सत्यमेव जयते

National Training
on
QUALITY SEED PRODUCTION TECHNOLOGY OF CEREAL CROPS
(December 04-08, 2023)

Training Manual

Organized by:

Government of India
Ministry of Agriculture & Farmers Welfare
Department of Agriculture & Farmers Welfare
National Seed Research & Training Centre, Varanasi

NATIONAL TRAINING
ON
QUALITY SEED PRODUCTION TECHNOLOGY OF CEREAL CROPS
(DECEMBER 04-08, 2023)

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QUALITY SEED PRODUCTION TECHNOLOGY OF CEREAL CROPS
(DECEMBER 04-08, 2023)

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VARANASI-221 106 (UTTAR PRADESH)

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राष्ट्रीय बीज अनुसंधान एवं प्रशिक्षण केन्द्र
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FOREWORD

Cereal crops play a crucial role on a global scale, significantly impacting food security, economies and overall human well-being. These crops including Paddy, Wheat, Maize, Sorghum and millets are vital not only for direct human consumption but also for animal feed and industrial processing. India notably ranks as the second-largest producer of rice and wheat worldwide.

The nutritional significance of cereal crops is evident in their role in providing essential nutrients and energy in the daily human diet. Cereals, characterized by a higher percentage of carbohydrates compared to other food plants also contain significant amounts of protein, fats and vitamins. To enhance the amino acid profile, combining cereals with other protein sources such as legumes is recommended.

National Seed Research and Training Centre, Varanasi has organized a National Training Programme on "Quality Seed Production Technology of Cereal Crops" during December 04-08, 2023. The primary objective was to update the knowledge of participants engaged in cereal seed production and quality control. The program aimed to provide a platform for the exchange of ideas to improve the production and availability of quality cereal crop seeds for the farming community across the country.

This training module encompasses valuable information on various aspects of the seed-to-seed system in cereals. The compilation is expected to serve as a comprehensive resource book and guide for all individuals involved in cereal seed production, contributing to the advancement of knowledge and practices in the field.

Date: 08.12.2023

Place: Varanasi

(Manoj Kumar)
Director

National Training
on
Quality Seed Production Technology of Cereal Crops
(December 04-08, 2023)
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NSRTC at a glance...

National Seed Research and Training Centre (NSRTC), Varanasi established under Govt. of India, Ministry of Agriculture& Farmers Welfare, Department of Agriculture and Farmers Welfare, during October 2005.

The prime objective of establishment NSRTC is to have a separate National Seed Quality Control Laboratory, which is serving as **Central Seed Testing Laboratory (CSTL)** as well as to act as **Referral laboratory** for hon'ble court of the entire country.

Further, this **CSTL** has to coordinate and monitor the functioning of all the **notified State Seed Testing Laboratories** presently available in our country in order to obtain Uniformity in Seed quality Regulation at National level.

More importantly for facilitating International seed Movement, our CSTL the member laboratory of International Seed Testing Association (ISTA), ZURICH, Switzerland and expected to become accreditated Laboratory very soon and thereafter will be eligible for issuing International seed movement certificates on behalf of Government of India.

NSRTC is the National Centre for Training Human resources for the officials who are all involved in the **Seed Quality Control, Seed Law Enforcement and stake holders of Seed Industry.**

In order to fulfill the mandate, NSRTC organize National trainings, workshops, National seed congress for the benefit of personnel involved in seed development and quality control programme and stakeholders of seed industry for updating their knowledge and skills.

The NSRTC is situated under greater periphery of the Holy city Varanasi, which is located 7 KM away from heart of city towards south – west on Varanasi - Allahabad GT road, Collectry farm, surrounded by Banaras Hindu University (6 km), Indian Institute of Vegetable Research (20kms) and well linked by Air, Train and Road.

PRIME OBJECTIVES:

- To have a separate National Seed Quality Control Laboratory, which is serving as **Central Seed Testing Laboratory (CSTL).**
- To act as **Referral laboratory** for hon'ble court for the entire country w.e.f 1.4.2007 onwards.
- Member laboratory of **International Seed Testing Association (ISTA)**, Switzerland,
- Centre for testing all transgenic crop seeds etc., in future
- **To organize National and International seed related conferences, symposium and trainings** for the benefit of personnel who are involved in seed development and quality control programme and stakeholders of seed industry.
- Centre for training human resource on all seed related aspects.

VISION:

Our vision is to

- Contribute integrated approach towards quality seed availability.
- Have separate National Seed Quality Control Laboratory as CSTL.
- Maintain uniformity in seed testing and seed quality control at National level.

- Make Seed Industry in India globally competitive.

MISSION:

Our mission is to lead and engage in downstream programmes on Seed Science and Quality Control to disseminate the values of seed production and availability of quality seed to the need of National and International seed community.

STRATEGY:

NSRTC pursues its Mission and Goals through

- Integrated approach and system –based programs on seed quality control and act as Referral Lab for the hon'ble Court.
- Strengthening Seed Technological Research in seed production disciplines of major crops.
- Total seed quality management through systemic seed certification and law enforcement process.
- Interaction with stake holders of seed industry, officials of seed certification and law enforcement, seed producers and other seed organizations that share's NSRTC mission.
- Continued efforts in improving / updating knowledge and skill of human resources involved in seed certification and quality control as a training human resource on all seed related aspects
- In order to meet out these vision and missions strategy the NSRTC is housed in a modern building with all latest infrastructural facilities, equipments and machineries, excellent conference/ seminar hall, workshop /class rooms, exclusive ISTA member laboratories, museum, well stocked library.

Staff strength:

The Ministry of Finance sanctioned of 23 posts for National Seed Research and Training Centre, Varanasi for making the centre functional so as to meet out the mandate.

NSRTC is especially designed for continuous dissemination of knowledge of seed and thereby improve skill, competency and scientific soundness of individuals engaged in seed development programme. NSRTC regularly organizes training on various aspects of seed for the officials working in Seed Certification Agencies (25 in number), Seed Testing Laboratory (147 in number), Seed Law Enforcement Agencies, Agricultural Universities and other institutes dealing with seeds. The NSRTC, Central Seed Testing Laboratory acts as a referral lab under clause 4(1) of the Seeds Act, 1966. CSTL, NSRTC is testing more than 20,000 samples per year and performs at par with ISTA (International Seed Testing Association) with regard to seed testing net work in the country.

National Seed Testing Laboratory as Central Seed Testing Laboratory

The testing of seed material will be flowing from different State Seed Corporations as well as Seed Producing Organizations for physical purity, seed health and at later stage genetic purity that is mostly required in referral cases. At present the mandate of Central Seed Testing

Laboratory (CSTL) is to receive 5% samples from seed producing organizations all over the country. In addition, CSTL act as a Nodal centre for coordinating the activities of Seed Quality Control programmes on behalf of Government of India in accordance with the Act and Rules with the State Notified Seed Testing Laboratories.

Grow Out Test

NSRTC have been allotted 10 hectares of land out of which the office premises have been constructed in about 2.5 hectares of land and remaining land have been kept reserve for organizing Grow Out Test for which Green House/Poly House and other necessary facilities have been created.

NSRTC is geared to go Global

NSRTC is a globally competitive Institute in Seed Science and Quality control, marching ahead with:

- To promote the availability of quality seed to meet the challenges of Science based Agriculture.
- Making of promising Technologies reach the seed entrepreneurs and other stakeholders through innovative Trainings, Conferences, Workshops & Symposia.
- Establishing uniformity in Seed production & Quality Control programmes at National level.
- Innovative curriculum planning and implementation to make Seed Science & Research more vibrant and responsible to match the vision and needs of present and future.

Manoj Kumar, IAS
Director, NSRTC

Hybrid Seed Production Techniques In Maize

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Introduction

Maize (*Zeamays* L.) belongs to the large and important family, Poaceae and is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. Globally, maize is known as "Queen of Cereals" because it has the highest genetic yield potential among the cereals. . It is widely cultivated throughout the world. The United States is the largest producer of corn with 386.97 million tones from an area of 35.25 million hectares followed by China which contributes 277.00 million tons from an area of 43 million hectares. Globally, United States has also recorded highest productivity with 10.98 tons/hectare. Other top producing countries includes Brazil, Mexico, Argentina, India and Nigeria. India ranks fifth in maize production with 34.30 million tons grown on an area of 10.00 m. ha with productivity of 343 kg per hectare (Anon. 2023/24).

In India, maize is important cereal crop next to rice, wheat and sorghum. It is mainly grown in Karnataka, Madhya Pradesh, Maharashtra, Rajasthan, Bihar, Telangana, Andhra Pradesh, Tamilnadu, West Bengal, Uttar Pradesh and Punjab. It is gaining significance importance on account of its growing demand for diversified uses, especially feed and industrial uses. At the same time, substantial investment in maize research has generated through improved production technologies that helped the farmer with the means to respond to increasing demand.

Karnataka is one of the major maize producing states in the country. During 2021-22, a total of 1.59 million hectares of maize was grown with a production of 5.22 million tons and average productivity of 3279 kg per hectare. The average productivity of state is much higher than the national productivity, Area under maize is increasing rapidly in the state, because of better environment and soil condition. Thus, there. is a greater scope to increase maize productivity to a global level.

A principal objective of seed production is to increase the harvest of particular genotype. During this process, varietal characteristics must be conserved, which is achieved by maintenance breeding. If the seed produced does not represent the genetic purity of the cultivar, it will lose value, even if it has high germination and vigor. Because of this, seed producers understand the value of the genotype or cultivar they increase as well as its economic value.

Hybrid Seed Production

The hybrid seeds are the unique kind of plant products which give rise desired dividends to the farmers upon sowing under suitable set of environments. The maize hybrid results from crossing of two dissimilar genetically unrelated parents. The plant that bears the seed is called the female or seed parent, while the plant that provides the pollen to fertilize the female is called the male or pollen parent. In other words, the female plant is crossed with the male plant to produce hybrid seed. Resultant seed bears a unique genetic make-up from the female and male parents and will produce a plant with particular characteristics. There are several factors that determine the success and quality of hybrid seed production, which are as follows:

1. Female and male parent identity, purity and identity preservation.
2. Ratio of female to male rows in the seed field.
3. Time of planting of the female and male plants.
4. Timely removal of the tassels from the female plants before they shed pollen and before silk emergence.
5. Timing of female silk emergence relative to male pollen shed.
6. Avoidance of contamination of female silks with unwanted pollen, particularly from females, offtype males and foreign pollen.
7. Avoidance of seed mixtures between and within the male and female plants.

Popular maize hybrids and their parents

Hybrid	Seed Parent	Pollen Parent	Released by
Pusa Early Hybrid Makka -1	CM 135	CM 136	IARI, Delhi
Pusa Extra Early Hybrid Makka 5	CM 150	CM 151	IARI, Delhi
Pusa Early Hybrid Makka-3	CM 213	CM 142	IARI, Delhi
Pusa Early Hybrid Makka-2	CM 137	CM 138	IARI, Delhi
Vivek Hybrid 4	CM 212	CM 141	VPKAS, Almora
Vivek Hybrid 5	CM 212	V 25	VPKAS, Almora
Vivek Maize Hybrid 9	CM 214	CM 145	VPKAS Almora
Vivek Maize Hybrid 15	CM 152	CM 212	VPKAS Almora
Vivek Maize Hybrid 17	CM 153	CM 212	VPKAS, Almora
Vivek Maize Hybrid-21	CM 212	V 341	VPKAS, Almora
Vivek Maize Hybrid 23	V 351	V 341	VPKAS, Almora
Vivek Maize Hybrid-25	V 341	V346	VPKAS, Almora
Vivek Maize Hybrid-27	V 335	V 345	VPKAS, Almora

Vivek QPM 9	VQL 1	VQL 2	VPKAS, Almora
Vivek Maize Hybrid 39	V-373	CM 212	VPKAS, Almora
Vivek Maize Hybrid 43	V-373	V-341	VPKAS, Almora
HIM 129	(CM 128 x CM 129)	CM 502	VPKAS, Almora
VL Baby Corn 1	(VL 16 x Murulia)	VL 16 x VL 16	VPKAS, Almora
HQPM 5	KHI-163	HKI-161	CCSHAU, Karnal
HM-5	HKI 1344	HKI 1348-6-2	CCSHAU, Karnal
HM-9	HKI-1105	HKI-1128	CCSHAU Karnal
HQPM -1	HKI-193-1	HKI 163	CCSHAU, Karnal
HM 4	HKI 1105	HKI 323	CCSHAU, Karnal
HM-10	HKI -193-2	HKI 1128	CCSHAU, Karnal
HM-8	HKI 1105	HKI 161	CCSHAU, Karnal
HM-11	HKI-1128	HKI-163	CCSHAU, Karnal
HQPM-7	HKI-193-1	HKI-161	CCSHAU, Karnal
HHM 2	HKIW-1352	HKIW-1344	CCSHAU, karnal
HQPM-4	HKI-193-2	HKI-161	CCSHAU, Karnal
HSC-1	HKI 1831	HKI SCST-1	CCSHAU, Karnal
HHM 1	HKI-536	HKI-295	CCSHAU, Karnal
Pratap Hybrid Maize	EI 116	EI 364	MPUAT, Udaipur
PMH-1	LM 13	LM 14	PAU, Ludhiyana
PMH-2	LM 15	LM 16	PAU, Ludhiana
PMH 3	LM 17	L M 14	PAU, Ludhiana
PMH 4	LM 5	LM 16	PAU, Ludhiana
PMH 5	LM 16	LM 18	PAU, Ludhiana
Parkash	CM 139	CM 140	PAU, Ludhiana
Buland	LM 11	LM 12	PAU, Ludhiana
PAU-352	LM 15	CML 32	PAU, Ludhiana
Shaktiman 1	(CML 142 x CML 150)	CML 186	RAU, Dholi
Shaktiman 2	CML 176	CML 186	RAU, Dholi
Shaktiman 3	CML 161	CML 163	RAU, Dholi
Shaktiman 4	CML 161	CML 169	RAU, Dholi
Rajendra Hybrid Makka-3	Dholi inbred 32	Dholi inbred 40	RAU, Dholi
DHM 111	BML-6	BML-15	ANGRAU, Hyderabad
DHM 113	BML-2	BML-7	ANGRAU, Hyderabad
DHM 117	BML-6	BML-7	ANGRAU, Hyderabad
DHM 119	BML 2	BML 15	ANGRAU,

			Hyderabad
COBC 1	(UMI 90 x UMI 285)	UMI 112	TNAU, Coimbatore
CO H 3	(UMI 101 x UMI 130)	(UMI 90 x UMI 285)	TNAU, Coimbtur
COH (M) 4	(UMI 90 x UMI 285)	UMI 112	TNAU, Coimbtur
COH (M) 5	UMI 285	UMI 61	TNAU, Coimbtur
DMH 2	CI-4	KDMI 10	UAS Dharwad
Matungha	(KDMIG x KDMI 10)	CM 501	UAS, Dharwad
Shalimar KG Maize 1	Pool-39	Gurez Local	SKUAS&T, Srinagar
Shalimar KG Maize 2	Pool-42	Gurez Local	SKUAS&T, Srinagar
Malviya Hybrid Makka 2	HUZM 185	HKI-1105	BHU, Varanasi
NAH 2049	SKV-50	MA 1105	Naganahalli
Gujarat Makai 4	LGC-40	WRF-15 (HS)	AAU, Gujrat
Narmada Moti	LGC-40	EH-2922 (HS)	AAU, Gujrat
Azad Kamal	(Azad Uttam x Navjot)	Surya	CSAUAT, Kanpur
Sharadmani	Chain crossing in Azad Uttam, Farrukhabad local, Agethi-76, Kanpur local, Kanchan, Jaunpur local		CSAUAT, Kanpur
Chandramani	Chain crossing in Azad Uttam, Kiran, Kanchan and Navjot improved through simple recurrent selection		CSAUAT, Kanpur

Principles:

Production of hybrid maize involves three steps viz. i) Maintenance of parental lines i.e. inbred lines ii) Production of single cross hybrid i.e. crossing between two dissimilar inbred lines and iii) production of commercial hybrid i.e. three-way cross – cross between a single cross hybrid and an inbred line; double cross hybrid- cross between two single cross hybrids and double top cross hybrid-cross between certified single cross hybrid and certified open pollinated varieties. These hybrids differ in their parental composition but, in all cases, the hybrid seed sold to farmers is a cross between two parents – a female and a male. Since maize has separate male and female plant parts, it is relatively easy to make a cross between two plants. In a hybrid seed production field, male and female parents are planted in sequential row patterns,

usually with three-to-six times the number of female plants or rows to a single male plant or row. The male flower (tassel) of the female plant is removed (de-tasseled) before pollen shed, so that the only source of pollen for the female flower (the cob or ear) on the female plants is the tassels on the male plants. The maintenance of inbred lines and production of single cross is referred as foundation class of seed while production of double cross, double top cross and three-way cross is designated as certified class of seed.

Management of Seed Production Plots

Selection of Land, Agro-climatic Region and Season for Seed Production:

The maize seed production programme can be taken on the land free from volunteer maize plants and well-drained. The soil should be well aerated and suitable for maize growing. Maize can be grown in all seasons viz; Kharif (monsoon), Rabi (winter) and spring (Zaid). During Rabi and spring seasons to achieve higher yield at farmer's field assured irrigation facilities are required. To harvest bountiful crop, the sowing time should be such adjusted that the active reproductive phase should not coincide with heavy rains, too low and high temperature and dry warm winds to avoid low seed filling in cobs.

Source of Seed

Procure breeder/foundation seed from a source approved by a seed certification agency to multiply foundation/certified seed respectively.

Isolation Requirements

Maize is a highly cross-pollinated species and pollen is blown by wind over long distances. Thus to avoid any chance of contamination it is desirable that the isolation requirements as outlined below mentioned table for the various categories of seed are rigidly followed. However, these isolation requirements should be related to the time of flowering and not in the absolute context of space. This aspect is important since even in the same field it is possible to create isolation blocks by suitably spreading the sowing dates over a period of time.

Factor	**Minimum Distance (m)**	
	Foundation Class of Seed	***Certified Class of Seed**
Fields of any maize with same kernel colour	400	200

and texture		
Fields of any maize with different kernel colour and texture and teosinte	600	300
Fields of the same single cross not conforming to varietal purity requirements for certification	400	200
Fields of the other single crosses having common male parent and conforming to varietal purity requirements for certification	5	5
Fields of the other single crosses having common male parent and conforming to varietal purity requirements for certification	400	200

Note: 1. Differential blooming dates are permitted for modifying isolation distances, provided 5.0% or more of the plants in the seed parent do not have receptive silks when more than 0.20% (for foundation class) and 0.5% (for certified class) of plants in the adjacent field(s) within the prescribed isolation distance are shedding pollen.

*Distances less than 200 meters may be modified by planting border rows of male parent, if the kernel colour and texture of the contaminant are the same as that of the seed parent.

Seed Treatment

To protect the maize crop from seed and major soil borne diseases and insect-pests, seed treatment with fungicides and insecticides before sowing is advisable/ recommended. The seeds which are to be used for sowing should be treated with Bavistin + Captan in 1:1 ratio @ 2.0g/Kg seed to control Turcicum Leaf Blight,, Banded Leaf and Sheath Blight, Maydis Leaf Blight and imidacloprid @ 4.0g/Kg seed.

Planting Ratio

For single cross and commercial hybrids seed production, the sowing of two specified inbred lines and two single cross hybrids are required. One line is used as a male parent and other as a female parent. The planting ratio between male and female parent for single cross hybrid and commercial hybrid are kept at 2:4 and 2:6, respectively. To facilitate subsequent roguing and detasseling operations, it is necessary to mark male rows at both ends with pegs. To avoid mistakes while sowing of parental lines, a few precautions should be taken like i) check bags carefully before putting them in the planter to avoid mixtures of male and female parents seed ii) marks both ends of the male rows and iii) avoid planting mistakes e.g. mistakes in planting ratios, etc.

Sowing, Fertilization & Irrigation

Management of seed production block is materially different than the growing of a regular commercial grain crop. Since the sale price of the seed is likely to be at least 100-200% more remunerative than the grain crop the seed producer can afford better investment. The target, however, is to produce more of a processed certified and graded quality seed. Few tips are: i) grow about 5.0-5.5 plants/m² which are well spaced, it is 10-15% lower than the plant population recommended for commercial grain crop, ii) apply 150:100:60 kg of NPK/ha and also apply Zn wherever needed iii) avoid water logging and irrigate the crop whenever needed, special care should be exercised at the flowering and grain filling period. Frequent irrigation is required during *Zaid* season. For single cross seed production, 10 and 5 Kg and for commercial hybrid seed production, 12-14 Kg and 4-5 Kg female and male parent seed is required. The optimum time of sowing for *Kharif, Rabi and Spring* maize is Last week of June to first fortnight July, Last week of October for inter cropping and up to 15th of November for sole crop and First week of February, respectively. The maize is sown in rows with the help of a maize planter, or is dibbled by hand in furrows. The depth of seeding is kept at 5-6 cm. The row × plant distance should be kept 60-75 × 20-30 cm depending upon type maize.

Weed Management and Interculture Operation

Weeds are the serious problem in maize, particularly during kharif /monsoon season they competes with maize for nutrient and causes yield loss up to 35 %. Therefore, timely weed management is needed for achieving higher yield. One to two hoeing are recommended for aeration and uprooting of the remaining weeds, if any. Intercultivation should not be more than 3-5 cm deep so that the roots are not damaged. The last Interculture operation should also include earthing of the crop.

Atrazine being a selective and broad-spectrum herbicide in maize checks the emergence of wide spectrum of weeds. Pre-emergence application of Atrazine (Atratraf 50 wp, Gesaprim 500 fw) @ of 1.0-1.5 kg a.i ha-1 in 600 litre water, Alachlor (Lasso) @ 2-2.5 kg a.i ha-1 , Metolachlor (Dual) @ 1.5-2.0 kg a.i ha-1 , Pendamethalin (Stomp) @ 1-1.5 kg a.i. ha-1 are effective way for control of many annual and broad leaved weeds.

ROGUING

Proper rouging of seed production plots is necessary with a view to ensure that all plants which do not precisely represent the true type are eliminated before they shed any pollen. It is better that all doubtful plants should be detasselled to avoid their contribution to the seed production block, it can, however, be later decided Rouging has to be carried out at all stages from germination onwards, at pre-flowering, flowering, dry silk stage, harvest and at sorting out of the ears before shelling. Thus a constant vigilance has to be kept on the seed production block. Relatively grater care is needed in

rouging the inbred lines. This is essential in view of the fact that all errors in seed production multiply in geometric progression.

Field Inspection

A minimum of four inspections is done by the inspection team in such a way that one is made before flowering and remaining three during flowering. The seed field should meet the following field standard after final inspection.

Factor	Maximum Permitted (%)*	
	Foundation Class	Certified Class
Off-type plants that have shed or shedding pollen in male parent at any one inspection during flowering when 5.00% or more of the plants in the seed parent have receptive silks.	0.20	0.50
Tassels of the plant that have shed or shedding pollen in seed parent at any one inspection during flowering when 5.0% or more of the plants in the seed parent have receptive silks.	0.50	1.00
Total of pollen shedding tassels including tassels that have shed pollens from all three inspection conducting during flowering on different dates.	1.00	2.00
Off-type plants in seed parent at final inspection	0.20	0.50

Detasselling

Detasseling is the removal of tassel from female parent. Timely detasseling of the female rows in the single-cross and double-cross seed production field is vital. Timely initiation of the detasseling helps in obviating any subsequent problem. Detasseling is done when the tassel emerged out of the boot leaf, but before an athesis have shed pollen. Anthers take 2-4 days to dehisce after complete emergence. Only in few cases, the anthers start dehisce before its complete emergence. In such case detasseling should be done earlier. Detasseling is done every day from the emergence of tassel up to 14 days. The following techniques may be followed for proper detasseling.

1. Hold the stem below the boot leaf in left hand and the base of the basal in right hand and pull it out in a single pull.
2. Grasp entire tassel so that all the pollen parts are fully removed.
3. Do not break or remove leaves as removal will reduce yields and will result in lower quality of seed.

Precautions to be adopted during detasseling

1. No part should be left on the plant as it causes contamination.

2. It should be uniform process done daily in the morning in a particular direction.
3. Do not break the top leaves as the yield may be reduced due to the earning of source material to accumulate in sink [seed] as removal of 1 leaf cause 1.5% loss 2 leaves 5.9% loss and 3 leaves 14% loss in yield.
4. Detassel only after the entire tassel has come out and immature detasseling may lead to reduced yield and contamination.
5. Mark the male rows with marker to avoid mistake in detasseling
6. Look out for shedders [shedding tassel] in female rows as they may cause contamination.
7. After pulling out the tassel drop it there itself and bury in soil. Otherwise late emerging pollen from detasseled tassel may cause contamination.
8. Do not carry the tassel through the field as any fall of pollen may lead to contamination.
9. Do not practice, improper, immature and incomplete detasseling.
10. There should not be any shedding tassel.

Plant Protection Measures

The seed production plots are affected by borer, foliar diseases or stalk rots, recommended chemical control measure should be followed or even prophylactic measures based on the experiences of the previous year should be used.

Sl. No.	Factor	Control Measures
A. Insect-Pest Management		
1.	Stem Borer & Pink Borer	Apply carbofuran 3g granules in whorls after 20-25 days of sowing. Spray methyl demeton 25 EC or Dimethoate 20 EC 500 ml/ha or apply phorate 10 G 18 Kg/ha at the time of sowing.
2.	Army worms	Spray azadartine 1500 ppm @1litre/ha or 5 ml/litre at 6 leaf stage twice at 15 days interval Spray Thiamethoxam 12.6%+lambda cyhalothrin 9.5% @ 0.25 ml/litre at seven leaf stage twice at 10 days interval.
3.	Shoot Fly	Spray imidacloprid 17.8 SL @ 500 ml/ha two times at seedling stage or apply phorate 10 G granules at 15 Kg/ha before sowing.
B. Disease Management		
1.	Seedling Blight & Leaf Blight	Spray Zineb at 2.5 @ 2.5 Kg/ha 3-4 times, depending upon the intensity of disease, at an

		interval of 9-10 days
2.	Downy Mildew	Spray Dithane M-45 @ 1.5 Kg in 500 litres of water per hectare.
3.	Brown Stripe & Downy Mildew	Spray Dithane M-45 @ 3.0 Kg in 1000 litres of water, 4-6 times soon after the symptoms are noticed.
4.	Bacterial Stalk Rot	Apply bleaching powder at 3.3 g in 10 litres of water at the base of plants (800 litres per hectares)
5.	Pythium Stalk Rot	Drainage field properly Spray 2.5 Kg captan or Thiram in 1000 litres of water 30-35 days after sowing.
6.	*Cephalosporium* Stalk Rot, Charcoal rot	Rogue out the affected plants.
7.	Leaf Rust	Spray Dithane Z-78 at 2-3 Kg in 1000 litres of water per hectare 3-4 times.
8.	Head Smut	Use seed treated with carboxin @ 2.5g/Kg seed; Apply Phomasan 40 mg/sqm
9.	*Fusarium* Kernel Rot; *Cephalosporium*, *Gibberella*, *Rhizoctonia*, *Pencillium*, *Aspergillus* ear rot,	Sort out the affected ears.
10	*Helminthosporium* Leaf Blight	Spray Zineb 2.5 Kg/ha in 1000 litres of water at an interval of 7-10 days.

Harvesting

Special care should be taken in determining the appropriate time of harvest, under no situation seed plots should be harvested until the crop has reached physiological maturity as indicated by the formation of black layer, at this stage the grain shall have 20-25 per cent or less moisture. Male rows should be harvested first and keep aside then seed parent should be harvested carefully to avoid any chance of mechanical admisxture. Ears should be dried at moderate to low temperature, avoid highly humid environments to ensure good seedling vigour. Immature seed, kept under high humidity and high temperature rapidly loose vigour and even viability.

Sorting, Drying and Shelling of Maize Ears

After harvest, sort out all off-types maize ears, particularly those sowing different colour and texture, and the diseased ears before placing them in bin drying. After drying, the ears are once again examined and any off-types and diseased ears removed before shelling. The certification standard requires bin inspection of maize ears before

shelling. Therefore, shelling should be done after the approval of seed certification agency has been obtained.

Seed Processing and Seed Standard

Maize seed cleaning and upgrading is primarily based on physical differences in seed volume, test weight and density. The sieve aperture sizes of top and bottom screens of air screen cleaner differ with genotypes. The top screen may be around 10.50r or 11.00r mm or 8.75r with round holes and the bottom screen at 6.40r or 8.00r or 4.25r or 4.75r with round holes depending on the cultivars. The specific gravity separator helps in upgrading the quality of seeds by rejecting the seed that is inferior in specific gravity. After grading of seed, it should be treated with appropriate fungicides. Seed treatment provides protection against storage pests as well as diseases infection. The fungicides like Thiram or captan @ 3g/kg is recommended for seed treatment. Processed seed can be packed in cloth bags or HDPE bag @ 8kg/bag, sewed with proper label of particular seed class and can be sealed with lead seal.

