapt effectively or in the specific area for which it was originally intended. In cases where it's grown in non-adaptable areas due to certain reasons (like insufficient isolation or to prevent soil-borne diseases), it should be limited to one or two seasons. Moreover, the fundamental seeds, namely the nucleus and breeder seeds, must be multiplied in areas where the variety thrives and adapts well.

Mechanical Mixtures: This constitutes the primary source of variety contamination throughout the seed production process. Mechanical mixtures can occur at various stages, spanning from planting to harvesting and processing, manifesting in several ways, including:

a. Contamination via the field: self-sown seeds or volunteer plants
b. Seed drill usage: if the same seed drill is employed for sowing two or three different varieties
c. Coexistence of two different varieties during transportation
d. Cultivating two different varieties in adjacent plots
e. Impact on the threshing floor
f. Usage of combines or threshers
g. Contamination in bags or seed bins
h. Instances during seed processing

To prevent such mechanical contamination, it's crucial to employ various measures. This includes regularly inspecting and removing unwanted plants or foreign materials from the seed fields at different stages of crop growth. Additionally, meticulous care should be taken throughout the entire seed production process, including during harvesting, threshing, and processing, to minimize the risk of contamination.

Mutations: The significance of spontaneous mutations is relatively low, typically occurring at a rate of 10^{-7}. Should any noticeable mutations be detected, they ought to be eliminated through rouging, the process of removing these variants from the crop. For vegetative propagated crops, regularly increasing the stock of true-to-type specimens would effectively eliminate these mutants over time.

Natural Crossing: The introduction of genes from unrelated stocks or genotypes serves as a significant source of contamination in sexually propagated crops, primarily through introgression. This contamination's magnitude hinges on the degree of natural cross-fertilization, occurring due to inadvertent breeding with undesirable types, off-types, and diseased plants. Conversely, in cross-fertilized or frequently cross-fertilized crops, natural crossing stands as the primary source of contamination. The level of genetic impurity in seed fields due to natural crossing is contingent upon factors such as the species' breeding system, the isolation distance maintained, the quantity of varieties cultivated, and the agents involved in pollination. To address the challenge posed by natural crossing, it's crucial to uphold isolation distances. Increasing these distances serves to decrease the extent of contamination. The level of contamination is influenced by factors like the direction of prevailing wind flow, the presence of insects, and their activity within the environment.

Genetic drift: When seeds are multiplied in extensive areas, only a small portion of the total seed produced is selected and stored for the subsequent year's planting. Due to this sub-sampling, not all the genotypes present in the initial generation are represented equally in the succeeding generation. This unequal representation results in alterations to the genetic composition, a phenomenon termed as genetic drift.

Minor Genetic variation: Although not of significant importance, minor genetic alterations might occur throughout production cycles due to environmental disparities. These changes could potentially impact yields. To mitigate such minor genetic variations, it's essential to conduct periodic testing of varieties, starting from the breeder's seed and nucleus seed in self-pollinated crops. In often cross-pollinated species, minor genetic variation is a common occurrence; therefore, extra care should be exercised in the maintenance of nucleus and breeder seed stocks.

Selective influence of Disease: It's crucial to implement adequate plant protection measures against major pests and diseases to prevent infections in both the plants and the seeds. Foliar diseases can affect the size of seeds due to a reduced supply of carbohydrates from infected photosynthetic tissues. Seed and soil borne diseases like downy mildew, ergot of Jowar, smut of bajra, and bunt of wheat pose a risk, making it unsafe to use infected seeds for commercial purposes once a crop is contaminated. New crop varieties may often become susceptible to new disease races that are outside seed production programs. For instance, Surekha and Phalguna became vulnerable to gall midge biotype 3.

Breeder techniques: Varieties can experience instability due to genetic irregularities if not properly assessed at the time of release. Premature release of a variety, specifically bred for a particular disease, can lead to the coexistence of resistant and susceptible plants, contributing significantly to deterioration. For example, when the Sonalika and Kalyansona wheat varieties were released in India for commercial cultivation, their genetic variability was still in the initial stages, prompting breeders to make several secondary selections.

Breakdown of male sterility: Indeed, in hybrid seed production, any breakdown of male sterility can result in the emergence of self-pollinated plants alongside the intended F1 hybrids. This breakdown leads to a mixture containing both the desired hybrids and self-pollinated plants, affecting the purity and characteristics of the seed batch.

Improper Seed Certification: While it may not be a direct factor causing the deterioration of crop varieties, any gaps or shortcomings in the previously mentioned factors could potentially contribute to such deterioration if left unchecked. Each factor plays a role in maintaining the purity, genetic integrity, and quality of crop varieties. Any lapse or oversight in addressing these factors could gradually impact the overall quality and stability of the crop varieties over time. Therefore, ensuring comprehensive checks and measures across all these factors is essential to prevent any potential decline or deterioration in crop varieties.