Factor	Standard	
	Foundation Class	**Certified Class**
Pure seed (Minimum)	98.0%	98.0%
Inert matter (Maximum)	2.0%	2.0%
Other crop seed (Maximum)	5/Kg	10/Kg
ODV based on kernel colour and texture (Maximum)	5/Kg	10/Kg
Weed seed (Maximum)	None	None
Germination (Minimum)	80%	90%
Moisture pervious container (Maximum)	12.0%	12.0%
Moisture impervious container (Maximum)	8.0%	8.0%

Seed Storage Management

Seeds of most of the maize cultivars can be stored under ambient conditions for seed certification for at least 12-15 months, if seed moisture does not exceed 10-12 per cent. To avoid the storage losses and to keep seeds free from insect pests during storage, one must adopt the following preventive and remedial measures.

Preventive measures before storing the seed:

1. The seed moisture content should be preferably below 9%. The moisture content fluctuates during storage in cloth and hessian bags, but if seed store is reasonably moisture vapor proof, the fluctuation in seed moisture content would be low.
2. New bags should be used to avoid both insect infestation and mechanical mixture.

3. The storage structure should be thoroughly cleaned and white washed.
4. The storage structure should be disinfected with residual sprays of insecticides such as Malathion 50EC (one part in 100 parts of water) @ 5litres per 100 sq. m.
5. Proper stacking should be followed for arranging seed bags in storage structures.
6. It should be ascertained that the seed is properly treated with disinfectants before keeping the seeds in storage.
7. Seeds of different types such as cereals, pulses, and vegetables should be stored separately to avoid the spread of insect infestation.

Maintenance of seed storage:

1. The processing units and storage structures should be clean.
2. All sweeps should be kept far away from the premises of seed godown so that insects will not breed and re-infest seeds.
3. The inspection of seed lots in storage structures should be carried out every fortnightly. Seeds must be thoroughly fumigated at regular intervals.
4. Fumigation can be done with 1) Aluminium phosphide, 2-3 tablets (3g each) per ton of material with an exposure period of 5 - 7 days or 1 tablet per cu. m. space. 2) Ethylene dibromide (EDB) @ 32g per cu.m. space with an exposure period of 5-7 days.
5. Ethylene dichloride carbon tetrachloride (3:1) (EDCT) mixture @320-480 g per cu. m. space with an exposure period of 24-48 hrs.
6. Of all these fumigants, Aluminium phosphide is safest. Its repeated application does not impair seed quality. Maximum of 3 fumigations may be given at an interval of 40-50 days.
7. During fumigation and surface sprays handle the chemicals carefully as they are highly toxic to human beings.
8. Seed structures should be aerated and thoroughly cleaned with brush or hard broomsticks to remove all dead and moribund insects.
9. To prevent re-infestation, surface treatment with Malathion 50EC or Finitrothion 50EC @ 4-5 litres per sq.m. area or Malathion dust 5% @ 3-4 kg per 100 sq.m. should be given.
10. Surface treatment of seed godown and processing units should be carried out at an interval of 2-4 weeks depending upon the severity of pest check on re-infestation and prevents insect resistance to insecticides.

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Molecular Basis of analyzing the quality of seeds in Cereal crops

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Concept

The quality of seeds is considered as an important factor for increasing yield. The use of quality seeds helps greatly in higher production per unit area to attain food security of the country. Quality seeds have the ability for efficient utilization of the inputs such as fertilizers and irrigation.

Biochemical and Biotechnological approaches have been used for developing and improving the crop plants for improved seeds with improved nutritional quality like Golden rice, Golden mustard and nutraceuticals, for better oil-content, with more by-products like glycerine, oleosins, etc. and for hybrid seed production.

The quality of seeds is considered as an important factor for increasing yield. The use of quality seeds helps greatly in higher production per unit area to attain food security of the country. Quality seeds have the ability for efficient utilization of the inputs such as fertilizers and irrigation.

Biochemical components like gibberellins, enzymes like alpha amylase and other hydrolytic enzymes present in the seeds of cereal grains and grasses stimulate the mobilization of food and mineral elements in seed storage cells. The level of these biochemical constituents evaluates the seed quality, its germination and viability. These can be quantified or tested using various biochemical techniques. Seed germination, seedling vigor and viability tests are performed based on biochemical approaches.

Studies related to genetic stability of the seed are based on evaluation of morphological traits, isoenzyme patterns and DNA markers like RFLP, etc. that serve as biotechnological tools.

Introduction

Seed is the major source of regeneration and seed storage is an integral part of conservation programs. Seeds of clonal crops are conserved as DNA clones due to their genetic heterogeneity. Both the plant breeder and the seed producer have "quality requirements" determined as seed purity that need to be met. The biochemical constituents and their levels evaluate the seed quality, its germination and viability

Genetically Modified seeds are presently being grown in 25 countries covering more than 130 million hectares of land.

Seed quality is the sum of all the attributes which differentiate the seed from grain.

Seed Quality Parameters

Purity	**Physical or Genetic**
Health	Diseases or Insect Pests
Processing	Value addition
Storage	Storage conditions and packaging

Importance of Seed Quality

- Better crop establishment
- Better uniformity and purity

- Improved quality and production
- Improvise handling during sowing
- Reduces loss while storage
- Eliminates weeds, pests & diseases

Seed Quality Control and enforcement

Central and State Govt are responsible to ensure seed quality measures of seeds marketed in the country. This is done through legislation in the form of Act.

- Seed Certification
- Seed Labelling
  - Seed Act 1966
  - Seed Rules 1968
  - Seed Control Order 1983 (Under essential commodities Act 1955)

Parameters for Evaluation of Seed Quality

Physical parameters

- Seed size
- Seed colour
- Seed coat thickness
- Seed surface

Physiological parameters

- Seed germination
- Seedling vigor
- Seed coat protein
- Seed viability
- Level of biochemical constituents
- Isoenzymic pattern
- Genetic makeup

Imaging techniques for physical and seedling vigor

The physiological parameter of seed is assessed by use of imaging techniques in a non-destructive manner. It is advantageous as it provide instantaneous visualization of heterogeneity. The most common techniques in use are Thermography, Bioluminiscence Imaging, Reflectance Imaging, Flourescence Imaging, Magnetic Resonance Imaging and Multispectral Imaging.

For testing the seedling vigor of seeds, tests like Cold test, Accelerated aging test and imaging tests are performed. The Seed Vigour System (SVIS) is now being used as an alternative to traditional vigour tests, which require longer time and are less reliable when compared with field tests.

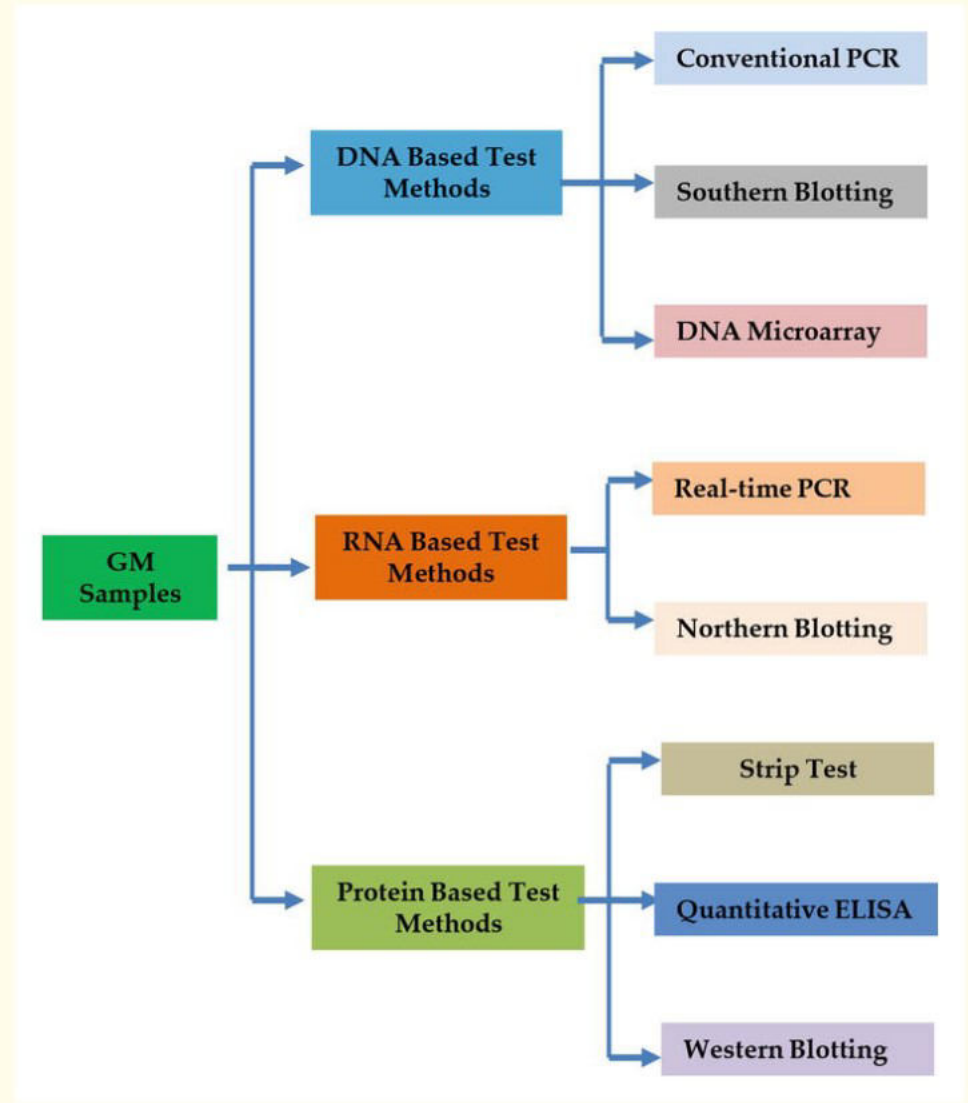
Embryo culture for seed germination

Embryo culture technique can be used to determine the germination potential of seeds, wherever normal germination tests cannot be used for the seed lots of interest. Such a situation arises when seeds require a period of after-ripening or a brief storage to overcome dormancy and the seed has to be used immediately after this period.

Germination of embryos is more reliable test for seed germination than seed viability testsbased on staining methods. Young embryos are removed from developing seeds and

areplaced in suitable nutrient medium to obtain seedlings. The cultured embryos generally donot complete development, but germinate prematurely to give rise to seedlings, called asprecociousgermination.

Molecular test methods for identification of Seed Samples

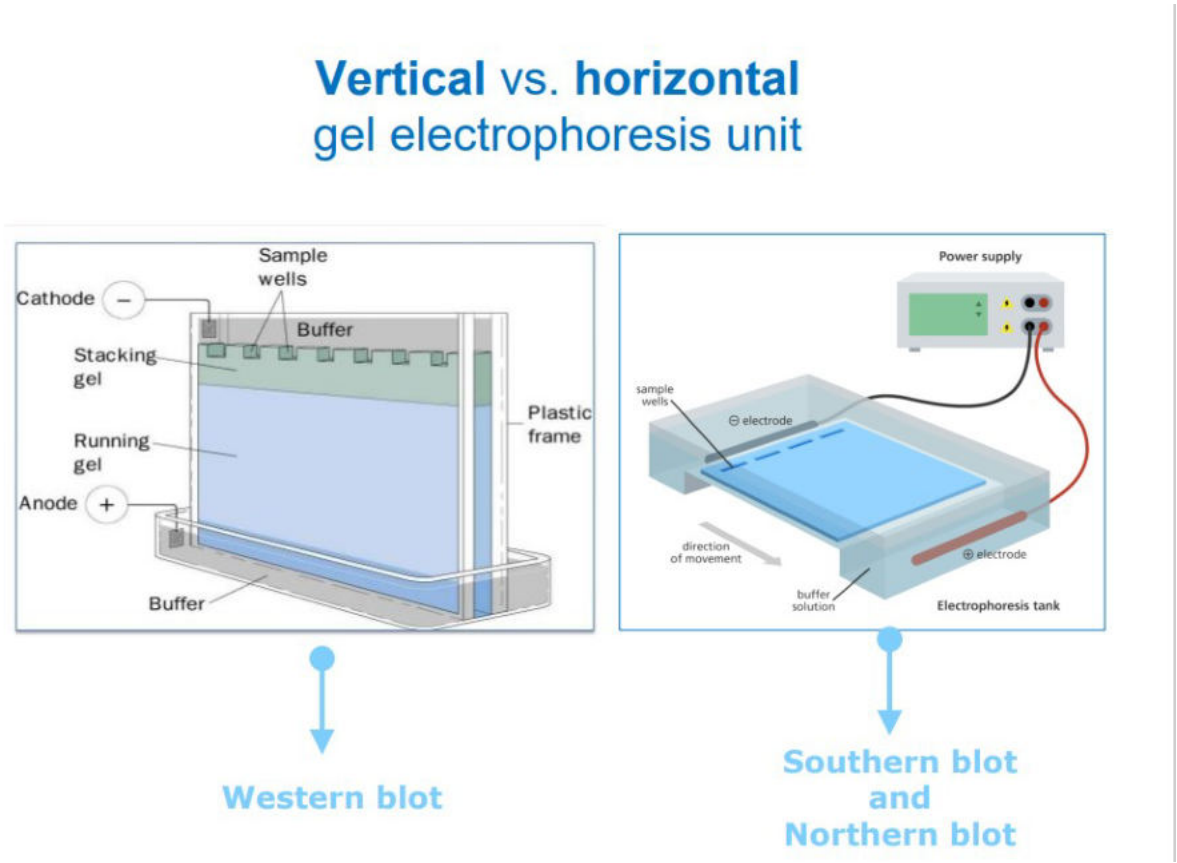


Gel Electrophoresis

Gel electrophoresis is a procedure for separating a mixture of molecules through a stationary material (gel) in an electrical field.

The variations of the gel electrophoresis technique include:

- Agarose gel electrophoresis (used for DNA/RNA)
- Polyacrylamide gel electrophoresis (used for enzyme protein)
- SDS-PAGE (used for protein and its subunits)



Polymerase Chain Reaction (PCR)

DNA tests using PCR (Polymerase Chain Reaction) technology are also used to make decisions concerning storage or separating grain lots, but more often are used for breeding, production and marketing decisions involving seed, grain, food ingredients, and finished food products. DNA/PCR methods are more sensitive, accurate, and robust and are generally considered to be the preferred method for detecting "any GMO." As long as appropriate protocols, samples, and sample sizes are used, false positive or false negative results are extremely rare events.

RT-PCR

The Reverse Transcriptase Polymerase Chain Reaction is a technique used in genetic studies that allows the detection and quantification of mRNA.

It is a very sensitive method that shows whether or not a specific gene is being expressed in a given sample.

RT-PCR is a very important test in the field of seed genetic studies because it gives researchers a mechanism to test whether any specific gene is turned on (active) or turned off (inactive).

This allows researchers to identify the benefits of a genetically-modified seed with respect to their "natural" counterparts and search for any significant differences in which genes are expressed in the two types of seeds.

RT-PCR shows us whether or not a specific gene is being expressed in a sample. If a gene is expressed, its mRNA product is produced, and an associated band appears in the final agarose gel with the correct molecular weight for the gene.

This is used for transgenic seeds to identify if a gene that has been transplanted and is present in the hybrid seed has undergone any changes.

Also, RT-PCR can quantify exactly how active the gene is in the sample.

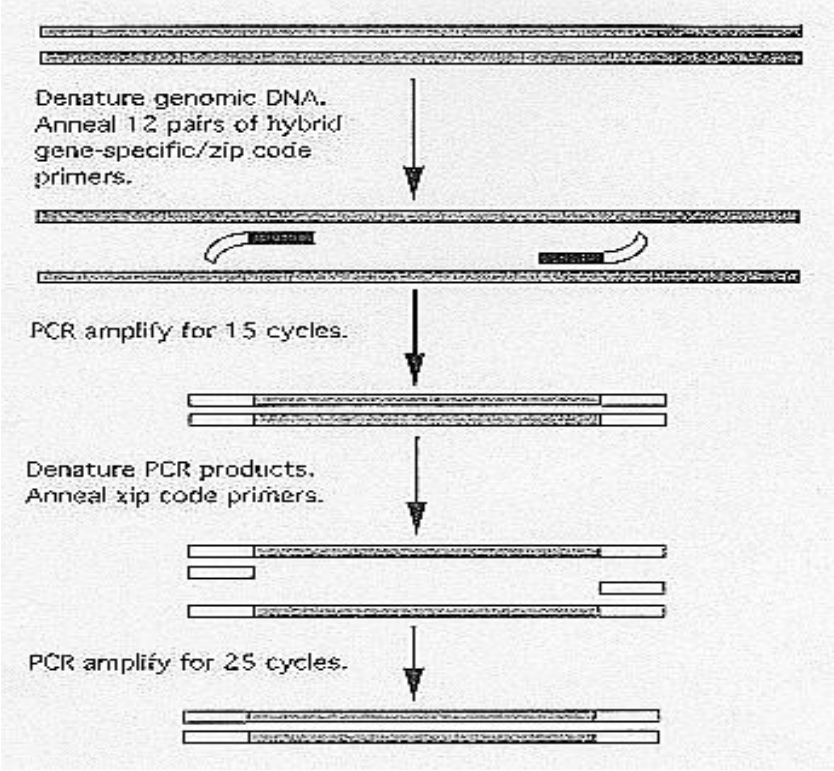
RT-PCR Technique

RT-PCR is used to locate and quantify known sequences of mRNA in a sample.
The first step in RT-PCR uses reverse transcriptase and a primer to anneal and extend a desired mRNA sequence.
If the mRNA is present, the reverse transcriptase and primer will anneal to the mRNA sequence and transcribe a complimentary strand of DNA.
This strand is then replicated with primers and Taq Polymerase, and the standard PCR protocol is followed.
This protocol copies the single stranded DNA millions of times in a small amount of time to produce a significant amount of DNA. The PCR products (the DNA strands) are then separated with agarose gel electrophoresis.
If a band shows up for the desired molecular weight, then the mRNA was in fact present in the sample, and the associated gene was being expressed.

Multiplex PCR

Running multiple PCR experiments in a single tube is referred to as multiplex PCR.
Typically the experiment involves amplifying multiple targets on the same strand of DNA at the same time, which is useful if multiple amplicons need to be expressed from the same strand and is essential if the amount of sample is very limited.
Typically the amplicons are designed so that they are all different lengths and can be separated by conventional gel techniques.

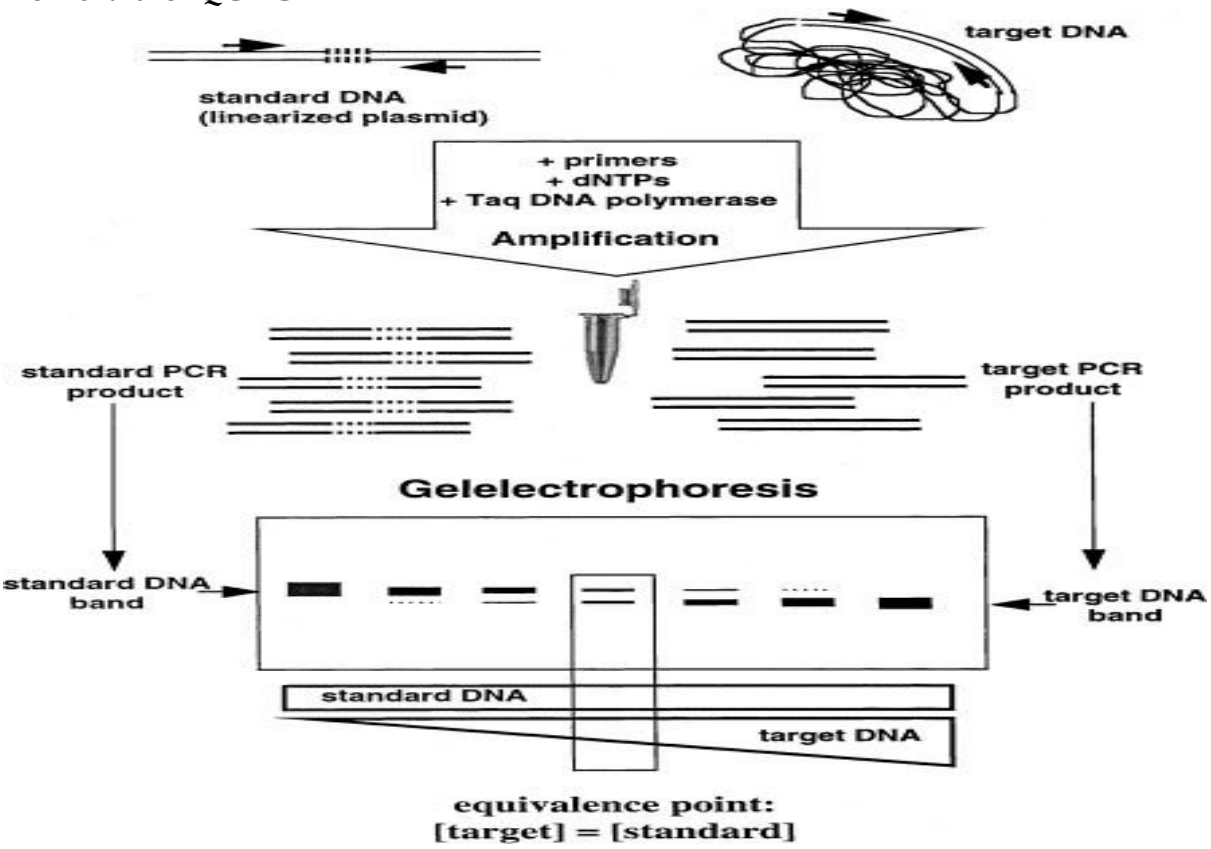
Flow chart for Multiplex PCR:



Quantitative competitive PCR (QC-PCR)

Standard DNA and target DNA are co-amplified in the same reaction tube.
The standard DNA consists of linearized plasmid carrying a modified PCR amplicon.
The modification can be a DNA insertion as shown above, a DNA deletion or a point mutation.
After PCR, the products are separated by agarose gel electrophoresis whereby the amplified standard DNA can be distinguished from the amplified target DNA by size.
At the equivalence point the starting concentrations of internal standard and of target are equal if the validation criteria are fulfilled.

Flow chart for QC-PCR



e-PCR

A computer simulation of PCR to predict PCR products by searching a sequence database.
Electronic PCR (e-PCR) is computational procedure that is used to identify sequence tagged sites(STSs), within DNA sequences.
e-PCR looks for potential STSs in DNA sequences by searching for subsequences that closely match the PCR primers and have the correct order, orientation, and spacing that could represent the PCR primers used to generate known STSs.

Molecular Markers of Seed Quality

Many genes have been described that are involved in germination, dormancy and other parameters for seed quality. Provided the expression pattern of these genes is consistent, mRNA abundance could be used as a marker for seed quality of a range of species. Potential molecular markers can be subdivided into several classes.

The first class of molecular markers would be genes involved in metabolism, which are up-regulated upon imbibition Expression of these genes would be expected to indicate the viability of a seed. For example, if induction of ribosomal proteins correlates with imminent radicle protrusion and low expression with dormancy, then expression of these ribosomal proteins could serve as a molecular marker for germination.
The second class of molecular markers would be genes involved in dormancy or quiescence, which are up-regulated when seeds are dormant and down-regulated when completion of germination is imminent.
Other classes that may contribute to seed quality are genes involved in seed development, desiccation tolerance, and longevity.

How to find these genes?
In order to find these (widely applicable) molecular markers, target genes (cDNAs) are cloned in a species.
Expression patterns are assessed using a model species and in a range of other species using Northern analysis, in order to predict applicability.
The genes with the highest interest are those that are highly conserved. This high degree of homology provides a certain guarantee for its applicability.
Apart from Northern analysis, semi-quantitative RT-PCR with gene specific primers is performed to complement Northern analysis.

ELISA
ELISA technology targets specific proteins produced from the insertion of a transgene.
This testing technology uses an antibody system to capture the targeted protein, which is detected by an enzyme-substrate reaction that causes a color change.
ELISA protein antibody tests are being used primarily to help farmers and elevators separate their GMO grain lots from non-GMO grain lots.
Protein strip tests and ELISA tests are preferred for these types of applications because they allow relatively rapid turnaround times, and they require a relatively small investment in equipment and persons.

ELISA Tests for Specific Events
Currently Available
Qualitative

CP4 (EPSPS)	Soybean RR (also soymeal, full fat flour, defatted flakes), Corn RR (NK603),Cotton RR
Cry1Ab	Corn (Mon809, Mon810, Bt11, E176)
Cry9C	Corn (CBH351, Starlink)
T25	Corn (PAT, BAR, Liberty Link)
Cry3Bb	Corn (Mon863)
Cry1F	Corn (Herculex)
Cry1Ac	Cotton (Bollgard I)
Cry2A	Cotton (Bollgard II)
Cry3A	Potato (New leaf, New leaf +, New leaf y)

Quantitative

Cry1Ab	Corn (Mon809, Mon810, Bt11, E176) (~0.15% detection level)
Cry9C	Corn (CBH351, Starlink) (~0.04% detection level)
Cry1F	Corn (Herculex)
CP4 (EPSPS)	Soybean RR (~0.05% detection level)

Antibody Strip Tests for Specific Events
Qualitative

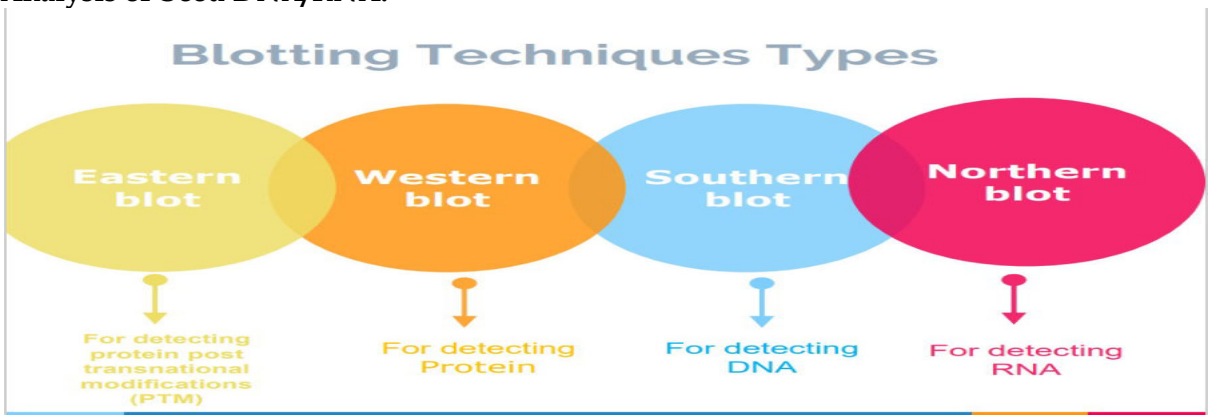
Cry1Ab	Corn (Mon809, Mon810, Bt11, E176)
T25	Corn (PAT, BAR, Liberty Link)
Cry3Bb	Corn (Mon863)
Cry9C	Corn (CBH351, Starlink)
Cry1F	Corn (Herculex)
Cry1Ac	Cotton (Bollgard I)
Cry2A	Cotton (Bollgard II)
CP4 (EPSPS)	Soybean, RR, Corn RR, Cotton RR

Other ELISA Tests
Qualitative Aflotoxin Assay
Qualitative Fumonisn Assay
Qualitative Vomitoxin Assay
Qualitative Ochratoxin Assay
Qualitative Zearalenone Assay
Qualitative T-2 Assay

Testing viability of Virus by Bioassay
The bioassay is a method of detecting viable (active) virus particles by using a host plantthat gives a specific reaction when inoculated with the target virus. Tobacco is commonly used as a "host plant" to detect Tobacco Mosaic Virus (TMV), Tomato Mosaic Virus (ToMV), and Pepper Mild Mottle Virus (PMMV) by eliciting a rapid lesion called the "Hypersensitive Response (HR)".

Method- The Seed sample is ground in a buffer solution and inoculated on fully expanded tobacco leaves. The plant leaves are gently wounded during the inoculation to allow the virus particles to more easily enter the plant. After approximately seven days, if there are no lesions, the sample is considered to have no evidence of the targeted virus.
Another type of bioassay utilizes a 'systemic reaction' (those that appear on leaves other than the one that is inoculated) to detect viral pathogens that can move systemically through the plant.
The bioassays are more time consuming due to the length of time that is required for symptom expression after inoculation.

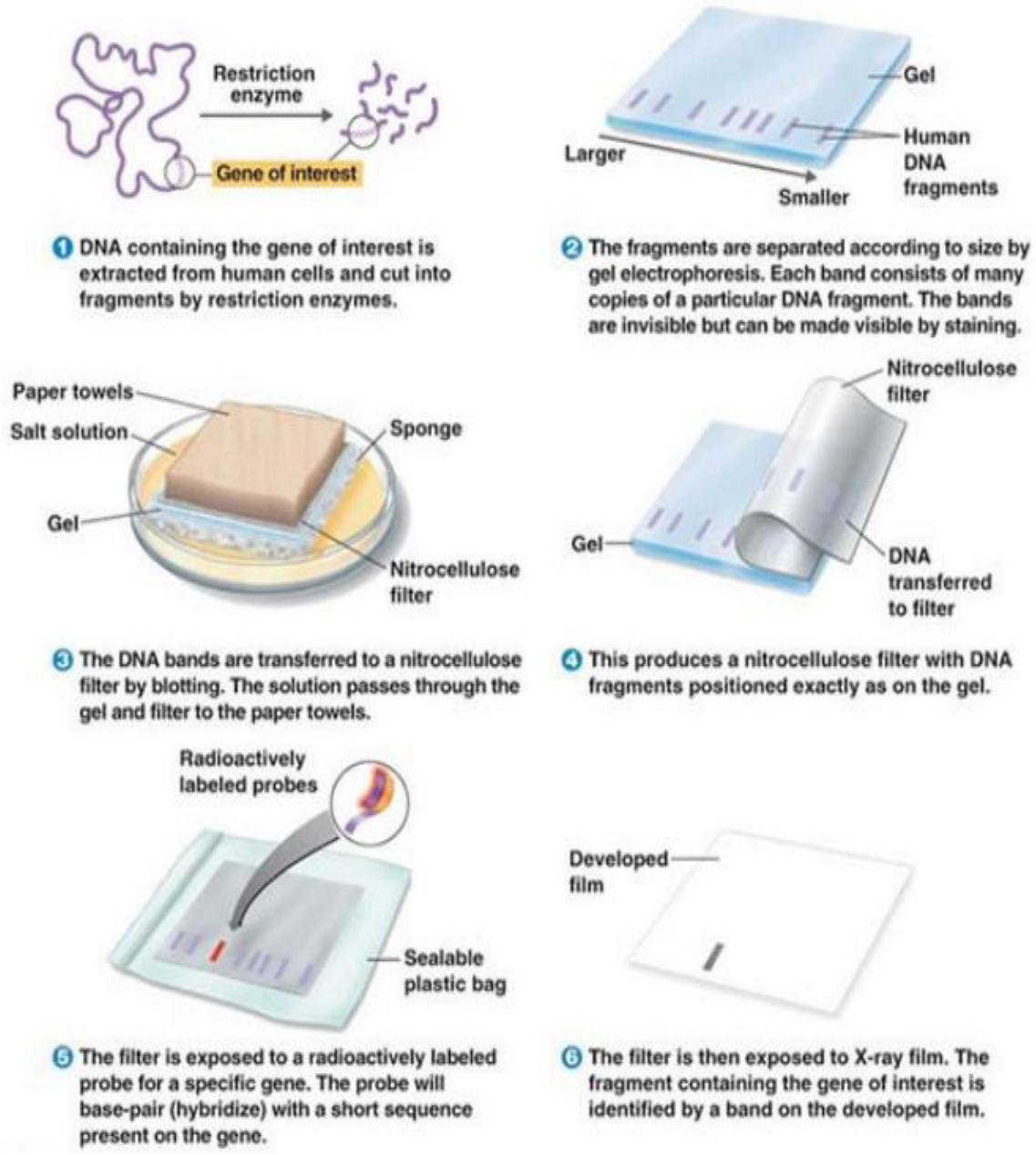
Analysis of Seed DNA/RNA:



Southern Blotting:

Principle, Procedure & Applications

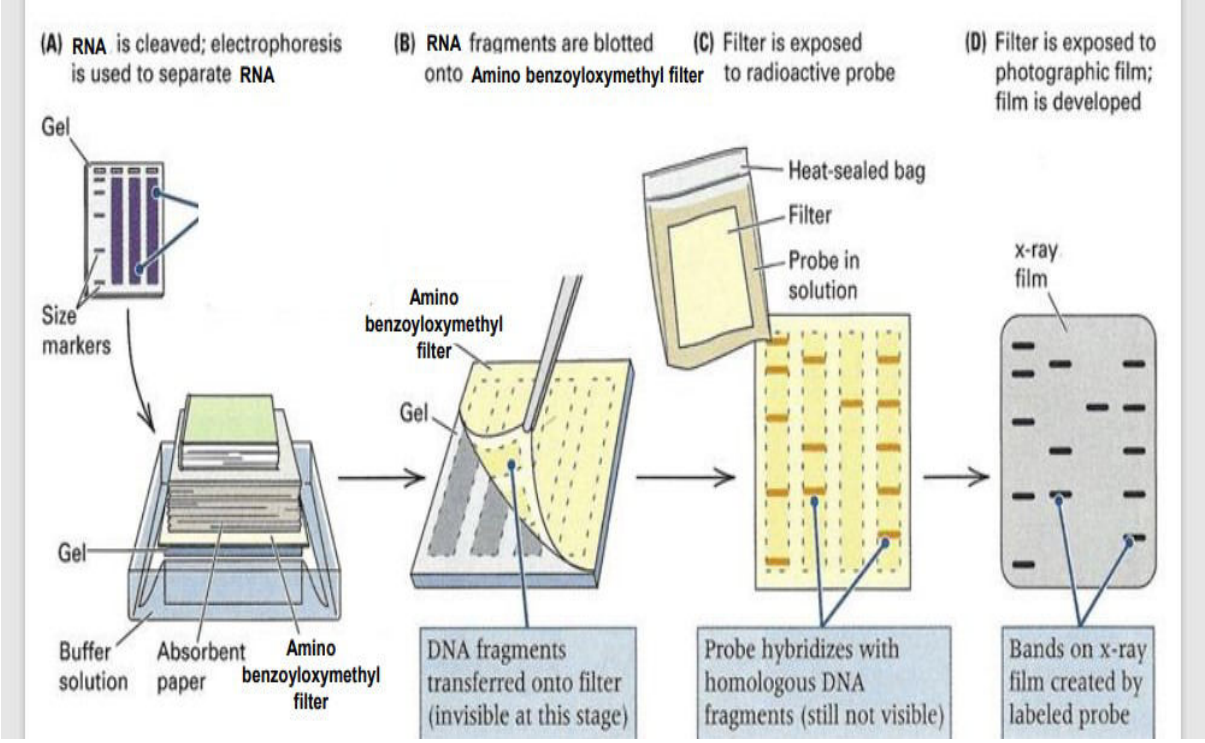
1. Extract and purify DNA from cells
2. DNA is restricted with enzymes
3. Separated by electrophoresis
4. Denature DNA
5. Transfer to nitrocellulose paper (Blotting)
6. Add labeled probe for hybridization to take place
7. Wash off unbound probe
8. Autoradiograph



Southern blotting evaluates a seed for

- Presence of a particular gene and number of its copies present in the genome of theseed under test
- The degree of similarity between the chromosomal gene and the probe sequence
- Whether recognition sites for particular restriction endonucleases are present in the gene. By performing the digestion with different endonucleases, or with combinations of endonucleases, it is possible to obtain a restriction map of the gene i.e. an idea of the restriction enzyme sites in and around the gene- which will assist in attempts to clone the gene
- Whether the cloned seed has undergone any changes upon storage or in field.

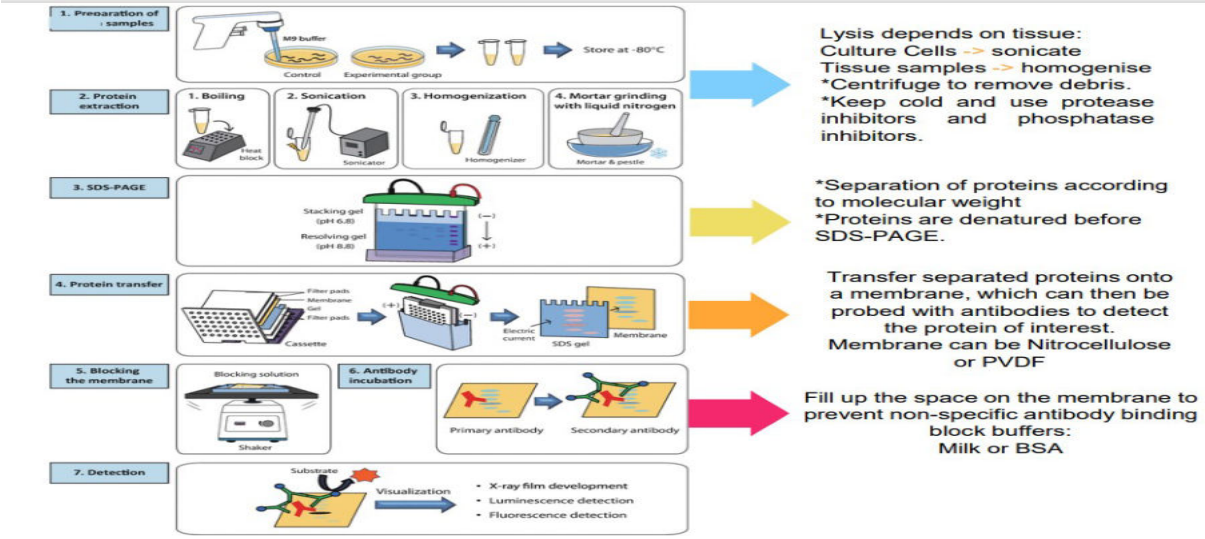
Northern Blotting:



Northern blotting tests for seed evaluation express

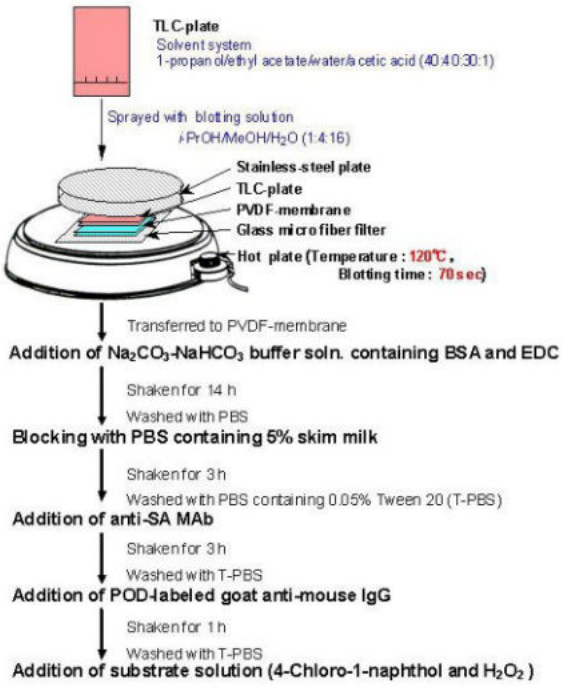
- Differential expression patterns of a particular gene
- In which tissue part of seed it is expressed
- At what stage of seed development it is expressed
- If expression changes under differing conditions/treatments

Western Blotting:



Eastern Blotting:

is a biochemical technique used to analyze **protein post translational modifications (PTM)** such as lipids, phosphomoieties and glycoconjugates. It is most often used to detect carbohydrate epitopes. Thus, Eastern blotting can be considered an extension of the biochemical technique of Western blotting.



Comparison of Southern, Northern, and Western blotting techniques

	Southern blotting	Northern blotting	Western blotting
Molecule detected	DNA (ds)	mRNA (ss)	Protein
Gel electrophoresis	Agarose gel	Formaldehyde agarose gel	Polyacrylamide gel
Gel pretreatment	Depurination, denaturation, and neutralization	-	-
Blotting method	Capillary transfer	Capillary transfer	Electric transfer
Probes	DNA Radioactive or nonradioactive	cDNA, cRNA Radioactive or nonradioactive	primary antibody
Detection system	Autoradiography Chemiluminescent Colorimetric	Autoradiography Chemiluminescent Colorimetric	Chemiluminescent Colorimetric

Certified/standard reference materials for GMO testing

Validity and authenticity of GMO testing results is doubtful until the use of positive and negative controls at each testing step.

Use of certified reference material (CRM) or standard reference material (SRM) during testing produce not only validate the testing results but at the same time, assess the performance of test method, equipment, personnel and other environmental conditions in which testing being performed.

CRM must contain the certificate of analysis, should be prepared by following ISO-Guide 34, have information about which GM events or elements present and what is its concentration, storage requirements, preparation and expiry date etc.

While SRM have all the similar information but lacks the certificate of analysis and was not prepared by a certified company.

Both CRM and SRM could be used to validate the testing results but CRM is more reliable and globally acceptable.

Each GMO needs specific CRM which is used in testing and conclusion about the presence of specific GM event/element in testing samples. Normally seeds of GM and Non-GM crops are mixed at specific percentage and homogenized to make powder before analysis.

Conclusion

The seed characterization, germination percent, vigor tests and the genetic makeup constitute the basis of seed evaluation tests. The various biochemical and biotechnological techniques involved with the seed studies require a well-developed laboratory infrastructure and expertise in various techniques. A standardization of these methods in labs for cross-checking the results as per the type of seed is mandatory. The appearance of the seed and its germination with the stages leading to growth and the biochemical conversion of storage reserves as a measure of seedling vigor explains the seed quality and if it has undergone any changes or deterioration.Seed-informatics has led to an amalgamation of available data from biotechnology and various other techniques bringing forth a new avenue for utilization of the generated data for accurate comparison of a seed with its hybrid or a seed differing in type and origin. The future holds promises in advancement of seed technology by the proper use of computational biology in phases or phaseomics that biochemistry, biotechnology, molecular biology and genomics, proteomics, transcriptomics and metabolomics. The bond between plant breeders and farmers can be affirmed by evaluation of seeds for better confidence and product yield.

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The Causes and Remedies of Seed Quality Deterioration during production Cereal Crops

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Good quality planting seed is the first step to a successful season, while farmer can not control factors responsible for quality deterioration thus using quality seed is key production factor. Therefore, production of genetically pure and otherwise good quality pedigree seed is an exacting task requiring high technical skills and comparatively heavy financial investment. During seed production, strict attention must be given to the maintenance of genetic purity and other qualities of seeds in order to exploit the full yield potential of new superior crop plant varieties . In other words, seed production must be carried out under standardized and well-organized condition.

Basically, there are two seed production principles.

1. Genetic principles: It involves all the factors which may lead deterioration of genetic purity (true to type) of a crop variety. In negligence of genetic principles during seed production programme leads deterioration of the varieties.

2. Agronomic principles. Factors associated mainly during field operations which influence genetic and physical purity of any seed lot.

Genetic Principles –
The important factors & real deterioration of varieties listed by Kadam (1942) :
1. Developmental variations Mechanical mixtures
2. Mutations
3. Natural crossing
4. Minor genetic variations
5. Selective influence of diseases
6. The Technique of plant breeder

Developmental variation: When the seed crops are grown In difficult environment, Under different soil and fertility conditions, or different climate conditions , or under different photoperiods, or at different elevation for several consecutive generations --- The developmental variation may arise some times as differential growth response. termed as **genetic shift** .To minimize the opportunity for such shifts to occur in varieties it is advisable to grow them in their areas of adaptation and growing seasons.

Mechanical mixtures: (Varietal mixture) Mechanical mixtures may often take place at the time of **sowing**, **harvesting** and at the time of **processing, grading** and **packaging**. If more than one variety is sown with same seed drill, through volunteer plants of the same crop in the seed field or through different varieties grown in adjacent fields. Often the seed produce of all the varieties are kept on same threshing floor. Grading with same grader and packaging the seed in

the old gunny bags etc. To avoid this sort mechanical contamination it would be necessary. To rogue the seed fields at least at the three stages.(before flowering , at the time of flowering and after flowering)

Mutations: This is not a serious factor of varietal deterioration. In the majority of the cases it is difficult to identify or detect minor mutation due to its natural frequency 10^{-8}

Natural crossing: In sexually propagated crops, natural crossing is another most important source of varietal deterioration due to introgression to genes from unrelated stocks which can only be solved by prevention. Natural crossing occurs due to following three reasons:
a) Natural crossing with undesirable types.
b) Natural crossing with diseased plants.
c) Natural crossing with off- type plants.
Natural crossing occurs due to six most prevalent factors:
a) The breeding system of species
b) Isolation systems
c) Varietal mass
d) Pollinating agent
e) Size of the pollen grains
f) Duration of pollen viability

Minor genetic variations: Minor genetic variations may exist even in the Varieties appearing phenotypically uniform and homogeneous at the time of their release. During later production cycle some of this variation may be lost because of selective elimination by the environment. To overcome these, regress yields trials are suggested

Selective influence of diseases: The selective influence of diseases in varietal deterioration is also of considerable importance. New crop varieties often become susceptible to new races of diseases often caused by obligate parasites and are out of seed programmes . Similarly the vegetatively propagated stocks deteriorate fast if infected by viral, fungal and bacterial diseases. During seed production it is, therefore, very important to produce disease free seeds/stocks.

Techniques of plant breeders: In certain instances, serious instabilities may occur in varieties due to **cytogenetical** irregularities not properly assessed in the new varieties prior to their release. Other factors, such as break down in male sterility in certain environmental conditions and other heritable variations may considerably lower the genetic purity.

Maintenance of Genetic Purity During seed Production:
The various steps to maintain varietal purity, are as follows.

1-Avoiding genetic shifts by growing crops in areas in their adaptation only.

2-Use of approved seed only in seed multiplication by adopting the three model of generation system as breeder seed –foundation seed – certified seed

3-Certification of seed crops to maintain genetic purity and quality of seed Inspection and approval of fields prior to planting.

4-Providing adequate isolation to prevent contamination by natural crossing or mechanical mixtures

5. Field inspection and approval of growing crops at critical stages for verification of genetic purity, detection of mixtures, weeds, and for freedom from noxious weeds and seed borne diseases etc. Rouging of seed fields prior to the stage at which they could contaminate the seed crop. Sampling and sealing of cleaned lots. Growing of samples of potentially approved stocks for comparison with authentic stocks (Grow out tests) Periodic testing of varieties for genetic purity

Agronomic principles-

1. Selection of aAgro-climatic Region

Growth of the plant and production of good quality seeds are strongly influenced by both genetic and environmental factors. Environmental factors include:

a)Temperature,
b) Rainfall,
c) Wind velocity,
d) Soil condition and texture,
e) Insect activity and their relationship with varietals adaptation in any given locality For good seed crop , a crop variety to be grown for seed production in an area where it must be adapted to the photoperiod and temperature conditions prevailing in that area. According to the various agro-climatic zones, we can classify the different kind of field crops and vegetable seed production programme to the different seed producing regions.

2. Selection of seed plot

The plot selected for seed crop must be free from – **volunteer plants**, **weed plants** and have good soil texture and fertility The soil of the seed plot should be comparatively free from soil borne diseases and insects pests etc.

3. **Isolation of Seed crops**

The seed crop must be isolated from- Other nearby fields of the same crop. and the other contaminating crop as per requirement of the certification standards.

4. Preparation of Land:

Good land preparation helps in- Improved germination Good stand establishment and destruction of potential weeds. It also aids in water management and good uniform irrigation.

5. Selection of variety:

The variety of seed production must be carefully selected, it should possess- Disease resistance, Earliness, Grain quality, higher yielder and adapted to the agro-climatic conditions of the region.

6. Weed treatment:

Depending upon the requirement, the following seed treatment may be given- Chemical seed treatment.(Therum or corbendazem) Bacterial inoculation for the legumes. Seed treatment for breaking dormancy.

7. Time of planting
The seed crops should invariably be sown at their normal planting time. Depending upon the incidence of diseases and pests, some adjustments, could be made, if necessary.

8. Seed Rate:
Lower seed rates than usual for raising commercial crop are desirable because they facilitate rouging operations and inspection of seed crops.

9. Method of sowing:
The most efficient and ideal method of sowing is by mechanical drilling.

10. **Depth of sowing:**
Depth of sowing is extremely important in ensuring good plant stand. Small seeds should usually be planted shallow, but large seeds could be planted a little deeper.

11. **Rouging:** Adequate and timely rouging is extremely important in seed production. Rouging in most of the field crops may be done at many of the following stages as per needs of the seed crop. Vegetative / pre-flowering stage Flowering stage Maturity stage:

Characters	**Maximum Permitted (%)**		
	Foundation Seed	**Certified Seed**	
VARITIES Off Types Objectionable Weed plant **HYBRID** Off type in seed parent Off type in pollinator Pollen shedders in female Objectionable weed plants			

12. Supplementary pollination: Provision of honey bees in hives in close proximity to the seed fields of crops largely cross pollinated by the insects, ensure good seed set thereby greatly increase seed yields.

13. Weed control: Good weed control is the basic requirement in producing good quality seed. Weeds may cause contamination of the seed crop, in addition to reduction in yield.

14. Disease and insect control: Successful disease and insect control is another important biotic factor in raising healthy seed crops. Apart from reduction of yield, the quality of seeds from diseased and insect damaged plants is invariably poor.

15. Nutrition: In the nutrition of seed crops, nitrogen, phosphorus, potassium, and several other elements play an important role for proper development of plants and seed. It is, therefore, advisable to know and identify the nutritional requirements of seed crops and apply adequate organic fertilizers.

16. Irrigation: Irrigation can be important at planting for seed crops on dry soils to ensure good uniform germination and adequate crop stands. Excess moisture or prolonged drought adversely affects germination and frequently results in poor crop stands.

17. Harvesting of Seed crops: It is of great importance to harvest a seed crop at the time that will allow both the maximum yield and the best quality seed. The crop can be harvested in both physiological as well as field maturity depends on situations. In case of orthodox seeds 15-20 percent moisture content should be present at the time of harvest.

Post harvest operations during seed production

18. Seed Processing:-the seeds are to be graded by using recommended sieves for varieties. The seed deviate from original tan color also to be removed.

19. Seed Testing: Seed samples are drawn from the processed seed for seed testing in authorised seed testing lab for ascertaining the minimum seed certification standards , as mentioned in following table:

Seed Standards:

Standards	Foundation Seed (%)	Certified Seed (%)
1. Physical purity (%) (max)		
2. Inert matter % (max)		
3. Other crop seed (max)		
4. Weed Seed (max)		
5. Other distinguishable varieties (max)		
6. Moisture content (max)		
a). moisture pervious container		
b). moisture vapour proof container		
8. Germination % (min)		

20. Seed Treatment: After seed testing, if seed sample maintains the required minimum seed certification standards, they are subjected to seed treatment either by thirum or by corbendazem @ 2g / Kg seed.

21. Bagging and Tagging: Treated seeds are packed in cotton bags / gunny bags by adopting the rules of seed certification. The tags (Yellow - Breeder seed ,white-foundation seed and azure blue –certified seed) and label (green color) are intacted on bags.

22. Storage: Seeds are stored in optimum conditions for maintaining the viability and vigour up to next sowing season.

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Quality Seed Production Technology in Fodder Oats

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Forage crop production has its unique limitations and availability of good quality seeds in enough quantity is among the major constraints. As per an estimate only 25-30% of required quantityof quality seed is available in cultivated fodders and <10% in range grasses and legumes in India. Improvedpackage of practices for forage seed production would be helpful in increasing forage seedproduction. Seed production technology for forage oat involves a series of location specific and general practices to ensure high-quality seed production.

Advantages of fodder oats as a fodder crop

Fodderoats is high yielding, easy to grow and ensile, medium energy protein crop. It is a flexible crop that can be grazed, cut as forage or grain depending on grass supply andwinter forage stocks. It is drought tolerant and less susceptibility to biotic agents such as pest and diseases. Adapted to sustainable management, low demand for nitrogen andhighly competitive to weeds.

Requirements for quality seed production of fodder oats

Climate: Oatrequires cool and dry climate (between15-32°C for growth). Growth and development retards during severe cold period and at extremely high temperature. Seed formation is higher in mild weather.

Soil: Good quality soil is essential to set platform for achieving higher production. Generally fertile soils with good moisture-holding capacity and normal soil reaction (free from acidity and alkalinity) are ideal for seed production. It can be grown on both heavy and lighter soil with ideal type being loamtoclayloamsoil,welldrained,pHupto8.5.

Land Preparation: Prepare the land by ploughing, levelling, and ensuring proper drainage. Adequate soil fertility and pH levels are essential for good seed production.

Variety Selection: Select high-yielding and disease-resistant varieties for seed production. Ensure that the chosen varieties are well-adapted to the local conditions (Table 1).

Isolation Distance: Maintain proper isolation distance of 3 meter between different varieties to prevent cross-pollination or mechanical mixture. This is critical to maintain the genetic purity of the seeds.

Sowing: Follow recommended sowing practices, including seed rate, row spacing, and planting depth. Line sowing through drill is preferred option.

Table1.Spacing, seedrate and varietiesforfodderoats

Crop	Spacing(cm)	Seed rate(kg/ha)	Varieties
Oat	30-40 x5	60 (large seeded),	Kent, JHO-822, Bundel Jai 851,JHO-99-1, JHO-

		40 (small seeded)	99-2, JHO-2000-4, Phule Harita (RO-19).

Nutrient Management: Apply fertilizers as per soil test recommendations to meet the nutrient requirements of the crop(Table 2).

Table2.Fertilizerrequirementinseedproductionof fodderoats

Crop	Nutrientrequirement (kg/ha)			Stage of application	
	N	P_2O_5	K_2O	Basaldose	Topdressing
Oat	80	40	30	50%Nandentireamountof Pand K	50% N30-45daysaftersowing

Weed Management: Implement effective weed control measures to minimize competition for nutrients and space. Herbicides, manual weeding, or mulching can be used depending on the crop and weed pressure.

Irrigation: Provide consistent and adequate irrigation throughout the crop's growth cycle to ensure optimal seed development. The water requirement may vary depending on the variety and local climate (Table 3).

Table3. Soilmoisturerequirementforseedproduction in fodder oats

Crop	Optimum soilmoisture regime forirrigation (%ASM)	Irrigationinterval(days)	No. ofirrigations	Waterrequirement(mm)	Water-useefficiency (kgdm/ha-mm)
Oat	75	12-14	6-8	340	32

Pest and Disease Management: Leaf blotch and root rot are major diseases. Seed treatment with thiram @ 2gm/kg is recommended. Monitor the crop regularly for pests and diseases. Apply appropriate pesticides or biocontrol agents when necessary to prevent damage to the plants.

Rouging: Remove off-type or diseased plants to maintain the genetic purity of the seed crop from time to time as per guidelines issued by certification agencies. Two inspections at pre-flowering and flowering stages are recommended.

Harvesting: One cut at 10 cm height at 50 days after sowing is taken after which crop is left for seed production. Harvest the crop when it reaches the physiological maturity stage where plants turn to golden yellow colour. For forage seed production, it's crucial to harvest at the right time to maximize seed yield and quality.

Threshing and Drying: After harvesting, thresh the seeds and dry them properly to reduce moisture content. Drying helps prevent seed damage and fungal growth during storage.

Seed Cleaning: Use seed cleaning equipment to remove impurities and ensure the seeds are of high quality. Seeds of grasses need special care such as defluffing in dinanath seeds for better storage, transport and enhancement.

Seed Storage: Store the cleaned seeds in a cool, dry place in suitable containers to maintain seed viability. Proper storage conditions are essential to prevent deterioration. The storage must be well ventilated and regularly inspected. Issue of rodents, insects and microbial diseases along with physical contaminants such as seeds from different seed lots, unprocessed seed lots, infested seed lots must be looked thoroughly.

Seed Testing: Periodically test the seed lot for germination and purity to ensure it meets quality standards.

Certification: Seek certification from relevant agricultural authorities to label and sell the seeds as certified/ TL crop seeds.

Table4.Harvestingtimeandseedyieldindifferentfoddercrops

Crop	Harvestingstage	Seedyield(q/ha)
Oat	Seedhardensandthe strawturnsinlightyellowcolor	10-15

Documentation: Maintain detailed records of all activities related to seed production, including crop management practices, inputs used, and harvesting details.

Seed certification standards for fodder oat

As per IMSCS, following seed standards must be met with for commercial utilisation of seed lots.

Table5.Seed certification standards for fodder oat (certified/TL class)

Sl.No.	Parameters	Percentage
1.	Genetic purity (minimum)	98
2.	Physical purity (minimum)	98
3.	Inert matter (maximum)	2
4.	Germination (minimum)	85
5.	Moisture (maximum)	12%
6.	Other crop seeds (maximum)	20/kg
7.	Weed seeds (maximum)	20/kg

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Nutrient Management in Quality Seed Production of Cereals

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Cereals and cereal products are staple foods in most human diets (Kushi*et al* 1999; McIntosh 2001; McKevith 2004), in both developed and developing countries, providing a major proportion of dietary energy and nutrients. They are composed of approximately 75% carbohydrates, mainly starches and about 6–15% protein, contributing in global terms more than 50% of energy supply (WHO 2003). The importance of cereals and cereal products is also supported by the fact that global food security depends to the greatest degree on cereal production, which yearly amounts to approximately 2600 million tons (FAO 2019).

The food value of cereals is very high and they contain a high percentage of carbohydrates than any other food. It is becoming very important to increase the yields of cereals to feed the growing population. Seed is also an important component of agricultural production and availability of viable and vigorous seed at the planting time is very important for achieving the yield target (Peerzada*et al* 2016). Quality seed is pure, clean and viable. Pure seed is without any mixture of other types or varieties whereas clean seed is free from weed seeds, litter, stones and diseased, damaged or deformed grains. Viable seed is a healthy seed with appropriate moisture content and high germination potential.