Maintenance of Genetic Purity during seed Production: Horne (1953) proposed several methods to ensure the maintenance of genetic purity in crops:

1. Utilizing approved seed during seed multiplication processes.
2. Conducting inspections of seed fields before planting to verify quality.
3. Implementing field inspections and approvals at crucial stages to verify genetic purity, identify any mixtures, address weed presence, and detect seed-borne diseases.
4. Sampling and securely sealing cleaned lots to maintain their integrity.
5. Growing samples alongside authentic stocks or performing Grow-out tests to validate genetic purity.

Hartman and Kester (1968) recommended several steps for maintaining genetic purity:

- Implementing isolation measures to prevent cross-fertilization or mechanical mixtures.
- Conducting rouging of seed fields before planting to eliminate undesirable plants.
- Periodically testing varieties to ensure genetic purity.
- Cultivating crops exclusively in adapted areas to prevent genetic shifts in the variety.
- Certifying seed crops to uphold genetic purity and overall quality.
- Adopting a generation system to manage and monitor seed production effectively.

Safe guards for maintenance of genetic purity: Safeguards are crucial for maintaining genetic purity during seed production:

1. Control of seed source: Ensuring the use of seeds from approved sources to maintain desired genetic traits.
2. Preceding crop requirement: Implementing specific requirements for the preceding crop to prevent contamination and maintain purity.
3. Isolation: Establishing physical isolation measures to prevent unintended cross-pollination or mixing with other varieties.
4. Rouging of seed fields: Removing off-types, weeds, or other unwanted plants from the seed fields before planting.
5. Seed certification: Certifying seeds to validate their quality and genetic purity, confirming they meet set standards.
6. Grow out test: Conducting tests by growing samples alongside authentic stocks to verify the genetic purity of the seeds produced.

The control of seed source involves ensuring the use of specific seed classes, as defined by the Association of Official Seed Certification Agencies (AOSCA). These classes are as follows:

a. **Nucleus Seed:** This comprises of a small quantity of seed carefully maintained by the responsible breeder for further multiplication. Nucleus seed contains all the desired characteristics established by the breeder and maintains the highest level of genetic purity. Typically, the quantity of nucleus seed is measured in kilograms.

b. **Breeder Seed:** Produced either by the responsible breeder or a sponsoring institute, this seed is used to generate foundation seed. Breeder seed boasts 100% genetic purity. It is marked with a golden yellow label/tag, and its quality is overseen by a government-appointed monitoring team.

c. **Foundation Seed:** Originating from breeder seed, foundation seed is cultivated and upheld with specific genetic traits and purity. It can be produced on government farms or by private seed producers. Foundation seed maintains a genetic purity of over 98%. Its quality is certified by a seed certification agency, and it is identified by a white tag or label.

Preceding Crop requirement: This has been fixed to avoid contamination through volunteer plants and also the soil borne diseases.

Isolation: Isolation plays a critical role in preventing various forms of contamination during the different stages of seed production. It helps in avoiding:

1. Natural crossing with unwanted or off-type plants within fields.
2. Mechanical mixtures that can occur during sowing, threshing, and processing.
3. Contamination resulting from nearby fields carrying seed-borne diseases.

Protection against these sources of contamination is essential to uphold genetic purity and ensure the high quality of seeds produced. Maintaining isolation helps in preserving the desired genetic characteristics and traits of the seed variety, contributing to the production of superior quality seeds.

Rouging of Seed Fields: The existence of off-type plants is another source of genetic contamination. Off-type plants differing in their characteristics from that of the seed crop are called off-types. Removal of off-types is referred to as roughing.

Off-types can originate from various sources:

1. Segregation of plants due to specific traits or mutations.
2. Volunteer plants that grow from seeds of the previous crops.
3. Accidental planting of seeds from a different variety.
4. Plants affected by diseases.

Rouging out these off-type plants from seed plots before they reach the stage of shedding pollen and subsequent pollination is crucial. This process requires regular and meticulous supervision by trained personnel to maintain the genetic purity of the seed plots. By removing these off-types, the risk of unintended genetic variation and contamination is minimized, ensuring the preservation of the desired traits in the seed production process.

Seed Certification: Seed certification serves as a fundamental system to ensure and maintain genetic purity in seed production. The primary aim is to provide high-quality seeds to farmers. To achieve this goal, certified and skilled personnel from Seed Certification Agencies (SCA) conduct thorough field inspections at crucial stages of crop development. They also perform seed inspections by sampling from seed lots post-processing. The SCA personnel meticulously assess both field and seed standards, ensuring