Plant growth and development are directly depended on the source of nutrients. Basically, plants need different type of nutrients which are categories into two groups i.e. macro nutrients and micro nutrients according to their requirements. These nutrients include Nitrogen (N), Phosphorous (P), Potassium (K), Calcium (Ca), Zinc (Zn), Iron (Fe), Boron (B), Sulphur (S), Magnesium (Mg) etc. In the plant body, many nutrients influence biochemical processes as well as provide resistance against diseases and finally disturb the quality of crops. According to fast increasing in the world population and the decreasing trend in yields of crop make food safety a main challenge. That's why balanced application of nutrients is very important to raise the good quality crop yield and to attain the necessary increase in the production of food (Toor *et al* 2021).

Seed vigor and viability are important components influencing seedling establishment, crop growth, and productivity (Welch, 1986; TeKrony and Egli, 1991; McDonald and Copeland, 1997). Any biotic and/or abiotic factors that negatively affect seed vigor and viability during seed development will have adverse consequences for crop production, especially when the seeds are sown under environmentally stressful conditions (Fenner, 1992; Welch, 1995). Because significant amounts of seed nutrient reserves can be acquired from vegetative tissues, both size and number of seeds produced by maternal plants are most likely determined by their nutritional status at the time of flowering and bud initiation. Additionally, the timing of nutrient supplies to the maternal plant is critical to seed size, with earlier applications of nutrients having greater effects than later applications. Furthermore, the most important single determinant of mineral nutrient reserves in seeds is the mineral nutrient availability to the

maternal plant during reproductive development, with increasing supplies of a particular mineral nutrient enhancing the nutrient concentration in the mature seed (Fenner, 1992).

New research shows that micronutrients applied during seed production results in a much stronger seed for farmers. This means increased seed vigor, abetter germination rate and higher yields."Micronutrients are actually creating a more nutrient-dense seed. Ismail Cakmak, a plant scientist at Sabanci University in Istanbul, Turkey says that little attention is paid to the importance of seed nutrient reserves in production agriculture, but it's well known that larger seeds represent better seed vigor and field establishment. These larger seeds are often attributed to increased seed nutrient density. Depending on the crop, some of these nutrients include zinc, phosphorus, iron, boron and nitrogen. He also says that plants need up to 75 percent of their total phosphorus during the early growth stage. "Very early season phosphorus is more critical in achieving better yields than the supply of phosphorus at a later growth stage," he adds, highlighting the importance of seed phosphorous reserves. When seeds have sufficient nutrient reserves, the results are noticeable to the eye when looking at above ground biomass, germination and stand uniformity (Anonymous 2022).

To increase yield where soil micronutrients supply is not adequate several methods are adopted to improve the plant micronutrient status. But application of fertilizer to soils requires higher dose because of little nutrient-use efficiency (Singh 2007). Micronutrients can also be applied through seed treatment (priming) or foliar sprays. It has been seen that foliar sprays are most effective in seed enrichment and improving the yield (Biswas *et al* 2021; Ray and Bordolui 2020; Biswas *et al* 2020). Because of the high cost of foliar sprays poor farmers with less resource cannot adopt it widely [Johnson *et al* 2005]. Another issue with foliar sprays is that it is applied to established crop stand at later stage. So, from economical perspective seed treatment is a better option as smaller quantity of micronutrient is needed, easy application and seedling growth is also improved (Singh *et al* 2005). Seeds treatment with micronutrients can be done in different ways according to needs. They can be either soaked in the nutrient solution of different concentrations and different time durations depending upon nutrient and the crop. They can also be coated with micronutrient. Seed invigoration is a relatively new term in seed treatment where reciprocally used for both methods of seed treatment (Farooq *et al* 2009; Chakraborty and Bordolui 2021; Ray and Bordolui 2022).

Seed priming and treatment with micronutrients has the potential to meet crop micronutrient demand and improve seedling emergence and stand establishment, grain micronutrient enrichment and yield. Micronutrients may be applied to the soil, foliar sprayed or added as seed treatments or seed priming. While the essential amounts of micronutrients can be provided by any of these methods, foliar sprays have been more successful in yield improvement and seed quality enrichment. Due to high cost has limited its wider adjustment, particularly by wealth poor farmers. Micronutrients may be applied either by coating with micronutrients or by soaking in nutrient solution of a specific concentration for a specific duration (seed priming). The potential micronutrients for seed treatments are Zinc (Zn), Boron (B), Molybdenum (Mo), Manganese (Mn), Copper (Cu) and Cobalt (Co) for improving growth, development, yield and seed quality enrichment. Treated or primed seeds generally have better, faster and more integrated germination. Micronutrient application in seed can also be done through seed coating and pelleting. Seed priming or seed coating seems reasonable, inexpensive and an easy method of micronutrient delivery mostly by small land holders in developing countries (Bordolui*et al* 2022).

The method of seed priming involves 2 steps. First, they are hydrated partially so that different metabolic events can take place without germinating. In the next step seeds are again dried to their initial weight for routine handling (Bradford 1986). The germination speed is higher in case of primed seeds in relation to unprimed seeds (Farooq *et al* 2006; Farooq *et al*2009). Seed priming with micronutrients is known as nutri-priming, where micronutrients act as osmotica (Imran *et al* 2004; Singh 2007). Primed seeds appear superior and consistent germination (Farooq *et al* 2009) because of less imbibition time (Brocklehurst and Dearman 1983;McDonald 2000;Taylor 1998) and obtainability of germination increasing metabolites (Basra *et al* 2005 Farooq *et al* 2006). There are some reveals which indicate that nutripriming can improve wheat (Marcar and Graham1986;Wilhelm *et al* 1988) and rice (Peeran and Natanasabapathy 1980) yield. Although some reports showed that if seed priming is done with higher nutrient concentration, it can result into germination inhibition and seed damage.

Plant emergence, stand establishment, further growth and yield can be improved by seed priming with Zn. Germination and field emergence increased by 38 and 41%, respectively in when seeds were primed with 0.05% $ZnSO_4$ solution" (Babaeva*et al* 1999). Kaya*et al* 2007 found that in Barley *(Hordeum vulgare* L.) germination and seedling development can be improved by Zn-seed priming. "During seed development Zinc content in newly developed radicles and coleoptiles are higher, which indicates that Zinc is involved in early seedling development, their physiological processes and possibly protein synthesis, cell elongation, various membrane function and resistance to abiotic stresses" (Cakmak 2000). "Higher Zinc content in seed might be helpful in protection of soil-borne pathogens during germination and seed development stage which in turn ensures a good crop stand" (Marschner 1995) and a better yield. By comparing Zinc ($ZnSO_4$ (0.4%) seed primed and non-primed seed it has been observed that the Zinc requirement of wheat can be entirely met and also higher yield (21%). Seed priming was also beneficial compared with soil application as benefit: cost ratio was 8 in soil application and 360 in seed priming (Harris *et al* 2005). The suitable concentration may vary from crop to crop. Harris and team also found that priming seeds with $ZnSO_4$ (1%) solution for sixteen hours crop yield, grain yield, grain zinc content of maize. Primed seeds showed 27% higher yield in comparison to non-primed seeds. It should also be noted that the primed seeds gave better benefit: cost value compared to soil application (Harris *et al* 2007). In 2008 the same team found that seed priming with Zn (0.3%) can increase wheat yield by 14%. 19% yield increase in chickpea was achieved by seed priming with 0.05% Zn. Zinc seed priming also increased zinc content of grain by 12% in wheat (Harris *et al* 2007). In rice also seed treatment was better and more economically viable than soil application and no application. Slaton and others found that Zinc seed treatment in rice improved growth and grain yield (Slaton *et al* 2000). There was another experiment where higher wheat grain yield was achieved by seed priming with Zn rather than foliar and soil application when it cultivated on Zn-deficient soil. Although, grain Zn concentration was not affected by seed priming in contrast to soil and foliar application (Yilmaz *et al* 1997; Yilmaz *et al* 1998). Zn was adhered to the wheat seeds by using Arabic gum by using zinc sulfate (ZnSO4, 7H2O) as a source. Control was sown with untreated dry seeds. Results showed that Zn seed treatments improved field emergence, seed priming with Zn (0.01 M) solution gave maximum numbers of seedlings. Grain yield, biological yield, and other yield related characteristic improved by seed osmo-primed with Zn (0.01 M) solution. Zn enrichment in grain and straw were also increased in seed osmo-primed with Zn (0.01 M) solution (Hassan *et al*2019).

The most effective method for increasing Zn in grain was the soil + foliar application method that resulted in about 3.5-fold increase in the grain Zn concentration. The highest increase in grain yield was obtained with soil, soil + foliar and seed + foliar applications (Yilmaz *et al* 1997). Timing of foliar Zn application is an important factor determining the effectiveness of the foliar applied Zn fertilizers in increasing grain Zn concentration. It is expected that large increases in loading of Zn into grain can be achieved when foliar Zn fertilizers are applied to plants at a late growth stage. Ozturk *et al* (2006) studied changes in grain concentration of Zn in wheat during the reproductive stage and found that the highest concentration ofZn in grain occurs during the milk stage of the grain development. Results show a high potential of Zn fertilizerstrategy for rapid improvement of grain Znconcentrations, especially in the case of late foliar Znapplication. In practical agriculture, it is known that foliaruptake of Zn is stimulated when Zn fertilizer ismixedwithurea (Mortvedt and Gilkes, 1993).

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Seed Sampling: Principles and Procedures

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Seed sampling is the process of obtaining the representative portions of small quantities of the seed from the seed lot. The process itself is a highly technical and it is the pre-requisite of seed testing. The analysis results obtained on the sample tested in the seed testing laboratory may cause the rejection of the seed lot for distribution or further multiplication, certification or may serve as evidence in the Court of Law against the seller of faulty seeds. It is neither physically possible nor practicable to test the entire quantity of the seed lot. Accordingly it is essential that the sample drawn from the seed lot must be representative to avoid problems in seed certification and seed law enforcement. It is customary that the analysis results on the sample tested in the seed testing laboratory should reflect the quality of the whole lot from where the sample was drawn.

Principles of Sampling:

Samples are derived from different portions of a seed lot and mixed to obtain a sample of required quantity representing the seed lot in true sense. From this composite sample, small portion of required quantity is obtained in such a way that even after reduction, it represents the seed lot. In each and every stage thorough mixing and dividing is necessary.

Seed Lot:

A seed lot is a specified quantity of the seed of one cultivar, of known origin and history and controlled under one reference number (lot number). It is an uniformly blended quantity of seed either in bag or in bulk.

Equipment and Materials: Trier, plastic tubs, bags, balance, seed divider, sticker and labels.

Trier: It is required to draw the primary sample from the seed lot stored in bags or containers. Two types of triers are required for sampling *Stick and Nobbe trier.*

Seed divider:

It is equipment used for getting desired quantity of true to the type sample for submission in laboratory for individual test. Three types of divider are used in seed testing Boerner *type divider* (conical divider), *Soil type divider* and *Gamet type divider* (centrifugal divider).

Sampling in processing plant

1) **Primary sample:**

It is a small quantity of seed taken from one point of the processed lot. The seed lot is arranged to approach conveniently up to individual container. Primary samples are drawn from different portions and depth by inserting the stick Trier with the closed slot diagonally in the seed bag or container up to desirable depth with minimum damage to seed. The flow of seed is facilitated in the tube by opening and closing of the slot. Finally, the trier is withdrawn with closed slot and collected sample is transferred to a container.

Stick Trier is inserted into a bag up to a desirable depth at an angle of 30 degree with the hole present at the pointed end facing downwards. The spear is withdrawn gently, so that, equal quantity of seeds enter into the hole from centre to the side of the bag. The point of insertion is closed with the help of a sticker or by running across the trier on the hole a couple of times in opposite direction. Minimum number of primary samples should be taken as per Table 1. and 2. The quantity of seed drawn in one primary sample depends on the sampling intensity, size of submitted sample and seed lot size of crop.

2) **Composite sample:** Primary samples drawn from different places of a lot are mixed and the mixture is known as composite sample. The size of composite sample should be 10 times more than the required submitted sample.
3) **Submitted sample**: The required quantity of seed, which is sent to seed testing laboratory, is known as submitted sample. The weight of the submitted sample varies accordingly to the kind of seed or the kind of test required. (Table 1 and 2). To prepare a submitted sample, the composite sample is mixed thoroughly and reduced up to required quantity with the help of seed divider or by repeated halving method.

Category of seed sample:

Mainly three categories of samples are received in the seed testing laboratory based on their usages. Viz.

a) Service samples
b) Certification samples
c) Enforcement/legal/official samples

Service samples:

These are the samples drawn from the farmer stored stock / dealers by extension workers or by the dealer/farmers themselves to know the quality of the seed for further immediate use. The result obtained on these samples is generally utilized for sowing or labeling purpose. The sample should contain the necessary information for documentation (sample slip). Non notified laboratories can also test these categories of seed samples.

Certification sample:

The samples drawn submitted to the seed testing laboratory by the authorized official from seed certification agency for certification purpose. Such seeds are tested in the seed testing laboratory to know whether they confirmed to the seed certification standard prescribed. Only notified seed testing laboratories are authorized to test the certification samples.

Seed law enforcement sample:

For seed quality regulation at distribution and marketing level these sample are drawn from sale/stock point by the notified seed inspectors in their respective jurisdictions as per the provisions of the section 14 (1) a, b Seeds Act 1966. These samples are also know as quality control samples and are tested only in notified: Seed testing laboratories. These samples are tested by the authorized or notified seed analyst as per the procedure laid down in Seeds Act 1966 and Seed Rules 1968.

Separate sample for determination moisture:

The seeds are hygroscopic in nature and tend to absorb atmospheric moisture when exposed. Therefore when the seed sample is to be taken for moisture content a separate seed sample of 100 gram (for species that require grounding) and 50 gram (for other species) in a polythene bag (700 gauge)/ moisture proof bag is to be apportioned, tightly secured and be submitted along with the submitted sample bag.

Sampling situations:

Seed sample are required to be drawn before or during processing and after bagging or packing operations. Seed may be stored in the form of heaps, in the storage bins/gunny bags / cloth bags, paper packets/pouches or moisture impervious containers such as laminated aluminum foils, sealed tins etc.

General principles of sampling:

1. Sampling should be carried out only by persons trained and experienced in seed sampling.

2. The seed lots shall be so arranged that each individual container or part of the lot is conveniently accessible. Upon request by the sampler, the owner shall provide full information regarding the bulking and mixing of the lot. Sampling may be refused when there is definite evidence of heterogeneity.
3. The size of the seed lot should also not exceed to maximum seed lot size prescribed in the rules, subject to a tolerance of 5%
4. Seed sampler may request the producer to get some bags emptied or partially emptied to facilitate sampling. The bags may then be refilled. This may be necessary since it is impossible to obtain sample deeper than 400 mm, i.e. from the lower layer in bags and bins.
5. The sampler should determine that all seed bags sampled are identified as belonging to a single lot, either by a label or stencil mark on the bag
6. The sampler must sample the minimum requisite number of bags from the seed lot in accordance with the sampling intensity.
7. Care must be exercised in reducing composite samples. Careless splitting of the sample cannot be expected to produce two similar portions.
8. Any seed know to have been treated with a poisonous fungicide should be identified so that the person who subsequently may handle the sample will be informed of the potential hazard.
9. While taking samples from machine sewed cotton bags, a few stitches at one of the top corners can be broken and then this break can be closed with a hand stapling device, after the contents of the bag have been sampled.
10. The sample drawn should not be less than the weight of submitted sample prescribed in the rules.

Table 1: Sampling intensity for a seed lot stored in container

Number of container	Sampling intensity
up to 5	Each container, at least 5 Primary samples
6 - 30	Sample 5 Containers or at least one in every three containers, Whichever is the greater
31 - 400	Sample 10 Containers or at least one in every 5 containers, Whichever is the greater
401 or More containers	Sample 80 Containers or at least one in every 7 containers, Whichever is the greater

Table 2: Sampling intensity for seed stored as bulk

Lot size (Kg)	Sampling intensity
up to 500	At least 5 primary Samples.
501 - 3,000	One primary sample for each 300kg, but not less than 5 primary samples.
3,001-20,000	One primary sample for each 500 kg, but not less than 10 primary samples.
20,001 and Above	One primary sample for each 700 kg, but not less than 40 primary samples.

Dispatch of submitted sample:

Sample should be dispatched to the seed testing lab as early as possible providing all the details like date of sampling, number of processing plant, crop, variety, class of seed, lot number, lot size / Quantity of seed in lot (kg) Senders Name and Address etc. and Tests required: 1) Purity (2) Germination (3) Moisture, apart from this sample, two reference samples are also prepared by the same method. One reference sample is stored by the office and second by producer. Office sample of seed lot passed in seed testing is stored for two years.

Sampling in seed testing lab:

The submitted sample received in seed testing lab is registered and designated by a code number. Submitted sample is tested for determination of seeds of other crop, weed, objectionable weeds, objectionable diseases and other distinguishing varieties by number. Three working samples of the submitted sample, which passes the seed certification standard by number are prepared. Each working sample consists of at least 2500 seeds (Table 3).

Preparation of working sample:

Mechanical divider: As described for preparation of submitted sample.

Repeated halving method: As described for preparation of submitted sample or the seed is poured on a clean smooth surface and shaped as a mound after thorough mixing. Mound is divided into two halves, each half is again halved, each portion is again halved giving total 8 portions. Alternate portions are combined i.e. 1st and 3rd of first row and 2nd and 4th of second row. The remaining portion is kept in a pan and the process is repeated to obtain required size of the working sample.

Random cup method: Six to eight small cups of equal size and shape are arranged at random on a tray. The seed is poured uniformly over the tray. The seeds, which fall into the cups, are collected as working sample. This method is useful for the crops with small seed size but not for chaff and round seeds.

Spoon method:

The seeds are poured evenly in one direction over the tray. If required, seed can be poured second time in opposite direction. Shaking of the tray is avoided, small quantity of seeds are collected with the help of spatula from minimum 5 random places to make a working sample of required quantity. The working sample is stored in paper bag marked with code number, name of the crop and purpose.

Table 3: Size of submitted and working samples required for different crops

Crop	**Submitted sample (g)**	***Working sample (g)***
FIELD AND FODDER CROPS		
Wheat, oat, triticale	1000	0120
Sorghum	0900	0090
Pearl millet	0950	0015
Italian millet	0090	0009
Kodo millet	0080	0008
Linseed, jute, common millet	0150	0015
Fieldpea, maize	1000	0900
Lentil	0600	0060
Chickpea, groundnut	1000	1000
Pigeonpea	1000	0300
Horse gram, moong bean	1000	0400

Grass pea	1000	0450
Castor, soybean	1000	0500
Rice, rajmash, urid bean	1000	0700
Sunflower	1000	0200
Safflower	0950	0090
Cotton	1000	0350
Gueina grass, Setaria grass	0025	0002
Marvel grass	0030	0003
Brassica juncea, taramira	0040	0004
Lucerne, Indian clover	0050	0005
Egyptian clover, finger millet, buffel grass	0060	0006
VEGETABLE CROPS		
Celery	0025	0001
Chinese cabbage, parsley	0040	0004
Carrot, lettuce	0030	0003
Tomato	0015	0007
Turnip	0070	0007
Onion	0080	0008
Brassica olerecea all varieties	0100	0010
Chilli, egg plantl	0150	0015
Cucumber, musk melon	0150	0070
Spinach	0250	0025
Radish	0300	0030
Pumpkin	0350	0180
Coriander	0400	0040
Fenugreek	0450	0045
Sugar beet	0500	0050
Cluster bean, asparagus	1000	0100
Okra	1000	0140
Water melon, sponge gourd	1000	0250
Ridge gourd	1000	0400
Bitter gourd	1000	0450
Bottle gourd	1000	0500
Indian bean	1000	0600
French bean and all squashes	1000	0700

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Hybrid Seed Production Technology In Sorghum

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Introduction:

Sorghum [*Sorghumbicolor* (L.) Moench] is commonly known as 'Jowar' is the fifth most important cereal in the world next to wheat, rice, maize and barley. It is a C_4 carbon cycle plant with high photosynthetic efficiency and productivity. This crop is widely cultivated in more than 100 countries around the world. The sorghum is recognized as a potential star crop due to its diverse end uses, high returns, more resilience to adverse climatic conditions and well performance under conditions of water and temperature stress especially in marginal lands.

India share 7.58 per cent of world sorghum production and ranks fourth after USA, Nigeria and Ethiopia. In India, sorghum is cultivated in an area about 4.10 million hectares with a total annual production of 4.40 million tones and productivity of 1100 kg ha^{-1} (Anon., 2023/24). The major sorghum growing states in India are Maharashtra, Karnataka, Andhra Pradesh, Madhya Pradesh, Rajasthan and Tamil Nadu. The Maharashtra state is one of the important sorghum growing states in India and accounts for an area of 2.17 million hectares and production of 1.81 million tones with an average productivity of 833 kg ha^{-1} (Anon., 2018). Uttar Pradesh share 3.4 and 4.3 per cent of the total area and production of the country, respectively with productivity of 1272 Kg ha^{-1}.

Seed is the paramount input in modern agriculture as the quality of seed determines the crop productivity. The high quality seed in terms of high genetic purity, physical purity, physiological and health quality assures the potential of crop production under favorable agro climatic conditions. The quality of the certified seed class of a hybrid or variety depends on the maintenance of genetic purity, physical purity, seed health, physiological potential during entire seed production chain. The followings are seed technological principles that govern the quality seed production in sorghum.

Seed Multiplication Chain:

In India, the seed multiplication is three generation system viz., i) Breeder seed, ii) Foundation seed, iii) Certified seed. The seed certification is voluntary as per Seed Act 1966. Apart from certified Seed, truthfully labeled seed is also sold in market. However the certified seed has the advantages like high genetic and physical purity, freedom from disease and pest, high germination and seedling vigor. The seeds of different classes can be produced based on the forecasting the demand of annual certified seed requirement based on multiplication ratio, replacement rate and additional seed requirement. The area to be planted and target seed of each class is calculated by multiplying area and quantity with a factor X 200 (Table 1).

Table 1a: Estimation of seed targets (t) and area requirement (ha) for different classes of seed multiplication

Particular	Breeder seed	Foundation seed	Certified seed	Grain
Area (ha)	0.5 ha=	100 ha =	20,000 ha	4 m ha
Quantity (t)	1 t	200 t	40,000 t	

Table 1 b: Seed multiplication ratio in sorghum

Foundation to certified	Seed rate kg/ha	Seed yield kg/ha	Multiplication ratio
a) Seed parent	7.5	750	100
b) Male parent	5	750	150
c) Varieties	10	1000	100

Maintenance of Genetic purity during seed production cycle

The genetically pure seed of a variety is expected to have all the unique economic and diagnostic characters. In sorghum inbred lines and varieties, the deterioration will be much faster due to contamination with undesirable pollen of other genotypes. The major factors causing deterioration of varieties or inbreeds leading to the production of seeds with low genetic purity are i) Minor genetic variation, ii) Developmental variations, iii) Out crossing iv) Mechanical mixtures, e) Selective influences of diseases. The following important measures should be followed during sorghum seed production in order to maintain genetic purity.

1. Proper attention must be given to land requirements, isolation, rouging, harvesting, drying, sorting of ears, threshing of ears etc., so as to maintain maximum possible genetic purity.
2. Proper class of seed should be the source for further multiplication.
3. The best cultural practices should be followed.
4. Inspection should be done at all critical stages of seed plots.
5. Mechanical mixtures should be avoided at sowing, harvesting, threshing, processing and storage.

HYBRID SEED PRODUCTION TECHNIQUES IN SORGHUM

Sorghum hybrid seed production is a highly commercial venture. It is essential to maintain efficient level of crop management in order to maximize production at minimum cost. The basics for hybrid seed production are as follows. The quantities of hybrid seed required should be roughly estimated on an annual basis in advance, depending upon the projected demand for the commercial hybrid under cultivation. It is desirable to maintain significant quantities of carry-over seed as an insurance against unforeseen seed crop losses. The hybrid sorghum seed is produced by utilizing cytoplasmic male sterility. In this system three lines viz. male sterile line/seed parent/A line, Maintainer line/non restorer line/B line/pollen parent and Restorer line/R line/pollen parent are involved. The foundation seed is produced by crossing between A line and B line, the resulting seeds are always sterile. The commercial hybrid or certified seed is produced by crossing of A line with R line, since R line has the

characteristic of restoring fertility of the A line seeds hence, the resulting seeds are always fertile and distributed to the farmers for commercial crop production.

1. **Selection of Land, Agro-climatic region and Season for Seed Production:**

The fields where sorghum was not grown in the previous season should be selected. In addition, there should be no Johnson grass in the seed field or within isolation distance. The field should be free from volunteer plants and soil borne pathogen and insects. The field should be well leveled and drained. The saline, alkaline or very lighter soils are not suitable. Uniform and level piece of land with good drainage should be selected. The pH should be around 5.5 to 8.5. Good irrigation facilities are essential for sorghum seed crop.

The area where the temperature during flowering ranges from 27-32°C is best suited for good seed production of sorghum. Night temperature should not fall below 11°C for longer period since it affects the seed development. Flowering and seed development stages should not coincide with the rains as the pollen loss and grain mold deteriorate seed quality. Sorghum seed production is mostly undertaken during *Kharif* in Maharashtra, Madhya Pradesh, Rajasthan, Gujarat and Uttar Pradesh. In the other sorghum growing areas it is taken in *Rabi* or summer season. Seed produced in seasons other than *Kharif* has good germination and vigour. During *Kharif*, problems due to grain mold arise frequently.

The seed of commercial hybrids is produced in *Rabi* and summer seasons both by public and private seed agencies and marketed in summer season itself. However, seed for *Rabi* has to be stored till the next *Rabi*. The seed production in *Rabi* is predominantly concentrated in Andhra Pradesh and adjacent part of Karnataka due to favorable ecological conditions.

2. **Selection of Hybrids:**

The government institutions/universities and private sectors are involved in R&D of sorghum. The first sorghum hybrid CSH-1 was developed and released in the year 1964 since then several hybrids have been developed and released by the different organizations. The popular hybrids and their parents are given as below.

Hybrid	Seed Parent	Pollen Parent
CSH-5	MS2077A	CS3541
CSH-6	MS2219A	CS 3541
CSH 7R	36A	168
CSH 8R	36A	PD 301-11
CSH-9	MS296A	CS 3541
CSH-13 R	MS296A	RS 29
CSH-14	AKMS14A	AKR-150
CSH-15R	CMS-104A	RS-585
CSH-16	MS-27A	C-43
CSH-17	AKMS-14A	RS-673
CSH-18	IMS-9A	INDORE-12
CSH-19R	104A	AKR-354
CSH 20MF	2219A	UPMC 503
CSH 22SS	ICSA 38	SSV 84

CSH 23	MS 7A	RS 627
CSH 24MF	ICSA 467	Pant Chari 6
CSH 25	PMS 28A	C 43

3. **Isolation of Seed Plot:**

Sorghum is an often-pollinated crop. The extent of out crossing ranges from 6-45% and depends on nature of ear heads. Selection of a field with required isolation distance depending on class of seed i.e., foundation or certified seed and the kind of contaminants. Isolation standard for the production of different classes of sorghum seed is mentioned as below.

Contaminants	**Minimum Isolation for each class (m)**	
	Foundation Class	**Certified Class**
Fields of other varieties of grain and dual purpose sorghum including commercial hybrids of the same variety.	300	200
Fields of the same hybrid not confirming to varietal purity requirements for certification.	300	200
Fields of other hybrids having common male parent and confirming to varietal purity requirement for certification	-	5
Fields of other hybrids having common male parent but not confirming to varietal purity requirements for certification.	-	200
Johnson grass and Forage sorghum with high tillering and grassy.	400	400

Note: Differential blooming dates for modifying isolation distance are not permitted.

4. **Source of Seed:**

Obtain breeder/foundation seed of the parents from a source approved by certification agency for seed multiplication of commercial hybrid seed production.

5. **Seed Treatment:**

The seed should be treated before sowing either with imidacloprid 70 WS @ 10g/Kg seed or thiamethoxam 25 WG @ 3g/Kg seed to control sucking pests and borers.

6. **Sowing:**

Maintenance of male sterile line (A- line) involves sowing of two parents i.e., A-line (male sterile) and B- line (male fertile, non-pollen restores). Similarly, certified seed production of hybrids includes male sterile A-line and fertility restorer R-line. The borders rows (4-6) should be sown with male line all-round the seed production plot. To facilitate frequent rouging operation, a spacing of 60 cm (row to row) and 15-20 cm (plant to plant) is advisable. Precautions should be taken to avoid admixing two parental lines at the time of sowing. For A-line seed production the seed rate is 7.5 kg/ha of A-line and 5 kg/ha of B-line. The general seed rate varies from 7-8 kg/ hectare depending on spacing.

7. **Planting ratio:**

Male sterile (A) and restorer (R) lines are sown in alternate strips of rows, normally in a ratio of 4A : 2R, depending on the local experience of success and the ability of the R-line to disperse the pollen. The borders on all four sides of the hybrid seed production field are sown with the restorer (R) lines to ensure an adequate supply of pollen and guard against incoming stray pollen. The ideal planting ratio between male and female 1 lines is two male rows alternated by 4 to 6 female rows. Where the male lines have the smaller ear heads and shorter span of flowering compared to the female ones, (as in case of CSH 14 and CSH 15R) it is desirable to allow only four female rows for each pair of male rows. The female rows for each pair of male rows can be increased to six as in case the male lines having larger panicle and longer span of flowering. A five row thick border all around the seed production plots must always be provided. Economizing on male lines both within the plots and borders may affect the seed set and is not a wise step which many seed growers are tend to do.

8. **Plant height:**

Most of the parental lines of sorghum hybrids have matching heights in the rabi season facilitating easy pollination process. The problem of disparity of heights can be avoided to some extent by planting the short parent on the raised ridges and the taller parent in the furrows below.

9. **Synchronization:**

It is essential that the parental lines chosen for hybrid seed production flower at the same time i.e, the viable pollen is available when stigmas are receptive. Therefore, a prior knowledge on the flowering patterns of both the parents in hybrid seed production is necessary. The male and female parents of the various hybrids, with different degrees of photo and thermo-sensitivities may react variably under different day length and temperatures at various locations or seasons. Several methods are employed to ensure synchrony.

Measures for synchronization of flowering of male and female parents:

- ✓ The growth stages of male and female parents should be critically examined at 4 weeks stage or even later depending upon the length of their vegetative growth period.
- ✓ The flower primordia and the apex of male and female plants be sampled randomly and observed critically by stripping the leaves of stem. The difference in the time of initiation and size of the panicle bud would indicate the difference in their time to 50% flowering.
- ✓ The parent lagging behind can be hastened by selective measures like supplementation of nitrogen in the soil(additional dose of 50kg N/ha) followed by foliar spray of urea spray (2%), soaking of seeds in water, GA spray at primordial initiation stage (Kannababu*et al.* 2002).
- ✓ Alternatively, selective irrigation of one parent and delayed irrigation of the other will also help in synchronizing the flowering date of the parents.
- ✓ Careful manipulation of nitrogenous fertilizers, foliar spray of GA and irrigation can synchronize the flowering of parents that differ by up to one week.

- ✓ If the male is advanced in the early stage due to adverse seasonal conditions, cut alternate plants to allow the tillers to come up and boost up such tillers with additional dose of nitrogen.
- ✓ In case of partial seed setting, sugary disease (ergot) may occur. Spray of Thiram/ Captan to control the disease and avoid prolonged sowings in the same areas, since the disease may invade the late sown crop in epiphytotic proportion. However, making available pollen to achieve good seed set ensures better control of ergot disease.

10. **Pollen production and dispersal:**

The pollen production is influenced by temperatures. During the winter months, especially in areas where the night temperatures are rather low, pollen production and dispersal is appreciably reduced. 2% borax spray (on both male and female lines), two times from ear-head emergence till the completion of anthesis would greatly solve the problem. In fact the staggered planting of the two male rows ensures adequate and prolonged availability of pollen. It is not safe to rely entirely on natural winds to aid in pollen dispersal. It is desirable to use artificial aids of pollen dispersal like tapping the male plant or blowing air through empty duster over the male heads. It is also advisable to spray 2% Borax to improve the pollen production and dispersal. If the pollen is not available in the same plot, collect the pollen in the morning from neighboring plots and instantly spray with water or dust on the ear heads of the female parent. If there is dew fall hampering spread of pollen, blow empty power duster on the male rows to disperse pollen towards female heads or tap the male heads.

11. **Stigma receptivity:**

Generally, the stigma retains good receptivity up to 4-5 days (MS 2219A, MS 296A and AKMS 14A) after flower opening, although in some lines it is extended beyond that period as in MS 2077A. However, during the hot summer months, the receptivity is lost faster owing to desiccation of stigmas.

12. **Fertilizer application:**

Recommended dose of fertilizers (80kg N: 40kg P_2O_3; 40kg K_2O/ha) should be applied for obtaining optimum yield and good quality seed. Application of 25 kg ZnSO4/ha and 2 sprays of 0.5% ZnSO4 at primordial initiation and boot-leaf increased pollen production, fertility, seed set and yield.

13. **Irrigation:**

Seed crops should be grown under assured source of irrigation. In sorghum flower primordial initiation, boot leaf, flowering and grain development are the most critical stages. Moisture stress at any of the stage will result in significant reduction in seed yield. Stop irrigation 10-15 days before harvest.

14. **Inter-culture:**

Hand weeding after 20 days of sowing is preferable. Inter-cultivation will help to control weeds and conserve moisture. Pre- emergence spraying of Atrazine (atrataf) at 0.5 kg active ingredient per hectare or propazine 50 percent wettable powder @ 1kg in 1000 lt of water can controls the weeds.

15. **Rouging:**

Rouging of the seed field is very important for quality sorghum seed production The rouging is done at three stages of crop growth i) Before flowering ii) At flowering and III) Pre-harvest stage. The specific certification standards are given in Table 3.

i) **Before flowering:**

- Start the rouging operation before off types, volunteers or shedders in the female rows start shedding pollen.
- All rouges and volunteer plants must be cut from ground level or pulled out to prevent re growth and subsequent contamination of seed crop.
- Out crosses can be identified because of their greater height and should be removed as soon as these are noticeable.

ii) At flowering:

Rouging should be done every day to remove pollen shedders in the seed The sterile types have only the stigma, or a few abortive anthers exerted. These should not mistaken for normal fertile plants. Normal fertile plants will have rich yellow anthers, which are full. of pollen out to the tips of both lobes. On shedding, these lobes rupture on distal and discharge pollen. All plants out of place, ie., plants in between the rows, male plants in female rows and vice-versa have also to be removed. Special attention should be given at the ends where the border rows and seed rows meet, as male seed may fall in female rows (or female in male rows). In addition, to remove off types and volunteers within the field eliminate other sorghum types and other related plants such as Johnson grass, Sudan grass and forage plants from within the Isolation distance. These sources of undesirable pollen must also be eliminated before pollen is produced.

iii) Pre-harvest rouging:

The field should also be rouged thoroughly before harvest and after the seed maturity to the stage when the true plant and seed characters are 'apparent'.

Specific certification standards for different classes of sorghum seed production

Factor	**Maximum permitted (%)**	
	Foundation Seed	**Certified seed**
Off-types (ear heads)at any one inspection at and after flowering.	0.05	0.10
*Ear heads infected by kernel smut and grain smut and head smut at final inspection	0.05	0.10

* Seed fields can however be certified if diseased ear heads are removed and burnt and the fields show on re-inspection, infection not more than maximum permissible level. Only one such re- inspection is permitted.

16. **Plant Protection:** The successful disease and insect pest management is one of the most important factors in raising a healthy seed crop.

i) Pest control:

Shoot fly: Seed treatment with imidacloprid 70 WS @ 10g/Kg seed before sowing controls shoot fly infestation. If the infestation is visible at plant stage, spray imidacloprid 17.8 SL @ 2ml/l of water or Dimethoate 30 EC@500 ml/ha at an interval of 15 days twice 30 DAS. It can also be controlled by applying Furadan 3G or Phorate 10G in the seed furrows @ 20kg/ha at the time of sowing.

Stem borer: Stem borer can be effectively controlled by application of Thiamethoxam 25 WG @ orFuradan 3G @8-12kg/ha at 20 and 35 days after emergence.

Midge: High levels of midge infestation can be controlled by spraying any of these insecticides: Endosulfan 35 EC 1 litre, or lindane 20 EC 1.2 litres, or malathion 50 EC 1 litre per hectare in 500-600 litres of water followed by second application 4-6 days later.

Head bug: The population density (50nymphs/ panicle) at pre bloom and 50% flowering stage requires dusting of Malathion 10D @ 20kg/ha.

ii) Disease control:

Grain molds in *Kharif* and charcoal rot in *Rabi* are the major diseases. Seed should be treated with Thiram or Captan @ 3g per kg of seed. Grain mold can be checked with Aureofungin solution @ 30g/10 It of water + Captan (30g/10 It of water) or Dithane M 45 + Captan @ 3% concentration). Charcoal rot can be reduced by proper soil management practices to conserve moisture, besides growing tolerant cultivars. Leaf spot such as rust can become serious in favorable climate during the *Kharif* and *Rabi* seasons, can be controlled by spraying Dithane M 45@ 3% concentration.

Sugary disease in hybrid sorghum seed production plots where female parent become infested, can be managed to certain extent by spraying Dithane M 45 or Dithane Z-78 @ 2g/It of water or Bavistin @ 5g/10 It of water at flowering stage. For chemical control of honey dew stage of ergot disease, spray Benlate (0.1%) at the stage of 50% flowering. For Downy mildew control, spraying of Dithane M 45 (0.4%) four times at an interval of one week starting from seventh day after planting has proved to be the best.

Grain Smut disease can be controlled by seed treatment with Vitavax power or Agrosan G.N. (0.2 per cent) or Thiram slurry (0.1 per cent).

16. **Harvesting and threshing:**

The seed crop must be fully ripe before harvesting. Harvesting should be done at physiological maturity stage when the black layer formation appears at the point of attachment of seed with the caryopsis. In general, the seeds harvested 35-45 days after flowering have

superior seed quality. The harvested heads should be sorted out to remove diseased or otherwise undesirable heads, and dried on the threshing floor for a week or so in thin layer before threshing. The border rows of seed plots should be avoided to prevent the chances of natural contamination.

The male rows should be harvested first and kept separately to avoid mechanical mixtures. After this, the female rows should be harvested. Threshing can be done by clean machine threshers at proper seed moisture content (13-14%). Seed should be dried to 10-12% moisture content before storage. Care should be taken to avoid mechanical mixtures while threshing.

17. **Seed yield:**

The seed yield depends on the potential of hybrids but under good agronomic practices, following quantum of yield can be obtained.

Hybrid	**Female Parent**	**Male Parent**
CSH-1	12-15 q/ha	5-7 q/ha
CSH-5	15-20 q/ha	10-12 q/ha

18. **Seed processing**

Seed processing is an integral part of sorghum seed production technology, which involves steps such as drying, cleaning, grading, treating, and bagging. Sorghum seed properly threshed can often be cleaned to the desired purity on the air screen cleaner alone. However, the gravity separator is commonly used, to remove light materials and improve physical quality of seed.

Specific seed standards for different classes of sorghum seed.

Factor	**Standard for each class**	
	Foundation Seed	**Certified Seed**
Pure seed (minimum)	98.0 %	98.0%
Inert Matter (Maximum)	2.0 %	2.0%
Other crop seed (Maximum)	5 /kg	10/kg
Weed seeds (maximum)	5/kg	10/kg
Other distinguishable varieties (maximum) Ergot, Sclerotia, seed entirely or partially modified as sceleortia, broken sclerotia or ergotted seed	10/ kg	20 /kg
(Sphecelliasoghi-Mc ae, &Clavicepsspp) (Maximum)	0.020.% (by no.)	0.040% (by no.)
Germination (minimum)	75 %	75 %
Moisture (Maximum)	12.0%	12.0%
For vapour proof containers (Maximum)	8.0%	8.0%

Seed Drying: High moisture in seeds reduces seed viability and causes mechanical damage during processing. In addition to this, high moisture in seeds provides favorable atmosphere for pest and disease attack in storage. If higher quantities are produced artificial drying can be considered. Maximum recommended air temperature for seed drying is 40° C, however in order

to reduce the risk of damage, drying temperatures should be lower than the maximum. If seed moisture is more than 18%, maximum recommended drying temperature is 32° C and if lower than 18%, 40° C is the temperature for drying.

Seed Cleaning and grading: Sorghum seed cleaning and upgrading is mainly based on physical differences in seed volume, test weight and density. The sieve aperture sizes of top and bottom screens of air screen cleaner differ with genotypes. Generally, the top screen may be around 12/64" or 4.75 mm with round holes and the bottom screen at 9/64"or 3.5 mm with round holes. The specific gravity separator helps in upgrading the quality of seeds by rejecting the seed that is inferior in specific gravity.

Seed Treatment and Packing: Sorghum seed after seed treatment can be protected from systemic pathogens like loose and head smut and non-systemic like *Helminthosporium* blight, *Fusarium* and bacterial blights. Seed treatment also provides protection against storage pests (rice weevil) and shoot fly. The fungicides like Thiram or captan @ 3g/kg and insecticides like Malathion dust (5%) (premium grade) @ 0.6g per kg seed are recommended for sorghum seed treatment. Processed seed can be packed in cloth bags or HDPE bag @3-4kg/bag, sewed with proper label of particular seed class and can be sealed with lead seal.

19. **Seed storage management**

Seeds of most of the sorghum species can be stored under ambient conditions for seed certification for at least 12-15 months, if seed moisture does not exceed 9-10. To avoid the storage losses and to keep seeds free from insect pests during storage, one must adopt the following preventive and remedial measures.

Preventive measures before storing the seed:

8. The seed moisture content should be preferably below 9%. The moisture content fluctuates during storage in cloth and hessian bags, but if seed store is reasonably moisture vapor proof, the fluctuation in seed moisture content would be low.
9. New bags should be used to avoid both insect infestation and mechanical mixture.
10. The storage structure should be thoroughly cleaned and white washed.
11. The storage structure should be disinfected with residual sprays of insecticides such as Malathion 50EC (one part in 100 parts of water) @ 5litres per 100 sq. m.
12. Proper stacking should be followed for arranging seed bags in storage structures.
13. It should be ascertained that the seed is properly treated with disinfectants before keeping the seeds in storage.
14. Seeds of different types such as cereals, pulses, and vegetables should be stored separately to avoid the spread of insect infestation.

Maintenance of seed storage:

11. The processing units and storage structures should be clean.

12. All sweeps should be kept far away from the premises of seed godown so that insects will not breed and re-infest seeds.
13. The inspection of seed lots in storage structures should be carried out every fortnightly. Seeds must be thoroughly fumigated at regular intervals.
14. Fumigation can be done with 1) Aluminium phosphide, 2-3 tablets (3g each) per ton of material with an exposure period of 5 - 7 days or 1 tablet per cu. m. space. 2) Ethylene dibromide (EDB) @ 32g per cu.m. space with an exposure period of 5-7 days.
15. Ethylene dichloride carbon tetrachloride (3:1) (EDCT) mixture @320-480 g per cu. m. space with an exposure period of 24-48 hrs.
16. Of all these fumigants, Aluminium phosphide is safest. Its repeated application does not impair seed quality. Maximum of 3 fumigations may be given at an interval of 40-50 days.
17. During fumigation and surface sprays handle the chemicals carefully as they are highly toxic to human beings.
18. Seed structures should be aerated and thoroughly cleaned with brush or hard broomsticks to remove all dead and moribund insects.
19. To prevent re-infestation, surface treatment with Malathion 50EC or Finitrothion 50EC @ 4-5 litres per sq.m. area or Malathion dust 5% @ 3-4 kg per 100 sq.m. should be given.
20. Surface treatment of seed godown and processing units should be carried out at an interval of 2-4 weeks depending upon the severity of pest check on re-infestation and prevents insect resistance to insecticides.

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Holistic Approaches in Varietal Maintenance during Basic Seed Production in Cereal Crops

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Seed production system in India is a robust route to mitigate the seed requirement of the country. The seed class involves Nucleus, Breeder (Basic seed), Foundation and Certified seed with different seed quality standard at different levels to safeguard the production of large quantity of quality seed for sustainable agriculture. The maintenance breeding is a mandatory step for the institute, involved in development of variety. The developer maintains the seed purity of released varieties by curbing the chance of both out crossing and genetic drift. The quality seed is the first and prime requisite for grain production, which alone contribute about 30% of yield improvement. Thus, it is important to deliver a healthy, improved variety seed to meet the seed requirement of the country and to dissect the seed traits for development of cultivar to cope with changing climate. Availability of good quality seed at the right time with agreeable price, very much plays a major role in the highest grain production of a nation. The Indian seed delivery system which is backed by both formal and informal seed system has a good structural network for sufficient availability of seed but, the seed replacement rate and the varietal replacement rate are under desirable limit; majority of seed requirement of our farmer is fulfilled by informal seed system is one of the major factor responsible for this. Gaps in seed systems which include nonavailability of many high yielding varieties in the seed chain, non-availability of sufficient quantity of quality seed, deterioration in seed quality, long time span for seed quality testing and non-assurance of genetic purity of Marker Assisted Selection developed varieties. The Strength of breeder seed availability is mainly depends on strong varietal maintenance programme, which finally ensure the availability of N/S vis-à-vis B/S. A precise about maintenance breeding has been given as follows.

A branch of plant breeding which deals with principles and methods of breeder seed production and its maintenance is called Maintenance breeding. It is a breeding procedure followed to maintain the genetic purity of the variety or parents of hybrid. It deals with ways and means of maintaining genetic and physical purity of released and notified variety. It is also known as varietal maintenance technology.

It undertakes breeder seed production of parental line of released variety. Genetic purity, physical purity seed health and germination are main point taken into account. Breeder seed is used as base material for starting Maintenance breeding programme. It prevents varietal deterioration (Mutation, cross pollination).

Maintenance of Nucleus and Breeder seed:

It is the handful of original seed obtained from selected individual plants of a particular variety for maintenance and purification by the originating breeder. It is further multiplied and maintained under the supervision of qualified pant breeder to provide breeder seed. It has the highest genetic purity and physical purity. Maintenance of nucleus can be divided into two groups: -

1. Maintenance of newly released varieties
2. Maintenance of established varieties

Maintenance of Nucleus Seed of Pre-released or Newly Released Varieties:

The procedure outlined by Harrington (1952) for the maintenance of nucleus seed of prereleased or newly released varieties is described below:

Sampling of the variety to obtain nucleus seed:

New numbers, lines which are highly promising, on the basis of performance in breeding nurseries and yield trials, should be sampled for seed purification. These samples provide a beginning for purifying new varieties and for possible increase and distribution to farmers. Not more than fifteen new varieties in any one crop at a station should be sampled in one year. Following steps are to be followed:

a. **Table examination of samples:** The two hundred plants of each sample should be threshed separately and the seed should be examined in piles on the table. Discard any pile appearing obviously off type, diseased or otherwise unacceptable. The seeds of each two hundred plant samples or less are now ready to be sown in a variety purification nursery called as nucleus.
b. **Locating and seeding of nucleus:** Each nucleus seed should be grown on clean fertile land at an experiment station in the region or in area in which this new variety could be grown, in the event of its release. The land must not have had a crop of the same kind in the previous year.
c. **Inspection of nucleus two-row plots and removal of off types:** Throughout the season of growth, from the seedling stage until maturity, the nucleus plot should be examined critically. Differences in the habit of early plant growth, leaf colour, rate of growth, time of heading, height head characteristics and diseases reactions should be looked for. If a plot differs distinctly from the average in the pre-heading stages of growth, it should be removed before heading.
d. **Harvesting and threshing of nucleus:**Each remaining plot, of which there should be at least 180 out of the original 200. should be harvested individually with a sickle and tied in a bundle. The total bundles of each nucleus should be labelled and stored until the current years yield tests for trials are obtained. The nucleus bundles of any new variety should be discarded, if it is found unworthy of being continued.

Later the seed should be cleaned in a fanning mill or by hand methods, the grain from each nucleus plot being placed in a pile on the seed table. The 180 or more piles of seed of one nucleus must be examined for approximate uniformity of seed appearance, and any pile, which appears to be off type discarded. All the remaining piles of the of seed should be masked together in one lot. This should treated with fungicide and insecticide, bagged, labelled and stored as **"Breeder's Stock Seed"** for use in the next year. Breeder's stock seed is the original purified seed stock of a new variety in the hands of the plant breeders.

Maintenance of Breeder's Seed of Pre-released or Newly Released Varieties:

The following steps are normally involved in the maintenance of breeder's seed.

a. Breeder's stock seed from the nucleus should be sown on the clean, fertile land, which did not grow a crop of the same kind in the previous year. The space required for the seeding the breeder's stock is about 1.2 ha in the case of wheat and as much as 3 ha in the case of transplanted rice.

b. The field should properly isolated.
c. The best farm procedures should be used in the sowing, raising and harvesting of breeder's stock.
d. It should be produced at the experiment station in the area in which the new variety has been bred.
e. The seeding should be done in such a way as to make the best use of the limited amount of seed available and to facilitate roguing. The row spacing should be sufficient to permit examination of plants in rows for possible mixture or off types.
f. **Roguing:** All plants not typical of the variety should be pulled and removed. There should be very few plants to rogue out if the previous years nucleus breeder's stock seed was well protected from natural crossing and careful roguing was done and there were no impurities during cleaning etc. The rouging should be done before flowering, as was done for the nucleus/breeder's stock seed.
g. Harvesting the breeder's stock: In the breeder's stock is harvested and threshed, the equipment used must be scrupulously clean and free from seeds of any other varieties. This cleanliness should be extended to cards and bags as well as threshing machine it self. The seed should now be about 99.9 per cent pure as to variety. This breeder's seed is ready now for increase of foundation seed. A portion of this breeder's seed should be retained by the breeders to sown a continuation breeders seed of the variety.

Maintenance of breeder's seed of established varieties:
The breeder's seed of established varieties could be maintained satisfactorily by any one of the following methods)

A. By raising the crop in isolation.
The breeder's seed of local varieties could be maintained by growing them in isolated plots and by very rigorous roguing during various stages of crop growth, where the various plant characters are observable. The method of handling the breeder seed crop is the same as described earlier for breeder's seed of newly released varieties.

B.By bulk selection.
The genetic purity of established varieties could be satisfactorily improved by bulk selection. In this method 2,000 to 2,500 plants typical of the variety are selected, harvested, and threshed separately. The seeds from each plant are examined and any pile which shows any obvious off-types, or otherwise appears dissimilar, are discarded.
The remaining piles of seed are bulked to constitute the breeder's seed. The other practices of handling remain the same.

Maintenance of Nucleus and Breeder seed in cross pollinated crops:
The maintenance of varieties of cross pollinated crops is much more complicated than self-pollinated crops. It involves Maintenance of nucleus seed of inbred lines Maintenance of breeder seed of inbred lines. Maintenance of nucleus seed of inbred lines After a hybrid has been thoroughly tested and if it is suitable the seed of parental lines must be increased in the following manner:

1.Hand pollination:
Method of maintaining nucleus seed of inbred lines involves selfpollination, sib pollination or combination of both. The individual selfed or sibbed ears should be examined critically. Those which are off types or inferior in any regard of differing in any character such as texture, seed

size, color, shape etc. should be discarded. The individual selfed or sibbed ears may then be threshed separately and sown in ear to row method in double row plots.

2.Seeding of hand pollinated seed:

The hand pollinated seed should be sown in fertile land which is free from volunteer plants. The same crop should not be grown in previous one season. The seed should be sown in the area where the hybrid is to be released.

3.Isolation:

Proper isolation distance should be provided to avoid natural cross pollination and spread of diseases. Distance or time isolation can be practiced to avoid contamination.

4.Inspection of double row plots and roughing:

The double row plots must be carefully checked for off types prior to pollen to shedding. It is very easy to recognize the off types, because they are more vigorous than the inbred lines.

5. Harvesting drying and shelling:

The nucleus seed crop can be harvested soon after it attains physiological maturity if artificial drying facilities exist. Piles should be critically examined for ear characters and all off colored, off textured and diseased or undesirable ears sorted out. If the overall percentage of off types is more than 0.1%, hand pollination should be done again. After discarding the undesirable ones, remaining ears may be bulked and dried in clean dry bin at a temperature not exceeding 43^0C. After drying shelling should be done in a cleaned machine to avoid mechanical mixtures at this stage. After shelling the seed may be cleaned treated with fungicide, insecticide, properly labelled and stored under ideal storage condition.

Maintenance of breeder seed of inbred lines:

For increasing Breeder seed the breeder stock seed obtained from nucleus seed is planted in an isolated field. During increase of Breeder seed adequate attention must be paid to: -

1. Land requirement 2. Isolation 3. Roguing 4. Field inspection 5. Harvesting and drying
6. Sorting of the ears.

Advantages of Maintenance Breeding:

It prevents cultivars from genetic deterioration and so it prolongs life of variety. It helps in purification of improved cultivars and parental line of hybrids. It is useful in studying the efficiency of various maintenance procedures. It helps in quality seed production which in turn leads to higher crop yield.

Limitations of Maintenance:

Breeding Some maintenance procedures require lot of experimentalmaterial for evolution. Large numbers of single plant have to be evaluated in term of agronomic performance hence only limited number of cultivars can be handled at a time. Progeny row method requires more time (2-3 seasons) for evolution of purity of a variety. Most of testing procedures are based on phenotypic performance only. Maintenance procedures are used for varietal purification. Hence, chance of evolve new variety through Maintenance Breeding are rare.

Carry-over Seed:

The breeder must carry-over at least enough seed to safeguard against, the loss of variety if there is a complete failure during the foundation seed multiplication phase. In addition, the breeder should further safeguard variety by arranging to have a portion of the seed originally released stored under the ideal conditions.

Inspection of Breeder seed:

Breeder seed is produced from nucleus seed under the supervision of a qualified plant breeder in a research institute of Agricultural University. This provide for initial and recurring increase of foundation seed. Breeder seed is monitored by a joint inspection team of scientists and officials of certification agency and National Seed Corporation. The genetic purity of breeder seed crop should be maintained at 100 per cent. The golden yellow is the color of breeder seed tag of 12 X 6 cm in size. One tag is generally issued for each and every bag of seed. The level contents in information like level no. crop, variety, class of seed, lot no., date of test, pure seed percent, inert matter percent, germination percent and producing intuition.

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Quality Seed Production Technology in Tropical Grasses

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India possesses nearly 85 mha of grasslands/rangelands which are mostly in degraded state. Revitalizing these denuded grasslands is the most plausible means to improve the availability of green fodder. The wider use of perennial tropical grasses selected for their special utility in the diverse land and climatic situations found in the arid and semi-arid tropics require seed or planting material of good quality and its continued availability to farmers through trade or farmer's own initiatives in multiplying material for his own use. For wide spread regeneration of marginal and uncultivable waste lands, forest lands and grass/range lands, seed are the best propagating material. One of the reasons reported to stumble the green fodder production is non-availability of quality seed in sufficient quantities. As per estimation only 25-30% of required quantity of quality seed is available in cultivated fodders and 20% and 15% in tropical grasses and legumes in India (Anonymous 2011). Seed production in tropical species is marred with myriad problems. Hence there is a great need to understand these problems and innovate different mechanisms to mitigate them through research. The farmers are unable to reap the benefits of latest developments in forage research due to difficulty in obtaining the certified/labelled good quality seeds. Seed production in forage crops is tedious, labour consuming and unsure marketability, which discourages farmers to produce forage seed. The availability of quality seeds is estimated to be around 15-25 per cent only for cultivated fodders. The productivity and availability of seed are vital because the fodder crops have been bred for enhanced vegetative potential and as such they are shy seeders with very low seed productivity.

Forage seed production depends on a number of environmental and physiological factors such as photoperiod, thermo-period, humidity, soil condition. Each forage crop is suited to only specific area for forage and/or seed production such as Berseem in the northern plains and Lucerne in the north-west India. Similarly, pasture grass like *Lasiurus* is best adapted and productive under low rainfall situations of western Rajasthan and Congo signal grass and guinea grass in the highly humid regions of Kerala.Forage seed production is largely concentrated in the unorganized sector, where the quality of seed is always compromised. Organized fodder seed production chain is very limited. It is mainly because of a large number of forage crops and their suitability to specific niches. Indenting for breeder seed for forage crops and its lifting is very poor. The seed production is not backed by any incentive to the producer or minimum support price for these crops. The production is largely confined to unorganized sector.

Constraints in seed production of tropical grasses species

Seed production in tropical grasses species is marred with myriad problems which are listed below-

Indeterminate growth: The tropical grasses species under natural conditions, are acclimatized for indeterminate growth leading to non-synchrony in reproductive and vegetative growth.

This is one of the major impediments for commercial or large-scale cultivation and mechanization.

- ***Uneven maturity***: The maturity varies from plant to plant and from branch to branch with in a plant. Even with in inflorescence / panicle starting from anthesis to seed ripening is observed. This highly non uniform maturity makes it impossible to realize the full potential of seed production and difficulty in harvesting.
- ***Seed shattering***: In tropical grasses species the easy shredding of the seed immediately after maturation leads to loss of seed during harvesting.
- ***Blank seed***: The reasons for this poor ovule to seed ratio are unknown. This is one of the main reasons for low germination percentage in grasses.
- ***Seed dormancy***: Most of the tropical grasses species have varying degrees of either physical or physiological dormancy. In nature it is highly useful trait but for commercial cultivation it is a negative trait.
- ***Influence of climatic factors***: Seed production in tropical grasses species is highly influenced by the photoperiod, thermos-period, humidity etc. The quality and quantity will be affected under varying climatic conditions.
- ***Low density of ear-bearing tillers***: Profuse tillering is observed in many tropical grasses species. But all the tillers won't flower and only 30-50 % tillers possess inflorescence at the time of peak flowering.
- ***Lodging***: Due to prolonged and vigorous vegetative growth lodging of seed crop is a common problem.
- ***Poor harvest index***: The harvest index is low mainly because of higher biomass production. Only 2-3% harvest index is observed in many tropical grasses.
- ***Lack of seed production technology***: The cultivated as well as tropical grasses species lacks specific seed production technology. In case of cultivated fodder since the varietal development is focused on fodder production, seed production technology is not well studied. In tropical grasses species lack of large scale production and because of above said problems no specific seed production technology is available.

Seed production principles

Suitability of forage:Forage seed production depends on a number of environmental and physiological factors such as photoperiod, thermo-period, humidity, soil condition. So based on the site of production suitable species should be identified. Grasses can be produced in wide range of climates and soils than legumes.
Crop establishment:It is the most difficult phase in tropical species. It requires good conditions for germination, emergence and growth. Pasture seed crops warrant more care during establishment with better land preparation.
Sowing type:Sowing in rows in case of tussock grasses and in vigorous sprawling legumes, broadcasting in creeping legumes and in stoloniferous grasses is ideal. The depth of sowing should not be more than 1cm for small sized seeds.
Crop management:During defoliation of grasses bulk of the stubble should be removed at the beginning of the season so that the final clean cut can be less severe. In case of legumes defoliation should be done early enough to allow complete recovery of canopy and to avoid excessive vegetative growth. Nitrogen fertilization is necessary in grasses after defoliation.

The seed production in specialist system requires certain package of practices to follow for enhanced seed yield.

Table 1. Seed production package of some important grasses

Crop	*Seed rate(kg/ha)*	*Row Spacing (cm)*	*N:P:K (kg/ha)*	*Isolation distance(m)*		*% offtypes*	
				FS	*CS*	*FS*	*CS*
Cenchrusciliaris	3-5	50	60:30:30	20	10	0.1	1
Cenchrussetigerus	3-5	50	60:30:30	20	10	0.1	1
Brachiariabrizantha	6-10	50	60:40:30	-	-	-	-
Pennisetumpedicellatum	5-8	50	60:40:30	20	10	0.1	1
Clitoriaternatea	10-15	40	30:40:40	-	-	-	-
Panicummaximum	3-5	50	80:50:50	20	10	0.1	1
Macropteliumatropurpureum	10-15	40	60:40:30	-	-	-	-
Stylosantheshamata	8-10	40	30:40:40	50	25	0.1	1
Chrysopogonfulvus	5-8	50	60:40:30	20	10	0.1	1
Dicanthiumannulatum	5-8	50	60:30:30	20	10	0.2	1
Setariasphacelata	5-8	50	60:40:30	400	200	0.1	1

Seed harvesting: The choice of harvesting is complicated in tropical grasses species due to their indeterminate growth and variation in the maturity levels within the inflorescence. Based on visual indicators and experience harvesting has to be done mostly either through hand picking or though cutting machines.

Table 2: Seed yield of important tropical grasses species

Sl. No.	Tropical grasses species name	Average Seed yield (Kg/ha)
1	*Andropogongayanus*	300
2	*Brachiariadecumbens*	520
3	*Brachiariadictyoneura*	170
4	*Brachiariaruziziensis*	590
5	*Brachiariabrizantha*	60
6	*Brachiariamutica*	45
7	*Cenchrusciliaris*	100
8	*Cenchrussetigerus*	70
9	*Chlorisgayana*	120
10	*Clitoriaternatea*	90
11	*Desmanthusvirgatus*	850
12	*Desmodiumovalifolium*	240
13	*Dicanthiumannulatum*	85
14	*Panicum maximum*	250

15	*Paspalumspp*	50
16	*Pennisetum purpureum*	230
17	*Pennisetumpedicellatum*	400
18	*Macroptelumatropurpureum*	200
19	*Setariasphacelata*	90
20	*Stylosanthesguianensis*	300
21	*Stylosantheshamata*	800

Source: Modified from Hacker and Loch, 1997

Seed testing, labelling and certification

The science of seed testing, has been developed to know the planting value of seed and to minimizing the risk of planting the low-quality seeds. After the quality tests, results are compared with the available crop-based seed standards known as Indian Minimum Seed Certification Standards (IMSCS). If the assessed quality is equal to or above the standard value it may be considered as quality seed and is allowed for sowing purpose. The recommended field standards and seed quality standards for different categories of seeds of some major forage crops are presented in Table 3.

Table 3: Seed quality standards of selected forage crops (IMSCS)

S.N.	Crops	Seed standards									
		Pure seed		Other crop seed (no/kg)		Total weed seed (no/kg)		OWS (no/kg)		Germination %	
		F	C	F	C	F	C	F	C	F	C
1.	Dhaman grass (*Cenchrusciliaris*)	80	80	20	40	20	40	-	-	30	30
2.	Dharaf (*Chrysopogonfulvus*)	80	80	20	40	20	40	-	-	15	15
3.	Dinanath (*Pennisetumpedicellatum*)	95	95	20	40	20	40	-	-	50	50
4.	Guinea (*Panicum maximum*)	80	80	20	40	20	40	-	-	20	20
5.	Marvel (*Dichanthiumannulatum*)	90	90	10	20	10	20	-	-	40	40
6.	Napier (*Pennisetum purpureum*)	99.5	98.8	-	-	-	-	-	-	-	-
7.	Setaria	95	95	20	40	20	40	-	-	50	50
8.	Stylo (*Stylosanthes spp*.)	90	90	10	20	10	20	-	-	40	40
9.	Teosinte	98	98	5	10	0	0	-	-	80	80

Strategies for seed production enhancement (Source: D. Vijay, 2018)

- Creating awareness to use quality seed of improved varieties.
- Increasing the seed replacement rate from the present 2-3 % to at least 10%.
- Seed chain should be followed to produce sufficient quantity of certified seed for farmers
- Improvement of seed chain network

- Seed production through farmer participatory approach
- Improvement of proper marketing facilities
- Research to increase the ovule to seed ratio in forages
- Channelizing the existing demand towards entrepreneurship development
- Improved crop management
- Village Seed Banks are to be developed.
- Utilization of forest waste lands for the seed production purpose.
- Utilization of new research innovations *viz*., *in vitro* maturation, exogenous chemicalapplication, high density nursery for rooted slip production, harvesting using morphologicalindicators, hormonal spray for enhancing seed setting, seed pelleting in tropical grassesetc.

It's essential to follow these best practices and adapt them to local conditions to ensure successful forage crop seed production. Collaborating with agricultural extension services and seed certification agencies can also be beneficial for guidance and support in seed production.

Conclusion:

Quality forage seeds are essential for sustainable livestock production and continuous improvement in quality and accelerated availability will not only help in reducing livestock rearing cost but also makes the whole business more profitable. Continuous research efforts led to new innovations in forage seed technology which will help in enhancing the seed yield. However strong seed chain and research backup along with public-private partnership is required to supply the required quality forage seeds and all these efforts needs to supplemented by favourable government policies in which forage seed producers should be given incentives. Constraints in seed production need to be answered through collaboration among the countries.

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Genetic Purity Assessment- GrowOutTest

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Genetic purity of seed is the most important parameter of seed quality as it determines the authenticity of seed and yield potential of variety/hybrid. In general, the negative impact on seed yield, consistency and quality is due to the presence of a large proportion of off-types. In the scientific production of seeds, special attention is paid to every step to maintain the authenticity of the variety."Genetic Purity of a seed lot is determined on the basis of distinct morphological characteristics of the variety expressed at seed, seedling and plant level by comparing its submitted sample with authentic sample under identical environmental condition."

Source of contamination

Generally, all these kind of impurities occurs as result of delusion or inaccuracy during seed multiplication, harvesting, drying, handling or packaging of seed. For example-

- Seed fertilized by foreign pollen, especially in open pollinated crops
- Mutation
- Unclean harvesting equipment
- Carelessness at the processing
- Mistakes in bagging and tagging
- Mechanical mixture of seeds of other varieties during sowing, harvesting or storage
  In some cases, two additional sources of contamination have appeared as a result of the particular method of seed production used in hybrids.
- Incidental collection of male rather female inbred.
- Sibs (seed produced by self or sib-pollination among female lines.

  All of these sources of contamination are preventable through prudent management. Sibs are the main concern in hybrids and they are difficult to avoid therefore it may cause a large proportion of contamination. Sibs originates from the failure of crossing management such as emasculation, male sterile or self-incompatibility.Examination to determine the genesis of the variety can be conveniently divided into the following three groups:
  - Laboratory examinations
  - Tests in glasshouses or growth chambers.
  - Field trial and field inspection.

  In that article, we discussed Grow-Out-Test, which is part of the field testing and inspection.

Grow-Out-Test

The grow out test is a widely used method for testing the genetic purity of seed samples. This test involves planting seeds in a controlled environment and observing the resulting plants for any off-types or impurities. The grow out test is a non-destructive test, meaning that the seeds can be used for planting after the test is complete. This test is relatively easy to perform and can be conducted in a short amount of time. However, the test may not be reliable in all situations, as environmental factors can affect the growth of the plants.The main purpose of the magnification test is to establish the authenticity (true-to-type) of the variety. The determination is based on the observation of plant characteristics of a variety that are least environmentally

influenced and are highly heritable. In general, differences between varieties are most pronounced under favorable growing conditions. In plot trials, the condition must be set up in such a way that the genetic differences to be examined are as clear as possible.

The amount of seed to be used on a plot is calculated on the basis of qualities of the seed. Before planting, seeds easily distinguished in the laboratory to be of another cultivar are separated, and their portion of the seed quantity is calculated. If possible, questionable seeds can also be separated, which can be seeded separately and examined in greater detail.

The different samples of the same cultivar are seeded in adjacent plots, with typical samples at appropriate intervals. This is especially important for cross-fertilized crops, where the examination, for the most part, is based on a comparison between the samples to be tasted and the standard sample.

The field plot must be carefully observed during the growing session, the appearance of each of the same cultivars is compared to the others, and particularly to the standard sample. The consistency of the stand is also considered. It is particularly worth noting when shooting and/or flowering starts, and how long each period lasts.

Sampling:

Submitted sample: The submitted sample for grow out test is drown simultaneously with submitted sample for other test. The sample size will vary depending on the plant species.

Table 1: Recommended sample size for growth test submission:

Crop	Size of sample (g)
Genera with seed size similar to pearl millets	100
Genera with seed size similar to *Beta vulgaris*	250
Sorghum, rice, wheat and other genera of similar seed size	500
Maize, cotton, groundnut, soybean and other of similar seed size	1000

Note:*The amount of the submitted sample is doubled if it's necessary to determine genetic purity at both the seed and plant levels.*

Working Sample: In order to observe the acceptable off-type plants specified as the minimum seed certification standard in the optimal population, i.e., at least 400 plants, the size of the working sample mostly depends on the test weight and germination percentage of the crop.

Table-2: Number of plants require for grow out test

Maximum permissible Off-types (%)	Number of plants required per sample for observation
0.10	4,000
0.20	2,000
0.30	1,350
0.50	800
1.00 and above	400

Planting Instructions:

1. To make sure that an approximately similar number of plants of the same species or cultivar are established in all plots, the weight of the seed sown should be adjusted in the event that the germination of the sample being sown exhibits significant variation.
2. It must be carefully checked to make sure that it doesn't already contain seed from a previous sample before adding another sample to a seed drill.
3. For each sample, there should be a minimum of two replicate plots. a fallback strategy or an alternative region inside the same field.
4. Any realistic size for the plots is acceptable as long as there are sufficient plants present to make the calculation with the required level of precision.
5. If the seed is planted *in situ*, it should ideally be mechanically planted in rows.
6. Plants and rows should be separated from one another sufficiently to allow for the development of the features being studied.
    a. Cereals, legumes and oil plants: Every plot should be seeded with a convenient number of rows. The recommended row spacing for flax and cereals is 200 to 250 mm, whereas the ideal row spacing for the other species listed below is 400 to 500 mm. The following number of plants per meter of row need to be thought of as ideal:

Table-3: Number of plants per meter of row:

Crop	Plants/Meter	Crop	Plants/Meter	Crop	Plants/Meter
Linum	100	*ViciaFaba*	10	*Pisum*	30
Cereals	60	*Other Vicia*	30	*Lupinus*	30
Brassica	30	*Papaver*	50	*Glycine*	30

The specification for different crops given in the Indian minimum seed certification standards are given in the Table-3. The certification agency may, however, change these specification, if deemed necessary.

Table-4: Spacing specifications

S. No.	Crop	Row length (meters)	Plant to plant distance (cm)	Space between rows (cm)	Space between plots (cm)	No. of replications
1.	Wheat, barley, oats	6	2	25	50	2
2.	Pea, cowpea	6	10	45	90	2
3.	Chickpea, green gram, black gram	6	10	30	60	2
4.	Maize	10	25	60	90	2
5.	Hybrid cotton	5	10	45	45	2
6.	Paddy:					
	very early to medium	6	15	20	45	2
	late and very late	6	25	30	60	2
7.	Pearl millet	6	10	60	90	2
8.	Sorghum	6	10	45	60	2

a. *Herbage plants:*It is advised to use rows that are between 300 and 450mm apart and measure approximately 15m in length overall.
   Where it is possible to discern between two or more cultivars through the examination of single plants, a special plant approach should be applied. Single plants are often grown by sowing each seed separately in a greenhouse or laboratory. The plants are moved onto field plots once they have reached an appropriate size. Under ideal circumstances, it may be feasible to sow the seed in place, in which case seedlings are separated into single plants. Plants should be spaced apart by at least 600mm in both directions.
b. *Root and Other Crops:* Root and other crops grown spaced in rows.Each plot should include at least two rows, with a total length that will provide 400 or more plants for analysis. In order to grow about the same number of plants in the test and control plots, the sowing rate should be modified because both transplanting and thinning are potential sources of error. Only when it is deemed to be absolutely required is it possible to thin out or transplant from another part of the plot.

Recording of observations:
Throughout the entire growth season, observations should be conducted, and any differences from the control sample should be noted. Plants that are easily identifiable as being of a different cultivar, species, or as aberrants should be counted and noted.

1. **Estimating the number of plants**
   When possible, the number of plants in the plot should be counted or estimated, ideally while the plants are being studied. This is required in order to give the field plots test's estimated percentage of aberrant individuals.
   Evaluation in conjunction with check counting is used for unthinned crops like grains. The plot contains at least two repeating locations where the number of individuals per meter of row is counted. The total number of plants in the plots can be computed using these counts. The best time to do this activity is after the plants have fully emerged but before they begin to tiller.
   It is highly impractical to count the number of plants on unthinned plots in perennial, strongly tillered species, such as herbage seeds. In these species, the quantity of aberrant plants may be expressed as a function of area, number of seeds dispersed, or another appropriate metric.

2. **Taking observations**
The minimum number of plants that needs to be examined are given in following table. The minimum number is dependent on maximum permissible off-types.

Table-5: Minimum number of plants to be observed in GOT

Maximum permissible Off-types (%)	Minimum genetic purity (%)	Number of plants required per sample for observation
0.10	99.9	4,000
0.20	99.8	2,000
0.30	99.7	1,350
0.50	99.5	800
1.00 and above	99.0 and below	400

Expression of Results:

a. Seeds and Seedlings: The findings of the determination of the seedlings are provided as a percentage of the number of typical seedlings evaluated.
b. When possible, the number of plants discovered to be of different cultivars, different species, or aberrant shall be calculated as a percentage of the total number of plants tested.

In the case of herbage plants and related species, when cultivated in rows with broad spacing, it is difficult to quantify the total number of plants inspected per plot. The outcome may be stated as the number of divergent plants produced by the weight of seed dispersed.
The mean and other statistics can be calculated when characters are measured. It is frequently difficult to describe properly all off-types in cultivars of cross-fertilizing species, such as rye, root crops, herbage plants, etc. In this situation, any estimations of percentage impurity should be accompanied by relevant comments about the veracity of test samples.
Tolerance may be applied by using the reject table given below.

Table-6 Reject number for prescribed standards and sample size:

Standard	**Reject numbers for sample size of**	
	800	**400**
99.5 (1 in 200)	8	*
99.0 (1 in 100)	16	8
95.0 (5 in 100)	48	24
90.0 (10 in 100)	88	44
85.0 (15 in 100)	128	64

**Indicates that the sample size is too small for a valid test.*

When nothing is worthy of special comments is found the results may be reported as *"The results of the field plot examination of this sample revealed nothing to indicate that varietal purity is unsatisfactory."*

Reporting of results

- The percentage of other species and cultivars of off-type plants must be indicated in the grow-out test findings.
- Results must be reported as such if the sample is discovered to be a cultivar different from the one specified by the sender.
- The report must specify that the sample contains a mixture of several cultivars if there are more than 15% plants from another cultivar.
- If no information deserving of special commentary is discovered, the report must mention that the sample's grow-out test findings showed nothing to suggest that the cultivar or species name provided by the sender is inaccurate.

Advantage:

- It is cheapest way to examine reasonable number of plants.
- It is possible to examine a large number of plots and for each plot it is possible to check large number of plants.
- The plants are examined during the whole period of growth. Some characters are more prominent at one time of the year than another, and the sample may therefore, be examined several times during the session.

Disadvantage:

- The results are not available until 4 to 12 months after the seed was receives for testing.
- The conventional grow-out test, which relies on morphological markers, is time- and space-consuming and frequently does not allow for the clear identification of genotypes. For a quick assessment of seed purity, molecular markers are crucial. Biochemical and molecular markers can be employed to support grow-out test results and mitigate their drawbacks.

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Microbial Inoculants: Applicability in Quality Seed Production of Cereal Crops

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Cereals are among the most important food commodities in terms of production and economic worth in Indian economy. The demand for cereal crops is quite higher in India to meet the challenges of hunger and poverty. One feasible and efficient remedy for the issues of low production and quality nutritious diet could be the microbial inoculants called biofertilizers and biopesticides. Microbial inoculants have a very cheap input cost and present no health risks. It is known that a wide range of inoculants that raise the soil's N, P, and K contents can boost crop productivity.

Plant beneficial microorganisms (PBMs), or plant growth promoting rhizospheric bacteria (PGPRs), are thought of as natural alternatives to synthetic agricultural inputs that can minimize the environmental threats brought on by chemical-intensive conventional farming. The usage of less agro-chemical, the restoration of soil fertility, and/or the overcoming of issues brought on by abiotic and biotic stresses can all be accomplished by these bacteria, which can assist plants in maintaining or increasing output. The use of PBMs or PGPRs to boost crop yields and resilience has attracted gradually increasing interest over the past few decades. However, agricultural practices including excessive soil tillage, extensive fertilization, and pesticide application can negatively impact soil microorganisms and their advantageous interactions with the target plants, limiting the effectiveness of PBM. Seed inoculation has been considered as a precise and cost-effective method to deliver microbial inoculants with the potential for large-scale application. Seed coating is a technique in which an active ingredient (e.g., microbial inoculant) is applied to the surface of the seed with the help of a binder and in some cases a filler that can act as a carrier. Seed coating has been proposed as a promising tool for inoculation of different crop seeds, since it is able to use minor amounts of inoculum in a precise application. The main types of seed coatings include seed dressing, film coating, and pelleting, which can be chosen differently, according to the purpose of application and the type of seed or selected microbes.

For a variety of cerealcrops, seed coating may be a strategy that eliminates the requirement for inoculum in comparison to traditional seed treatments. A more or less continuous layer of materials (solid or liquid containing dissolved or suspended particles) of bioorganic components, including chemical compounds, are applied uniformly to the seed surface to act as a physical barrier. Seed coating in cereal crops especially wheat, paddy, maize etc. and vegetable crops may protect plants from diseases and improve seed germination. In seed coating, a variety of instruments and methods are commonly used to provide acceptable application uniformity and adherence. Using the right seed coating technologies and methods can enhance plant establishment and seedling vigor under environmental challenges. In order to increase seed size, weight, and the delivery of active ingredients (such as plant growth regulators, micronutrients, and microbial inoculants), which protects the seeds from phytopathogens and encourages germination and plant growth, seed coating is the process of applying exogenous materials to the outside of the seed. It is widely known from numerous researches that seed coating with PGPB (such *Pseudomonas* spp., *Bacillus* spp.), AMF, and

*Trichoderma*was an efficient and acceptable method to transfer PBM into the rhizosphere and give them to plant roots and other tissues.Besides, a large number of microbial inoculants containing Bradyrhizobium, Azotobacter, Azospirillum, Pseudomonas, and Bacillus were developed and used extensively in pulses, oilseeds, and coarse cereals.

Seed coating is considered one of the best methods to promote sustainable agriculture where the physical and physiological properties of seeds can be improved to facilitate planting, increase growth indices and alleviate abiotic and biotic stresses. Several methods of seed coating are used to attain good application uniformity and adherence in the seed coating process. Seed coating has been tested in seeds of various plant species with different dimensions, forms, textures, and germination types. Plant beneficial microorganisms (PBM), such as rhizobia, bacteria, and fungi inoculated via seed inoculation can increase seed germination, plant performance and tolerance across biotic (e.g., pathogens and pests) and abiotic stress (e.g., salt, drought, and heavy metals) while reducing the use of agrochemical inputs (Table 1). The microbial seed coating processeshave ability to increase seed performance and protect plants from biotic and abiotic stresses and these facts are well discussed and highlighted in sustainable agricultural systems (Figure 1).

Binder, filler, transporters, and active substances are some of the ingredients used in seed coating. These elements help seeds release the right quantity of PBM under physiological conditions. Binders are polymers of natural and syntactic origin that guarantee the material's adhesion and cohesion on the seed surface and maintain the components' activity. In order to increase the survival of bacteria, rhizobia, and AMF sprayed to seeds, binders such as Arabic and xanthan gum can be used. In order to change the shape, size, and weight of the seeds, the fillers are often static powders (such as bentonite, calcium carbonate, talc, diatomaceous earth, sand, and wood dust). The active chemicals are distinct from those utilized in seed coating procedures. Protectants, such as fungicides, pesticides, insecticides, nematicides, predator deterrents, and herbicides, are the most often used active ingredient. They are intended to improve germination and emergence, growth, and yield by reducing pathogen predation and putridity.

Similarly, bio-priming is a biological seed treatment method that combines seed hydration and seed inoculation with PBM to protect seeds against soil-borne diseases and enhance germination, seedling establishment, and vegetative growth. For biocontrol objectives, it is frequently employed. Either seed coating or soaking seeds in microbial slurry can be used to inoculate PBM during bio-priming. Application of *Trichodermaharzianum* and *Pseudomonas fluorescens* by seed bio-priming significantly decreased the time needed for germination, increased germination rate, and decreased the incidence of Fusarium wilt in pot and field trials. The combinations of inoculants were more effective than single-isolate.For the test of seedling emergence and growth in *Phythiumaphanidermatum*-infested growing media, non-primed and primed slurry-coated cucumber seeds with commercial preparations of *T. harzianum* were used. Non-primed *T. harzianum*-coated seeds showed minimal incidence of damping-off brought on by *P. aphanidermatum*, whereas *T. harzianum*-coated primed seeds had increased seedling emergence and seedling shoot fresh weight. It has been demonstrated that applying *P. fluorescens* as a covering and primer to sunflower seeds increases their ability to resist *Alternaria*blight.

The ideal formulations for microbial seed coating will be those that adapt to regional growth circumstances and agricultural practices (such as the use of pesticides and fertilizers and irrigation management). As knowledge of the possible hazards associated with the inoculation of non-native microbes is developing, more research should be done on microbial

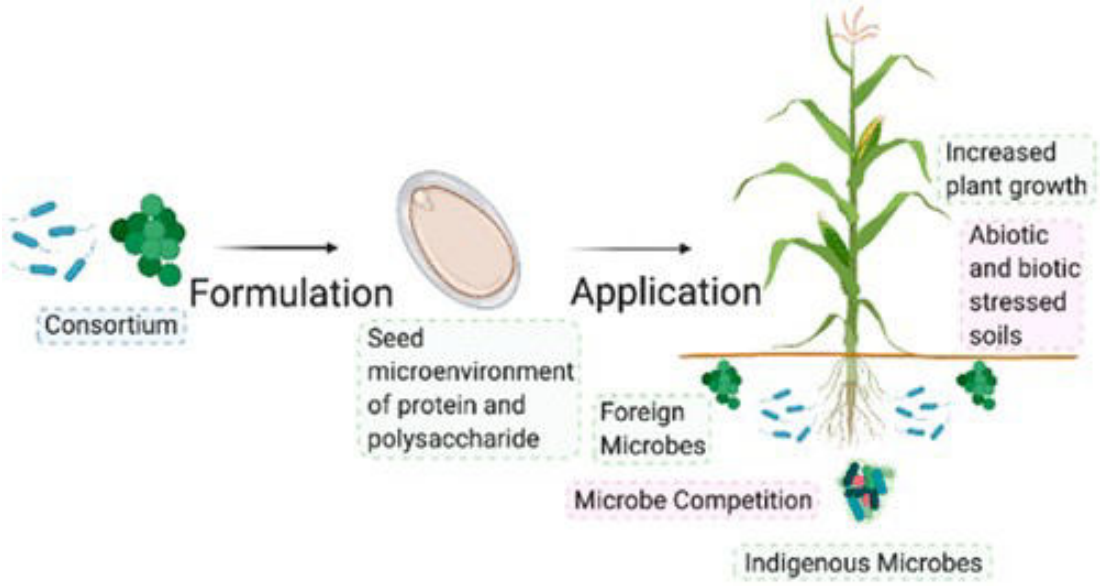
formulations that compare and include native strains under local conditions and agricultural techniques.

The use of microbial inoculants for enhanced seed production in cereals crops engages best agricultural practices that have unquestionably enormous promise. To play their part in a more sustainable agriculture, it is crucial to ensure that they are successfully applied. The use of seed coating for such task is possible. Its expanded use and incorporation in agricultural management methods, in both developed and developing nations, may be made possible by further development and investment.

Table 1. Effects of different methods of plant growth promoting bacteria inoculation on plant growth in major cereals

PBM	**Plant**	**Inoculation**	**Effect inoculation**
Burkholderiaphytofirmans	*Ryegrass*	Seed, soil, root	Soil inoculation increased plant biomass production.
Pseudomonas sp.	*Cicer arietinum*	Seed, soil	Method of soil inoculation was more effective on plant growth than seed inoculation.
Rhizobia	*Oryzasativa*	Seed	Seed inoculation was effective in increasing plant growth.
Streptomyces, Aspergillus, Bacillus	*Triticum* sp.	Seed	Seed inoculation increased the yield and reduced the Rhizoctonia root rot.
Pseudomonas aeruginosa, Bacillus amyloliquefaciens, and Trichodermaharzianum	*Oryzasativa*	Soil	Soil inoculation could manage disease of aerobic rice.
Pseudomonas fluorescens	*Arabidopsis thaliana*	Root	Root inoculation protected leaves against the oomycete *Peronosporaparasitica.*
Pseudomonas putida	*Zea mays*	Root	Root inoculation reduced leaf necrosis.
Bacillus megaterium, Trichodermalongibrachiatum and *Trichoderma simmonsii*	*Glycine* max	Seed	Seed inoculation improved germination and seedling indices against cold stress.
Providenciarettgeri, Advenellaincenata, Acinetobactercalcoaceticus, and *Serratia plymuthica*	*Avenasativa, Medicagosativa* and *Cucumissativus*	Soil	Soil inoculation increased the available nutrient (e.g., N, P, K) content.
Bacillus subtilis	*Triticumaestivum*	Soil	Soil inoculation decreased the chromium toxicity.

Figure: 1. Microbial inoculants as bioformulations for increasing plant growth and performance against stresses



The seed inoculation technique is the most applied method. Advantages and disadvantages of each inoculation method depend on the tool accessibility, inoculum and seed type (e.g., size, shape, and fragility), the presence of inhibitory components in the seed (e.g., fungicides, micronutrients, and PBM), and costs.

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Management of Major Insect Pests of Cereal Crops

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Globally, cereals constitute a significant portion of the human diet, and India stands as the second-largest producer of rice, wheat, and other cereals. In the agricultural year 2021-22, India's production figures were 130.29, 106.84, 33.62, and 4.23 million tonnes for rice, wheat, maize, and sorghum, respectively, cultivated across 46.38, 30.47, 10.04, and 3.81 million hectares (Agriculture Statistics, 2022). In India, insect pests are responsible for crop losses of approximately 15.7%, amounting to annual losses of US$ 36 billion (Dhaliwal et al., 2015). Post the green revolution, cereal crops in the country experienced a 21.3% increase in pest-associated losses, a surge of 15.9% compared to the pre-green revolution era. A detailed breakdown of the shift in pest-associated losses for specific crops is provided in Table 19.1. The respective percentages of pest-associated losses for rice, wheat, maize, sorghum, and millets are 25.0, 5.0, 25.0, and 30.0%, as reported by Dhaliwal et al. (2015).

More than 100 insect and mite species are associated with rice, with only 20 considered economically important in India. Noteworthy insects such as the yellow stem borer, brown planthopper, white-backed planthopper, leaf folder, gundhi bug, and gall midge hold national significance. Other insects and mites of regional importance are confined to specific areas within the country. Wheat crops, relatively less vulnerable to insect pests, face economic challenges from eight notable pests. Insects of national significance for wheat include the termite, wheat aphid, armyworm, American pod borer, pink stem borer, and shoot fly. Wheat thrips and ghujia weevil, on the other hand, have limited distribution, such as the infestation of ghujia weevil in wheat found in Uttar Pradesh (Goswami and Sharma, 2020).

Maize encounters over 130 insect species, of which 12 are economically important pests in India. Maize stem borer, pink stem borer, and shoot fly are recognized as significant pests at the national level. Various other insects, including white grub, cutworm, hairy caterpillar, aphid, armyworm, pyrilla, thrips, termite, and chafer beetle, are confined to specific regions. Among the 150 insect pests associated with sorghum, 20 species, including shoot fly, stem borer, midge, and white grub, are of national significance, while others like armyworm, cutworm, grasshopper, pyrilla, earhead caterpillars, shoot bug, earhead bug, and aphid are limited to specific areas. For pearl millet, approximately 12 insect species are considered important, with white grub and cutworm being of national significance. Other insects like shoot fly, grasshopper, white ants, grey weevil, stem borer, earhead bug, hairy caterpillar, earhead worm, blister beetle, and chafer beetle are confined to specific regions within the country (Goswami and Sharma, 2020).

The level of insect infestation has been subject to change due to various factors such as global warming, aberrant weather conditions, changing cropping patterns, adoption of technologies, and modifications in farming practices. Insects like the brown planthopper, green leafhopper, and gall midge, which have become or are expected to become serious pests, are

affecting rice crops. Brown planthopper outbreaks have been reported in several states, including Karnataka, Andhra Pradesh, Madhya Pradesh, Odisha, and Tamil Nadu. New biotypes of gall midge have emerged alongside the cultivation of gall midge-resistant varieties. The issue of aphids in wheat has recently gained national significance. Additionally, the shoot fly has become a prominent and regular pest for late-sown wheat crops since the adoption of semi-dwarf varieties. Infestations of pink stem borer have increased in wheat, maize, and sorghum. The problem of maize stem borer and midge has become more pronounced in sorghum. Moreover, polyphagous insects like termites, white grubs, hairy caterpillars, etc., are gaining prominence in specific areas.

Many components of Integrated Pest Management (IPM) for cereals have been in place for years. The continuous evolution of IPM involves refining current methods and introducing new components. IPM for cereal crops needs to focus on a sequence of rotational crops over several years rather than emphasizing a single crop in one year or a few years. New approaches to genetic resistance, utilizing conventional breeding and biotechnology, are in early stages. Transferring genes from related and alien species for abiotic stresses will complement genetic pest resistance. Biotechnology is also proving useful for a better understanding of the genetics of insect pests, aiding the deployment of resistance genes. IPM programs have either maintained or reduced the amounts of insecticides applied to cereals. The integration of data on crop growth models, cultivar susceptibility to pests, pest populations, and weather data into easily managed predictive systems will be crucial in efforts to reduce pesticide use.

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Recent Approaches in Hybrid Seed Production of Paddy

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The first-generation progeny (F1) obtained by crossing two genetically different varieties (parents) of is called 'Hybrid'. Rice being a self-pollinated crop, cytoplasmic male sterile (CMS) parent is used as female parent, which is normally called 'A' line. The fertility restoring line which is called 'pollinator' to the female parent is known as male parent and referred as 'R' line, used for hybrid seed production. The hybrid combines the desirable characters from A line (CMS) and R line. They exhibit vigour for several quantitative characters including yield.

Quality of grains in hybrids: It is assessed in terms of milling, head rice recovery, size, appearance and cooking characteristics. In rice, the cooking quality preferences vary from region to region. The adoption of hybrids depends on the profitability which in turn depends on its yield advantage over the inbred (pure line) varieties and market price of the produce as determined by cooking quality and eating characteristics. Therefore, quality characteristics are of paramount importance in popularization of rice hybrids.

Technique of Hybrid Seed Production: The success of hybrid rice technology primarily depends on genetic purity, timely availability and the affordability of hybrid seed costs to the farmers. The production of pure hybrid seed at affordable price in rice- a self-pollinated crop, is a highly skill-oriented activity. A good hybrid may not reach many farmers, unless it is feasible to commercially produce the seed on large scale economically. Though there are two systems viz 2-line and 3- line hybrid breeding and seed production, but at presently three-line method, using cytoplasmic male sterility system, is in vogue. In this system, three lines (parents) are involved in hybrid seed production. These parents are.

1. A line: It is cytoplasmic male sterile line which is used as female parent in hybrid seed production. It is maintained by crossing with the B line (maintainer line). Both these lines are iso-genic having homozygous recessive nuclear genes conferring male sterility, differing only in cytoplasm which is sterile (S) in A line and fertile (N) in its maintainer, the B line.

2. B line: It is iso-genic to A line and is used as pollen parent to maintain male sterility in A line. This line is maintained by growing in isolation, atleast of 5 m away from any rice variety.

3. R line: This is also called as fertility restorer or pollinator line. This is used in hybrid seed production by growing along-with A line in a standard row ratio. It is also maintained by growing in isolation, at least 5 m away from any rice variety.

Climatic and resource requirement: Karim Nagar, Warangal, Kurnool and Nandyal districts in Andhra Pradesh, Tumkur, Mandya and Mysore districts in Karnataka, Kohlapur district in Maharashtra and Erode and Bhawanisagar districts in Tamilnadu are most popularplaces being used for seed production of hybrid rice. Public and private sectors both have strong seed production programme in these districts. However, the private sector has taken lead in hybrid rice seed production. In these districts, on an average, hybrid seed yield of 15 to 20 q/ha is obtained.

i. Seeding time and season: The transplanting of seedlings of parental lines should be planned in such a way that flowering doesn't coincide with rains which result in poor seed setting due to pollen wash. This is the reason that hybrid seed production is not so successful during kharif (rainy season) both in the North and the South, but rabi season is most suitable in the Central and the Southern India. Other potential states for hybrid seed production of rice in the country are Chhattisgarh and Orissa.
ii. Temperature requirement: The transplanting of seedlings of parental lines should be planned in such a way that flowering coincides with most favorable conditions such as daily mean temperature of 24-300 C, relative humidity of 72-80 %, difference in day and night temperature in the range of 8-100 C, bright sunshine, moderate wind velocity and no continuous rains, particularly at the time of flowering.
iii. Soil conditions: The field should be fertile with uniform topography, having good drainage and irrigation facilities and free from 'volunteer plants'. The uniform topography and homogeneity of the field in respect of fertility will ensure synchronous flowering and ultimately the highest yield of hybrid seed.

Nursery raising and seed rate: To ensure multi-tillered (4-5 tillers) seedlings and convenience in uprooting, sparse seeding in nursery is desirable. For this, 30 g seeds/m2 would be required. 15 kg seed for A line and 5 kg seed for B or R line would be required for planting crop in one hectare of land. Since seed of parental lines is costly, fine preparation of nursery bed is essential for ensuring cent percent germination and normal healthy growth of the seedlings. Wet beds of one metre width and of convenient length with good drainage facility should be prepared. 250 kg FYM, 1 kg N and 1/2kg each of phosphorus and potash per 100m2 should be applied. Parental line seeds should be soaked in water for 12-15 hours. Pre-soaked seeds should be treated with carbendazim (50%WP) @ 4 g/kg of seeds. The seeds should be incubated in gunny bags for 1-2 days for better sprouting. The sprouted seeds should be sown sparsely and uniformly on well prepared seed beds. Total nursery area required for sowing 20 kg of seeds is 1000-1200 m2. A thin film of water should be maintained, and the beds should not be allowed to get dry at any time. The nursery beds should be top dressed after 15 days of sowing with 600-800g of Nitrogen per 100 m2. Appropriate plant protection measures should be taken during the period when the seedlings are in the nursery bed.

Isolation: For ensuring genetic purity of the parental and hybrid seeds, optimum isolation is required. The isolation of the hybrid seed production plot from other rice varieties can be provided by the following means:-
a. Barrier isolation: This can be achieved through physical barriers: (i) natural means like mountains, forests and rivers and (ii) growing taller crops like sorghum (jowar), maize, pearl millet (bajra), sugarcane, Sesbania (dhaincha), etc. These barrier crops are planted covering 30 m between hybrid seed producing plot/parental seed producing plot and other rice varieties.
b. Time isolation: It can be provided by planting the parental lines of the hybrid in such a way that they come in full flowering stage 21 days either prior or after the rice varieties grown nearby start flowering.
c. Space isolation: For providing the space isolation, it is essential that no other rice variety should be grown in a distance of 100 m. For the seed production of A line, this distance should be still larger (500 m).

Row ratio and planting pattern: The row ratio may vary from region to region, depending upon the weather conditions, morphological features of parental lines and management of crop rising. Following features of rice plant have profound effect on row ratio.

a. Taller the pollinator: Larger number of female rows it may cover or pollinate.

b. Vigorous pollinator: It may pollinate larger number of female rows.

c. Larger size of the inflorescence or panicle: It help the pollinator (R line), in production of larger quantity of pollen grains which will assistto pollinate larger number of rows of female (A) parent.

d. If the duration of opening of floret (flower) in A (female) line is longer, large number of female rows may be alternated with 2 rows of R line.

e. If the stigma of A line is fully exerted, the number of rows of this parent could be increased.

The row ratio of female (A line) and R (pollinator or male) parent is kept 10:2, whereas in seed production of A line, the row ratio of A and B line is usually kept 8:2. The higher outcrossing may be attained if the row direction is adjusted nearly perpendicular to the wind direction prevailing at the time of flowering.

Spacing and method of transplanting: The spacing between various parents should be as follows.

Male:Male	30 cm
Male:Female	20 cm
Female:Female	15 cm
Plant:Plant	15 cm or 10 cm

At each hill, 2-3 seedlings should be transplanted at the age of 21-25 days. The transplanting of older seedlings delays flowering, whereas for younger seedlings flowering occurs in advance.

Application of gibberellic acid (GA3): It is an efficient and effective growth hormone, which stimulates the cell elongation and thus advances the panicle exertion in female line. This hormone has the following favourable effects:-

- Increases the duration of floret opening, thus ensures pollination.
- Increases the stigma exsertion and its receptivity.
- Promotes plant height.
- Widens the flag leaf angle and thus facilitates easy entry of the pollen grains.
- Influences flowering and thus transplanting in parental lines can be adjusted.
- Promotes panicle exsertion and growth rate of secondary and tertiary tillers.

In hybrid seed production plots of rice, 5-10 % panicle emergence stage is most appropriate for first spraying (40%) and the remaining 60 % of GA3 should be sprayed on the following day. The ideal time for spraying is from 8 A.M to 10 A.M and from 4 P.M to 6 P.M. The spraying should be avoided during cloudy weather and when the wind velocity is high. The dose of 45-60 g/ha GA3 in 500 liters of water is optimum. This hormone does not dissolve in water and hence it should be first dissolved in 70 % alcohol (1 g of GA3 in 25-40 CC of alcohol).

Synchronization: Synchronization of flowering of male and female parents ensures higher hybrid seed yield. However, normally in most of the hybrid combination the parental lines differ in flowering. Synchronization in flowering can be attained by the following measures.

a. Seeding interval: The parental lines differing in their growth duration can be sown on staggered dates in the nursery beds, so that they come to flowering at the same time in the main field where hybrid seed is to be produced. This is called 'staggered' or 'differential' sowing. In South Indian conditions, R line is sown in three splits i.e., 3, 5 and 7 days after sowing of A line. However, the nursery of both the parents is transplanted on the same date. The nursery of R line sown on two dates is transplanted in alternate hills in the same rows.
b. Through fertilization: Depending upon the environmental conditions, synchronization of two parents can be adjusted by foliar spray of nitrogenous/ phosphatic fertilizers. The spray of 2% urea to early parent delays flowering by 2-3 days and use of phosphatic fertilizer to late parent enhances flowering by 2-3 days. However, the dose of the fertilizers will depend upon the difference in growth duration and responsiveness of the parental lines.

Roguing: Roguing is a process of removal of unwanted rice plants from the seed production plots. To ensure high genetic and physical purity of hybrid seed, it is essential to follow roguing in the following stages:-
a. At vegetative phase: On the basis of morphological characters of leaf and the plant, leaf shape and pigmentation.
b. At flowering: Early and late types, absence/presence of awns, panicle exsertion, anther colour, panicle characteristics, etc.
c. At maturity: Per cent seed set on plants in the female parent, grain type, shape, etc.

Flag leaf clipping: Generally, the flag leaves are longer and erect compared to panicle and therefore, they pose hindrance for easy pollen grain dispersal and could influence the out crossing rate. Therefore, clipping of flag leaf helps in free movement and wide dispersal of pollen grains to give higher seed yield. The flag leaves should be clipped off when the main culms are in booting or pre- emergence of panicle stage. About half to two-third portion of flag leaf from the top should be removed. However, the cutting of flag leaf is not advisable in the plots infested with diseases as this operation may spread the disease further.

Supplementary pollination: Rice is self- pollinated crop and hence there is need for supplementary pollination for enhancing out-crossing. In this operation, the pollen parent plants are shaken which helps in shedding and dispersal of pollen grains over the A line. This can be done either by rope pulling or by shaking the pollen parent with the help of two bamboo sticks. The first supplementary pollination should be done at peak anthesis time when 30 to 40 % of the spikelets are open and anthers are fully exserted. This process is repeated three to four times during the day at an interval of 30 minutes. This process should be done for 7-10 days during flowering period.

Weed management: 2.5-3.0 kg of Butachlor should be mixed in 50-70 kg of sand and apply in one ha area after 5- 6 days of transplanting. Need based hand weeding is also recommended to ensure healthy crop.

Nutrient Management: 25% of the recommended dose of N in the form of urea should be applied at 30-35 days of planting and remaining 25% nitrogen and 25% of potash should be applied at 70-75 days after transplanting or at panicle initiation stage.

Water Management: A thin film of water should be maintained for initial 30 days. The water level is increased later on to 4-5 cm when the crop reaches maximum tillering stage.

Harvesting, threshing and processing: In order to have high seed purity utmost care should be taken while harvesting female (seed) and R line. First, the male parent (pollen parent or R line) should be harvested, followed by the female parent. Also, the threshing should be done separately, if possible on separate threshing floors. After drying, the seed should be bagged with labels both inside and outside the bags.

Yield: The seed yields used to be very low (3 to 5 q/ha), but with experience over the years, 15 to 25 q/ha average yields are being obtained now. The seed yields are higher in dry season as compared to wet season. Hence large scale seed production is generally taken in dry season only.

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Quality Seed Production Techniques in Barley

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Barley (*Hordeum vulgare* L) is one of the important cereal crops after rice, wheat; maize etc. of India and significantly contributes towards food, feed and nutritional security of the region. Barley is well adapted for adverse climatic and soil conditions like salinity, drought and largely cultivated as *Rabi* crop by small & marginal farmers in the parts of Haryana, Punjab, Himachal Pradesh, Uttarakhand, Rajasthan, Uttar Pradesh, Bihar and Madhya Pradesh. Barley is preferred as a dual crop by farmers due to its ability to thrive well in marginal lands and having excellent fodder qualities like abundant foliage growth, regeneration capacity and nutritive values in addition to modest grain yield. Further, barley is an important industrial crop as widely utilized for malting and brewing purpose in Punjab, Haryana and Rajasthan with relatively better management to get quality product (Kumar, 2017).

ICAR–IIWBR, IARI, CCSHAU, RARS, Durgapura, BHU, CSAUT, NDUAT and other SAUs have developed numerous varieties of barley. AICRP on Wheat & Barley, considering need of the end users, varied sowing conditions and agro-climatic zones recommended different varieties for cultivation. There are varieties of barley developed for food and feed (dual purpose) considering requirement of the farmers and varieties suitable for malting and brewing considering demand of the brewing industries. Seed is the key input for profitable crop production and efficacy of all other agricultural inputs like land, fertilizer, labour and irrigation revolves around efficiency of seed used for sowing. It becomes imperative to use quality seeds of improved varieties by the farmers to assure uniform field establishment, plant growth and yield. Improved variety/ newly developed variety of crop is proven to be beneficial to the farmers/ end-users, only when sufficient quantity of improved variety seed is produced and distributed among the farmers at affordable price and right time.

As barley is self-pollinated crop, its quality seed production can be taken by farmers at own farm with due precautions. Quality seed produced by farmers on their own farm could be used for three consecutive years thereby improving the quality of Farm Saved Seed (FSS), promoting exchange of quality seed among farmers and assuring horizontal spread of improved varieties for barley growers. Seed production involves assured seed purity (physical and genetic), maintenance of isolation distance, identification of off-types, diseased plants and weeds and rouging of off-types to avoid contamination in seed multiplication chain. It is always recommended to carry out seed production activities in well drained, fertile soils with assured irrigation facilities to produce and maintain optimum quality of seeds.

Following package of practices may be followed by the farmers for quality seed production of Barley varieties at own farm:

Selection of varieties: As per the need and agro-climatic conditions, farmer may select any of the following varieties. Seeds of the recommended varieties should be procured from the reliable sources *viz*., ICAR-Institutes, SAUs, NSC, SSC and Department of Agriculture.

a) Food and fodder purpose varieties:

S No.	Variety	Year of release	Released for	Sowing Time & Conditions	Duration	Average grain yield/ acre (q)
1.	DWRB 137	2018	NEPZ & CZ	Timely sown, irrigated conditions	115 days	16.99
2.	PL-891	2019	NWPZ	Timely sown, irrigated conditions	144 days	16.80
3.	RD-2899	2018	Central Zone	timely sown, irrigated conditions	120 days	16.87
4.	RD 2907	2018	NWPZ and NEPZ	Timely sown, irrigated conditions, Saline/ alkaline soils	124 days	14.21
5.	BH 959	2015	Central Zone	Timely sown, irrigated conditions	109 days	19.96
6.	HUB 113 (Mahamana 113)	2014	NEPZ	Timely sown, irrigated conditions	119 days	15.50
7.	RD 2786	2013	Central Zone	Timely sown, irrigated conditions	111 days	20.08

b) Malt purpose Varieties:

S. No.	Variety	Year of Release	Released for	Sowing Time & Conditions	Duration	Average grain Yield / acre (q)
1.	DWRB 182	2021	NWPZ	Timely Sown Irrigated conditions	133 days	19.87
2.	DWRB 160 (Karan Maltsona)	2019	NWPZ	Timely sown, irrigated conditions	134 days	21.48
3.	DWRB 123	2017	NWPZ	Timely sown, irrigated conditions	130 days	19.48

4.	DWRB 101	2015	NWPZ	Timely sown, irrigated conditions	132 days	20.04
5.	DWRB 92	2014	NWPZ	Timely sown, irrigated conditions	131 days	19.92
6.	DWRB 91	2013	NWPZ	Late sown irrigated conditions	115 days	16.24

Selection of field: For seed production of barley, land should be fertile, levelled and well drain type in order to get optimum seed yield and better quality. Acidic soils are not suitable for barley cultivation. Seed plot needs to be free from volunteer plants cultivated in the previous year. This is will prevent contamination from other varieties or volunteer crops.

Isolation distance: Barley is self pollinated type crop and it is mandatory to maintain 03 meter of isolation distance between adjacent barley seed/ grain production plot to avoid any mechanical mixture or contamination from other varieties. However, for smut infected plots, it is recommended to maintain 150 meter of isolation distance.

Preparation of field: Well drained and leveled field should be ploughed to find tilth by two to three ploughing with cultivator followed by planking. As barley is sensitive to water logging, field must be levelled for proper water distribution across the seed plots.

Sowing time: In case of quality seed production, it is advised for timely sowing preferably between 10th -25th November for optimum seed yield and quality.

Seed rate & Sowing: In timely sown conditions, seed rate @ 40 kg / acre is recommended for optimum plant population and ease in rouging of off types. It is very essential practice to know germination of seeds before sowing of seeds in the field. 400 seeds may be selected for germination test in germination paper (paper towel method) or newspaper under moist condition for 7 days at room temperature. After completion of 7 days, number of seeds germinated/ health seedlings needs to be counted. If germination percentage is above 85 % in barley seeds, then the seed lot is considered as fit for sowing.

Seed Treatment: Seeds should be treated with Tebuconazole @1 gm/kg to protect it from smut disease.

Spacing during sowing: Line sowing is always preferred during seed production as it facilitates inspection and ease in rouging. Row spacing of 22.5 cm is recommended for barley seed production. Sowing should be preferably at the depth of 4-5 cm.

Rouging of seed production plot: Rouging refers to selective removal of undesirable plants *viz*., other varieties plants, diseased plants, off-types, other crop plants or weed plants, volunteer plants in the seed production plot to maintain genetic purity,physical purity and disease free

attributes of seed plot. In the barley crop, rouging is advised at heading and maturity stage, as most of the off-types and other varieties plants are easily identified during these stages of crop growth. It is recommended that, inseparable other crop plants *viz*., Wheat, Oat, Triticale and Gram should be rouged out from barley seed plot. Diseased plants and off-types may be carefully removed and dumped or destroyed in isolated place.

Nutrient management: For quality seed production of barley, timely sowing of seeds is preferred to produce seed of optimum quality. For timely sown conditions following fertilizer dose is recommended (per acre),

Stage	Nitrogen	Phosphorous	Potash
Timely sown & irrigated condition	24 kg N	12 kg P	08 kg K
1/2 N and entire P and K should be applied as a basal dose wherein remaining nitrogen at first irrigation; (26 kg Urea, 75 kg of SSP and 13 kg of MOP as a basal dose wherein 26 kg urea at first irrigation @ per acre) **Or** If using DAP, then apply 26 kg DAP; 15 kg of Urea and 13 kg MOP per acre as a basal dose wherein, 26 kg urea per acre at first irrigation @ per acre.			
Timely sown and irrigated condition for Malt purpose	36 Kg N	12 kg P	08 kg K
1/2 N and entire P and K should be applied as a basal dose wherein remaining nitrogen at first irrigation; (39 kg Urea, 75 kg of SSP and 13 kg of MOP as a basal dose wherein 26 kg urea at first irrigation @ per acre) **or** If using DAP, then apply 26 kg DAP; 28 kg of Urea and 13 kg MOP per acre as a basal dose wherein, 39 kg urea per acre at first irrigation @ per acre.			

Irrigation: In the barley seed production plot, normally three irrigations are recommended at following stages of crop growth;

Irrigation schedule	Days after sowing (DAS)	Stage of Crop
1st Irrigation	30-35	Crown root initiation
2nd Irrigation	65-70	Panicle emergence
3rd Irrigation	90-95	Grain formation

Weed management: Weed seed free seed production is pre-requisite for producing quality seeds and avoid further contamination in seed multiplication chain. For effective weed control, following herbicides may be applied considering need and type of weed flora,

Pre-emergence:Narrow and broad leaves weeds can be controlled as pre- emergence control by spraying of Pendimethalin (1250 ml per acre) at 1-3 days of sowing.

Grasses type:Variousweeds*viz., Phalris minor* (Mandus/ Kanaki), *Avenafatua* (Wild oat/ JangaliJau) are controlled by spraying of Pinoxaden 5 EC (400 ml/ acre) at 30-35 days of application.

Broad leaves type:Broad leaves weeds *Chenopodium album* (Bathua); *Convolvulusarvensis* (Hirankuri); *Melilotusindica* (Senji/Metha) can be controlled by2,4-D (400 ml per acre) at 30-35 days after sowing.

Disease and pest management:

1. Covered smut of Barley: Seed treatment with Vitavax @ 2g/kg seed and Vitavax& Thiram in the ratio of 1:1 for covered smut should be used.

2. Rust: Spraying with Propiconazol 0.1% (1 ml/litre of water) immediately after occurrence of disease may be done.

3. Leaf Blight: Spraying with Propiconazol 0.1% or (1 ml/litre of water) is recommended.

4. Aphid: Spraying with Imidacloprid (17.8 SL) @ 40 ml per acre is an effective way of controlling aphids. In case of heavy incidence the second spray can be made at an interval of 15 days.

Harvesting and threshing: Generally in India, harvesting is carried out manually however recently combine harvesters are being deployed for ease in harvesting and threshing. Therefore, it is essential to clean properly all combine machines to avoid any admixtures/ mechanical mixtures of different varieties. It is recommended that seeds should be dried properly for proper storage before storage to avoid storage losses due to high moisture. Seed crop is subjected to sun drying for 3-4 days to reduce the moisture content at safe level i.e. less than 12 %. It is recommended that well filled and diseased free seeds may be separated from properly dried seeds using seed processing facilities available at nearby locations. It is suggested that, always use new bags for storage of seed to avoid mixture or to avoid any infestation of storage pest.

Storage and fumigation: While storing the seed bags, it is recommended to use wooden/ plastic pallets to avoid take up of moisture by seeds from floor. Barley seeds absorbs moisture from atmosphere and may lose viability quickly therefore proper precaution may be taken at the storage. Fumigation may be done to control storage pests in stored condition at the rate of 03 tablets of Aluminum phosphide of 3 grams each per tonne of seed. Fumigation may be carried out under polythene sheets by making air tight chamber for 3- 5 days depending upon level of infestation. If possible, farmers may store the well dried and processed seeds in BOPP/HDPE/jute bags for better storability of seeds.

Seed Certification: For production of foundation and certified seeds of barley, minimum seed certification standards need to be followed as prescribed by Indian Minimum Seed Certification Standards, 2013, published by Department of Agriculture Cooperation and Farmers' Welfare, Govt. of India.

Table: Field & Seed Standards of Barley (As per IMSCS, 2013)

Class of seed	Minimum		Maximum permissible level (%)				Remarks
	Isolation (m)	No. of field inspections	Off types	Inseparable other crop plants	Objectionable weed plants	Plants/heads affected by designated diseases	*Infection of smut in excess of 0.10% and 0.50% for FS and CS
FS	3 (150)*	2	0.05	0.010	-	0.10	
CS	3 (150)*	2	0.20	0.050	-	0.50	
Class of seed	**Maximum permissible level (%)**						
	Purity (%)	Germination (%)	ODV (No./kg)	Total weed seed (No.)	Other crop Seeds (No.) #	Seed moisture (%)	Remarks
FS	98	85	10	10	10	12	
CS	98	85	20	20	20	12	

#Inseparable other crop plants- Wheat, Oat, gram and Triticale

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Management of Major Diseases in Cereal Crops

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Any grass that has been raised specifically for its grain, which is made up of the endosperm, germ, and bran and is botanically known as a caryopsis, is considered a cereal. Since cereal grain crops are the most widely farmed and offer the greatest amount of food energy, they are considered staple crops. They consist of barley, rye, oats, and wheat. The role of cereals can be understood from the fact that even in the Industrial Age ,all the current superpowers have historically remained first and foremost great cereal powers.

Due to a programme known as the Green Revolution, the production of high-yield cereal crops, particularly wheat and rice, increased significantly around the world in the second half of the 20th century. The Green Revolution's techniques were quite successful at raising total yields of cereal grains while focusing on preventing starvation and increasing output per plant. However, they did not sufficiently address nutritional quality. These contemporary high-yield cereal crops frequently lack balanced necessary fatty acids, balanced essential amino acids, vitamins, minerals, and other quality components. They also frequently have excessive levels of carbs and low-quality proteins.4With the "organic" movements of the early 21st century, so-called ancient grains and heritage varieties have gained appeal; however, there is a trade-off in yield-per-plant, putting pressure on resource-poor places as food crops are replaced with income crops.

Around 2,500 million tonnes of cereal are produced annually in the entire world. The FAO estimates that more than three-fourths of all grain output in the world is made up of maize (corn), wheat, and rice. India has estimated to have its domestic production of cereals to be above 288 million metric tons by the end of 2022. These cereals include, among others, rice, wheat, barley, millets, and ragi. India ranked second in the world for both rice and wheat production.

Diseases and pests are one of the most important constraints in the production of any crop and cereals are no exception. Many of the diseases take a heavy toll of the production every year accounting to billions of rupees directly (by causing losses in production) or indirectly (by increasing cost of cultivation through need of the costly plant protection agrochemicals).

Management of plant diseases is based on the principles that include (a) avoidance (b) exclusion (c) eradication (d) protection (e) disease resistance and (f) therapy of the diseased plants. In management of the diseases of cereal crops, however, all these may not be applicable but a combination of more than one forms the integrated management strategy of plant diseases to reduce the losses and optimize the gains from the crop including its yield and productivity.

In the following pages, we shall look into some important diseases of major cereal crops and their management strategies.

A. PADDY/RICE (*Oryza sativa*) DISEASES

1. Blast: The disease is caused by a fungus known as *Magnaporthegrisea*.In 1637, the disease was first noted in China. It is thought that it started in Japan as early as 1704. In India, the disease was first reported in 1918from Tanjore (Tamil Nadu). Depending on the crop stage of infection the disease causes yield losses ranging between 30 and 61 per cent which may be as high as 70-80 per cent under heavy infection and favourable environmental conditions.

Symptoms of the disease:

The fungus affects the crop at every stage, from nursery seedlings to main field headings. The typical symptoms include leaf sheath, rachis, nodes, and even the glumes being attacked in addition to the leaves. The disease has three distinct stages and symptoms of all these differ from one another. The three stages of the disease are:

a) Leaf blast: The lesions begin as little, water-soaked, bluish-green specks on the leaves but quickly grow to become recognisable spindle-shaped spots with a grey centre and a dark brown rim.As the disease worsens, the spots converge, and big sections of the leaves dry out and wither. On the sheath, the sheath likewise develops similar patches. Fields and nurseries that have been severely infested appear burned.

b) Nodal blast: Infected nodes have irregularly shaped black patches all around them. The damaged nodes may separate, and all plant portions above them may perish.(Node blast).

c) Neck blast: When the flower emerges, the fungus attacks the peduncle, encircling it and causing the lesion to turn brownish-black. Common names for this stage of infection include rotten neck, neck rot, neck blast, and panicle blast. Grain filling does not take place in the early neck infection, and the paniclestands upright like a dead heart, similar to that caused by a stem borer. Partial grain filling takes place in the late infection. On the glumes of the severely infected panicles, little brown to black patches may also be seen.

Cause of the disease:

As has earlier been said, the disease is caused by a fungus known as *Magnaporthegrisea*.The infected straw and seeds include mycelium and conidia, which are significant sources of primary inoculum.Due to the high soil temperature in June, the disease cannot be started on the plains by the seed-borne inoculum.The fungus overwinters in grain or stacks of straw in both tropical and temperate environments.In the tropics, infection of collateral hosts such *Panicum repens, Digitariamarginata, Brachiariamutica, Leersiahexandra, Dinebraretroflexa, Echinochloacrusgalli, Setaria intermedia, andStenotaphrumsecondatum* is one important mode of survival of the pathogen.The grass hosts and the early-sown paddy crop appear to be the disease's most likely sources of perennation and onset.The disease cycle is brief, and secondary infections are primarily responsible for economic losses.The conidia can travel great distances in the air.Air currents carry the conidia from various sources, resulting in secondary dispersion.The majority of conidia are released at night when it has rained or dew.Excessive nitrogenous fertilizer application, sporadic drizzles, cloudy conditions, high relative humidity (93–99%), low nighttime temperatures (between 15-20^{o} C or less than 26^{o}C), increased frequency of rainy days, prolonged dew duration, cloudy conditions, slow wind movement, and accessibility of collateral hosts, are known tofavour the disease.BLAST was the first leaf blast model developed

by Japan for forecasting the disease. Other models includePYRIVIEW,PYRICULARIA,P BLASTand BLASTAM. India has developed its own model for forecasting the disease and it is known as "Epi-Bla".

Management of the disease:

a. Healthy seeds from a disease-free crop

b. Rice variety Abhishek (IET - 17868)(RR-272-829) released in 2007 is highly resistant to blast disease. Also, varieties that are resistant/tolerant can be used for cultivation in the areas of high and regular incidence of the disease. These includeDRR Dhan 56 (IET 26803) (resistant to leaf blast), 27P27 (IET 25745) (PHI-16101) and DRR Dhan-55 (RP 5591-123-16-2; IET 26194) both of which are moderately resistant to leaf and neck blast, DRR Dhan 54 (IET 25653) (RP 5943-421-16-1-1-B) which is resistant to leaf blast, moderately resistant to neck blast, Indam 100-012 (IET 26999)- moderately resistant to neck blast, NLR 3041, NLR 40024 and JKRH 2154 (IET 24914), which are tolerant and CR Dhan 315 (IET 27179) which is moderately tolerant to the disease may be preferred for cultivation in such areas.

c. Clean cultivation is the key to the elimination of the primary inoculum and delaying the start of the disease. Removal of infected plant debris and collateral hosts givesmany advantages in the long term.

d. Splitting up the application of nitrogen and using nitrogenous fertilizers sparingly helps reduce the susceptibility of the plants to the disease.

e. Seed treatment in the areas where seedborne inoculum is a problem may be undertaken for the elimination of this important source of the disease. Treatment of seeds with a suitable fungicide helps reduce the disease. There are biofungicides also available for seed treatment. *Pseudomonas fluorescens* 0.5% WP (TNAU Strain Accession No. ITCC BE 0005) is one such biofungicide which can be used for seed treatment @10g formulation/kg seeds. *Pseudomonas fluorescens* 1.5% WP (BIL-331 Accession No. MTCC5866) can be used for the same purpose @5g/kg seeds. *Pseudomonas fluorescens* 1.5% LF (MTCC no. 5671, Strain designation Pf-1) can be used @4.5ml/kg seeds. For chemical seed treatment,Sedaxane 12.61% w/w + Azoxystrobin 3.15% w/w + Thiamethoxam 22.06% w/w can be used @3ml/kg seed.

f. Avoid close transplanting of seedlings to avoid canopy which builds microclimate for disease development.

g. Spray of any of the chemical pesticides including Carpropamid 27.8% SC (0.1%), Ediphenphos 50% EC (500-600ml/ha), Hexaconazole 5% EC (1000ml/ha), Isoprothiolane 40% EC (750ml/ha), Kasugamycin 3% SL (1000-1500ml/ha), Kitazin 48% EC (0.2%), Kresoxim-methyl 44.3% SC (500 ml/ha), Metiram 70% WG (1500-2000g/ha), Picoxystrobin 22.52% w/w SC (600ml/ha), Prochloraz 39.6% w/w EC (1000ml/ha), Pyraclostrobin 100 g/l CS (1000g/ha), Tebuconazole 25.9% EC (750ml/ha), Tebuconazole 25% WG (750g/ha), Tricyclazole 75% WP (300-400g/ha), Azoxystrobin 18.2% + Difenoconazole 11.4% w/w SC (0.1%), Azoxystrobin 120 g/L + Tebuconazole 240 g/L SC (830 ml/ha), Azoxystrobin 5.1%w/w+Tebuconazole 9.1% w/w+Prochloraz 18.2 % w/w EC (1750ml/ha), Azoxystrobin 16.7% + Tricyclazole 33.30% SC (500ml/ha), Carbendazim 12%+Mancozeb 63% WP (750g/ha), Difenoconazole 10 % + Mancozeb 50% WDG (625g/ha), Flubendiamide 7.5%+Kresoxim-Methyl 37.5% SC (667ml/ha),

Hexaconazole 4%+Carbendazim 16% SC (750ml/ha), Hexaconazole 5.00% + Validamycin 2.50% SC (1000ml/ha), Hexaconazole 4% + Zineb 68% WP (1000-1250g/ha), Iprodione 25% + Carbendazim 25% WP (500g/ha), Kasugamycin 5% + copper oxychloride 45% WP (700g/ha), Kasugamycin 6 % + Thifluzamide 26% SC w/v (300-345ml/ha), Kresoxim-methyl 40% + Hexaconazole 8% WG (500g/ha), Picoxystrobin 6.78% + Tricyclazole 20.33 %w/w SC (1000ml/ha), Prochloraz 23.5% + Tricyclazole 20.0% w/w SE (1000g/ha), Tricyclazole 20.4% w/w + Azoxystrobin 6.8% w/w SC (1000ml/ha) can be undertaken for effective management of the disease.

h. Soil application of Kitazin 17% GR (3kg/ha) at the time of the last ploughing can be done to minimize the severity of the disease.

2. Brown Spot or Helminthosporium leaf spot or *Helminthosporiose* or Sesame leaf spot:

This disease was the main factor behind the Bengal famine of 1942–1943 in India. It is known to occur in all the rice-growing areas.

Symptoms of the disease:

The fungus affects the crop at every stage—from seedling in the nursery to milk stage in the main field. Symptoms of the disease appear as small spots (lesions) on various plant parts principally those of leaf including coleoptile, leaf sheath, leaf blade, and glumes, being particularly noticeable on the glumes and leaf blade. The disease initially manifests as little brown specks that subsequently develop into cylinders, ovals, or circles. The leaf dries out as the various areas condense. Affected nurseries are frequently identifiable from a distance by their reddish burned look and the death of the seedlings. On glumes that have a significant number of conidiophores and conidia of the fungus, dark brown or black patches also occur. It results in seed germination failure, seedling death, and decreased grain quality and weight. Unusual soil conditions (potassium deficiency) make plants more susceptible to severe infection.

Cause of the disease:

The disease is caused by a pathogenic fungus *Drechsleraoryzae* (Sexual stage: *Cochliobolusmiyabeanus*). It produces phytotoxins called ophiobolin A, (or named Cochliobolin A after it), ophiobolin B(or cochliobolin B) and ophiobolin I. Ophiobolin A is the most toxic. The fungus is known to overwinter primarily in the infected plant parts. It is not soil-borne. The most frequent source of initial infection is contaminated seeds. The seedling blight, which is the first phase of the disease, may be caused by diseased seeds (externally seed-borne). The fungus also survives on its collateral hosts including *Digitariasanguinalis, Echinochloacolonum*, *Pennisetumtyphoides*, *Leersiahexandra, Cynodondactylon*and *Setariaitalica*. Environmental conditions with a temperature of 25-30°C and relative humidity above 80 per cent are highly favourable for the development of the disease. Excess of nitrogen is known to aggravate the disease incidence.

Management of the disease:

a. Use of disease-free seeds to avoid the primary inoculum.

b. Field sanitation and clean cultivation -removal of collateral hosts and infected debris in the field.

c. Crop rotation with legume crops

d. Adjustment of planting time to mismatch the most aggressive stage of the pathogen with the most prone stage of the crop

e. Proper fertilization and use of nitrogen-based on soil testing

f. The use of slow-release nitrogenous fertilizers is advisable.

g. Good water management to maintain relative humidity in the canopy below 80%

h. Grow disease tolerant/resistant varieties viz., SabourSampannaDhan (IET 25960), Swarna SmriddhiDhan (IET 24306) (both moderately resistant), CR Dhan 315 (IET 27179) (moderately tolerant and JKRH 2154 (IET 24914) (tolerant).

i. Seed treatment with *Pseudomonas fluorescens* 1.5% WP (BIL-331 Accession No. MTCC5866) @5g/kg seeds. Make a thin paste of required quantity of *Pseudomonas fluorescens* 1.5% WP with minimum volume of water and coat the seed uniformly, shade dry the seeds just before sowing. For chemical seed treatment,Sedaxane 12.61% w/w + Azoxystrobin 3.15% w/w + Thiamethoxam 22.06% w/w is used @3ml/kg seed dissolved in 8-10ml water for presoaked seeds and 15-20ml water for dry seeds.

j. Foliar spray of *Trichoderma viride* 5.0% liquid formulation (Accession no. NAIMCC-F-03034) has been recommended at a rate of 500 litre/ha. Alternatively, for chemical management foliar spray of any of the following is recommended-

i. Metiram 70% WG @1500-2000g/ha

ii. Azoxystrobin 16.7% + Tricyclazole 33.30% SC @500ml/ha

iii. Hexaconazole 4% + Zineb 68% WP @1000-1250g/ha

3. Sheath rot:

First reported from Taiwan in 1922 the disease is known to be prevalent in all the countries of South Asia.

Symptoms of the disease:

Usually occurring at the booting stage of the crop, the initial symptoms of the disease are noticed only on the leaf sheath (uppermost) enclosing the young panicles. The flag leaf sheath initially shows oblong or irregular greyish-brown spots. They enlarge in due course of time and develop a grey centre with brown margins. Several small spots coalesce into one another to cover major parts of the leaf sheath. The young panicles may remain within the sheath or may emerge partially. The affected leaf sheath and panicles rot and abundant whitish powdery fungal growth is formed inside the leaf sheath. The grains in such affected panicles discolour and shrivel.

Cause of the disease:

The disease is caused by a pathogenic fungus, Sarocladiumoryzae (Syn: *Acrocylindriumoryzae*). The pathogen is favoured by high doses of nitrogen, closer planting, high humidity and temperature between 25 and 30ºC. Injuries made by leaf folders, brown plant hopper and mites increase the chances and amount of infection. The disease spreads mainly through air-borne conidia and is also known to be seed-borne in nature.

Management of the disease:

a. Use healthy seeds from a disease-free field.

b. Apply only recommended doses of fertilizers. Avoid excessive use of nitrogen.

c. Follow optimum spacing to avoid the build-up of canopy favourable to the disease.

d. Spray with Hexaconazole 75% WG@66.7g/ha orFlubendamide 3.5% + Hexaconazole 5% WG @1000g/ha for effective control.

e. Soil application of gypsum in 2 equal splits (500 kg/ha) reduce the sheath rot incidence. Also,the application of Hexaconazole 0.5% GR @10kg/ha has been found effective in reducing the disease incidence.

4. Stem rot:

The disease was reported in India in 1913. Stem rot caused significant losses, according to early reports. Losses of as much as 18-56% due to the disease were reported in India.

Symptoms of the disease:

Near the water line, little black lesions start to form on the outer leaf sheath. As they grow, they also affect the inner leaf sheath. The affected tissues degrade, and the sclerotia exist in great abundance. Plants lodge as the culm falls.The infected tiller can be opened to reveal abundant mycelial development and numerous sclerotia.After harvest, the sclerotia can be seen in the stubbles.

Cause of the disease:

Sclerotium oryzae(Sexual stage: *Leptosphaeria salvinii*) is the fungus responsible for the disease. Sclerotia are primarily found in the top 5 to 10 cm of the soil in the field. During procedures such as weeding, puddling, and ploughing, these sclerotia float on the water. Propagules that come into contact with the sheath of a leaf develop appressoria and could spread infection. Having a wound makes infection easier to spread. After harvest, the fungus keeps expanding on the stubbles, producing a significant amount of sclerotia. The sclerotia are transported to nearby areas by irrigation water. The disease is made worse by a stem borer and leaf hopper infestation, as well as by excessive nitrogen fertilizer doses.

Management of the disease:

a. Deep summer ploughing and safe disposal of stubbles and infected straw reduced primary inoculum for the disease.

b. The use of resistant varieties has been found effective in the management of stem rot. Some varieties include Basumati 3, Basumati 370, Mushkan 7, Mushkan 41 and Bara 62.

c. Use recommended doses of fertilizers with an eye on the nitrogenous fertilizers.

d. Draining the irrigation water off may be doneto flush sclerotia. The soil may be allowed to dry afterwards.

e. Avoid flow of irrigation water from infected fields to healthy fields.

5. Sheath blight:

Sheath blight is one of the most important rice diseases in the world in respect to its financial impact. The disease causes a severe reduction in grain yield and quality. Reports of yield losses of up to fifty per cent have been made from a range of favourable locales. The disease spreads via the soil, and it is difficult to completely remove it from the earth.

Symptoms of the disease:

The crop is affected by the fungus when it is heading and tillering. Early signs are visible on leaf sheaths close to the water's edge. At first, irregular to oval-shaped, greenish-grey spots emerge on the leaf sheath. The centres of the spots enlarge and become greyish-white, while their margins adopt an uneven purple-brown or blackish-brown colour. On their upper portions, plant lesions multiply rapidly and finally cover the entire stool from the water line to the flag leaf. The majority of the time, a single leaf sheath with several large lesions causes the leaf to die. This type of blight may appear on all of the leaves of the plant in cases of severe infestation.Subsequently, the virus kills the entire plant when it reaches its inner sheaths. Older plants are usually more badly affected by the disease. Leaf-sheaths that are five to six weeks old are especially susceptible. High infection rates in plants result in poorly packed grains, particularly in the lowest panicle section.

Cause of the disease:

Rhizoctonia solani AG1-IA is the fungal pathogen that causes the disease. The sexual stage of the disease is called Thanetophoruscucumeris. The fungus produces a large number of orbicular sclerotia, which are initially white but later turn brown or purplish brown in colour. The pathogen can live for five to eight months in moist soils, but it can overwinter as sclerotia or the mycelium itself for about twenty months in dry soils. Over 188 crop species and 32 families are known to be affected by the disease. Sclerotia are dispersed by irrigation water. It is commonly recognized that strong doses of nitrogenous fertilizers, higher temperatures (30–32 0C), higher relative humidity (96–97 percent), and closer planting all encourage development.

Management of the disease:

a. Deep summer ploughing and safe disposal of stubbles/infected crop debris.

b. Apply organic amendments to promote the production of organic acids that can kill primary inoculum in the soil.

c. Grow disease-tolerant/moderately tolerant varieties like JKRH 2154 (IET 24914) and Swarna SmriddhiDhan (IET 24306).

d. Adopt optimum spacing to avoid canopy build-up.

e. Avoid excess doses of nitrogenous fertilizers.

f. Eliminate weed hosts.

g. Avoid the movement of irrigation water from infected fields to healthy ones.

h. In 500 litres of water, mix 2.5 kg of Trichoderma viride 1.0 percent WP. Spray one hectare of land three times at 15-day intervals, 30 days after planting, evenly.

i. Among chemical fungicides Difenoconazole 25% EC (0.015%), Flusilazole 40% EC (300 ml/ha), Hexaconazole 0.5% GR (10kg/ha), Hexaconazole 5% EC (1000ml/ha), Hexaconazole 75% WG (66.7g/ha), Iprodione 50% WP (2.25kg/ha), Kresoxim-methyl 44.3% SC (500ml/ha), Pencycuron 22.9% SC (500-625ml/ha), Polyoxin D Zinc Salt 5% SC (600g/ha) can be used for effective management of the disease.

6. False smut

The disease is known to inflict significant losses each year and is widely distributed throughout the continents.

Symptoms of the disease:

The pathogen changes individual grains into velvety-looking, yellow-to-greenish spore balls. Initially tiny, the balls eventually grow to be one centimetre or longer. These spore balls are initially wrapped in a thin layer that ruptures as they expand. The development of the pathogen's fructification causes the ovaries to change into huge, velvety green lumps. In a panicle, usually only a few spikelets are affected.

Cause of the disease:

The disease is caused by *Ustilaginoideavirens*, a pathogenic fungus (perfect stage- *Clavicepsoryzae-sativae*). The pathogen forms chlamydospores on the spore balls. The fungus overwinters in temperate climates by means of sclerotia and/or chlamydospores. Ascospores appear to function as the main inoculum and are formed on overwintered sclerotia. A significant portion of the disease cycle involves secondary infection, which is facilitated in part by chlamydospores. Rice plants typically become infected during the booting stage. During the blossoming and maturity periods, rain and overcast conditions are conducive to the development of diseases.

Management:

a. The most effective way to handle the disease is to use types that are resistant or tolerant. RH 150025 (ADV 8082) is moderately resistant, while DRR Dhan 54 (IET 25653) (RP 5943-421-16-1-1-

B), Swarna SmriddhiDhan (IET 24306), DRR Dhan 56 (IET 26803), and Indam 100-012 (IET 26999) are resistant varieties.

b. It has been observed that using chemical fungicides at the panicle emergence stage is effective. Good examples of chemical compounds for managing the disease include Copper Hydroxide 53.8 percent DF (dry flowable @ 1500g/ha), Copper Hydroxide 77 percent WP @ 2000g/ha, Fluopyram 17.7 percent w/w + Tebuconazole 17.7 percent w/w SC @ 550ml/ha, Picoxystrobin 7.05 percent + Propiconazole 11.7 percent SC @ 1000ml/ha, Tricyclazole 20.4 percent w/w + Azoxystrobin 6.8 percent w/w SC @ 1000ml/ha, and Tricyclazole 18.0 percent w/w + Tebuconazole 14.4 percent w/w SC @ 1000ml/ha are good examples of the chemical compounds for disease management.

7. Bacterial leaf blight

In 1959, the disease was initially discovered in India. In 1963, there was a serious outbreak of the disease in Uttar Pradesh and Bihar. Because it frequently kills entire young seedlings, the disease is commonly referred to as bacterial blight in the tropics. In severely diseased areas, yield losses can be as high as 30–40% and possibly as high as 50%. Every year, millions of hectares in India become infested. In some places where this disease is common, such as the Godavari district of Andhra Pradesh, yield losses have reached 60 percent. The Taichung Native 1 is quite vulnerable.

Symptoms of the disease:

Plant withering and leaf blight are the two symptoms that the pathogenic bacterium causes. Within three to four weeks of the crop being transplanted, seedlings exhibit Kresek syndrome, also known as wilt syndrome. Kresek causes a plant to either die completely or just wilt a few leaves. Through the hydathodes, the pathogen enters the plant and causes cut wounds on the ends of the leaves. Following entry, it spreads throughout the seedling and kills it completely. Usually discovered at the time of going, the disease can potentially appear sooner in extreme cases. Water-soaked, transparent lesions typically show up close to the leaf margin in adult plants.Over the course of a few days, the lesions cover the entire leaf and grow in length and width with a wavy edge. They eventually turn straw-yellow. The entire leaf blade is covered with lesions as the disease worsens, and the leaf blade may eventually turn straw-colored or white. Early in the morning, bacterial aggregates appear as opaque or milky dew drops on newly formed lesions. They leave behind a white crust when they dry out on the surface. The affected grains have patches of discolouration encircled by wet patches. When a leaf's cut end is submerged in water, bacterial ooze turbidizes the water.

Cause of the disease:

Xanthomonas oryzaepv. oryzae is a phytopathogenic bacterium that causes the disease. The bacteria has a monotrichous polar flagellum at one end and is a rod-shaped, stringent aerobe that is Gram-negative and does not generate spores. The bacterial cells cause wilting as they travel along the vascular tissues of the plant hosts after entering them. The organism is also transferred from field to field by irrigation water. The main way that germs become infected is by overwintering in seeds (husk and endosperm). Bacteria can live in detritus, soil, and plant stubble. Collateral hosts such as *Leersiaoryzoides, Leersiahexandra, Zizania latifolia, Cyprus deformis, Cyprus rotundus, Cyanodondactylon, Phalarisarundinacea*, etc. are also hosts to the disease.The

bacterial ooze induces secondary infection by acting as a secondary inoculum. Clipping the tip of the seedling while transplanting; intense precipitation, dense dew, flooding; deep irrigation water; strong winds; temperatures between 25 and 300 degrees Celsius; and excessive nitrogen treatment, particularly late top dressing.

Management of the disease:

a. Infected plant debris is to be destroyed safely.

b. Avoid flooded conditions or drying of the field (not at the time of flowering)

c. Remove and destroy weed hosts.

d. Cultivation of resistant cultivars like MTU 9992, Swarna, Ajaya, IR 20, IR 42, IR 50, IR 54, TKM 6, Mashuri, IET 4141, IET 1444, IET 2508, ChinsuraBoro, DRR Dhan 56 (IET 26803-released in 2021) and Moderately resistant like 27P27 (IET 25745)(PHI-16101),28S44 (IET 26549) (PHI-17108), SabourSampannaDhan (IET 25960), Swarna SmriddhiDhan (IET 24306), Field tolerant like CG JawaphoolTrombay (RTR-31) and tolerant like JKRH 2154 (IET 24914) helps reduce the losses from the disease.

e. *Pseudomonas fluorescens* 1.5 per cent WP (BIL-331 Accession No. MTCC5866) at 5 grams per kg of seed is used for seed treatment. Create a thin paste with the necessary amount of Pseudomonas fluorescens 1.5 per cent WP and the minimum volume of water, then coat the seeds evenly. The seeds should be shade-dried soon before they become visible. Another option is to use Pseudomonas fluorescens 2.0 percent AS (Strain No. IPL/PS-01, Accession No. MTCC 5727) at a rate of 10 ml per litre of water for seedling root dip therapy followed by spraying. After adding 4 foliar treatments to the paddy seedlings after 40–45 days after transplantation, soak the roots for 30 minutes with a solution of 10 ml of Pseudomonas fluorescens 2.0 percent AS in one litre of water.

f. Judicious use of nitrogenous fertilizers

g. Avoid clipping of tip of the seedling at the time of transplanting.

h. Avoid flow of irrigation water from infected to healthy field

i. Seed-borne inoculum is eliminated by seed treatment, seedling treatment, and spraying with 90% Streptomycin Sulphate + 10% TetracylinHydrocloride SP. Before sowing, prepare a 40 ppm solution of streptocycline and soak the seeds for 12 hours at room temperature. Treatment for seedlings: Soak the seeds in a solution containing 40–100 ppm streptocycline. The seedlings' vascular bundles will be penetrated by the antibiotic when it absorbs via the damaged roots. Spray: At the early root stage, spray 100–150 ppm of streptocycline solution 25. If needed, give it another shot before the grain sets.

8. Bacterial leaf streak:

In 1918, the Philippines reported the bacterial leaf streak in rice. Although it is absent from Japan and other region of the world, the disease is widespread in tropical Asia. Srivastava from

U.P., MP, AP, Maharashtra, Karnataka, Orissa, Haryana, and West Bengal reports on it. Jaya, Padma, and IR 8 are quite vulnerable to BLS.

Symptoms of the disease:

Small, linear lesions soaked in water between leaf veins are the first signs of the symptoms. Initially dark green, these streaks eventually turn pale brown or grayish-yellow. When the lesions are brought up to the light, they appear translucent. When the disease is particularly severe, entire leaves may turn brown and eventually die.

On the surface of leaves in humid environments, one may notice yellow droplets of bacterial ooze, which are made up of masses of bacterial cells. The earliest signs are tiny, transparent streaks that show up in between the leaf's veins. The lesions get brown, grow lengthwise, and spread laterally over larger veins. Around the lesions on highly vulnerable kinds, a golden halo forms. In humid situations, bacteria ooze out of the lesions' surface and form tiny yellow exudates that resemble bands. When the dry season approaches, the leaves can dry up.

Cause of the disease:

Xanthomonas campestrisp.v.oryzicola is a phytopathogenic bacterium that causes the disease. Gram-negative, the organism is a small rod measuring around 1.2µm 0.3 to 0.5µm. The virulence of the bacterial strains varies, with the more virulent types producing longer streaks. Crop debris cannot support the pathogen's survival, but contaminated seed may support it tomuch extent. The stomata and wounds allow the germs to enter the leaves. It does not enter the circulatory systems, instead mostly infecting parenchymatic cells. BLS is not adisease of the system. Exudate from diseased leaves spreads to other parts of the leaf and to other plants when the leaves are wet. Typhoons and rainstorms facilitate the disease's spread. It is known that the disease is favoured by high relative humidity (83–93%) or dew throughout the morning hours for two to three hours.

Management of the disease:

a) Affected stubbles are to be destroyed by burning or through ploughing

b) Grow resistant varieties. IR 20, Krishna and Jagannath are tolerant to BLS.

c) Avoid flooded conditions or drying of the field (not at the time of flowering)

d) Soak the seed in Streptocycline (250 ppm) followed by hot water treatment at 52 0C for 30 minutes eradicates seedling infection.

e) Judicious use of nitrogenous fertilizers

f) Avoid clipping of tip of seedling at the time of transplanting.

g) Avoid flow of irrigation water from infected to healthy field

h) Spray Streptocycline (250 ppm) along with copper oxychloride (0.3%)

9. Rice Tungro disease:

The states of West Bengal, Kerala, and other regions of India are affected by the disease. Throughout tropical Asia, tungro is one of the most common and deadly diseases.

Symptoms of the disease:

Both the main field and the nursery are infected. The plants are significantly stunted. On sensitive types, stunting is more severe; on more resistant forms, it is milder. Interveinal chlorosis and yellow to orange staining are visible in the leaves. "Japonica" variants typically exhibit yellow discoloration, whilst "Indica" varieties typically display orange discoloration. Beginning at the leaf's tip, yellowing may spread to the leaf blade's lower surface. Older leaves may have rusty streaks of varying diameters, while young leaves are frequently mottled with pale green to yellowish interveinal stripes. If the infection strikes the plants early, they can die. A weak root system reduces tillering. Few spikelets and tiny panicles with discoloured grains are present in the infected plants.

Plants infected with tungro can be recognised chemically using the Iodine Test. The tip of a ten-centimeter leaf is cut early in the morning, before six, and immersed in a solution of two grams of iodine and six grams of potassium iodide in 100 millilitres of water for thirty minutes. Dark blue streaks are visible on tungro-infected leaves.

Cause of the disease:

The two viruses that cause it are the rice tungro spherical virus and the rice tungro bacilliform virus (RTBV), which have different morphologies (RTSV). In addition to thediseasedrice plants in the farmer's field, additional significant sources of tungro are infected plants in surrounding rice fields, volunteer rice, and the stubble of past crops that had not been adequately ploughed under and harrowed.

There are two kinds of viral particles linked to the disease. Most of the disease's symptoms are brought on by bacilliform particles. The green leaf-hoppers' ability to spread the bacilliform virus is aided by spherical particles. Should the bacilliform virus particles be isolated within the rice plant, the leafhopper vector will not be able to spread them.

Only in areas where the host plants and their insect vector multiply year-round are they susceptible to serious damage from the virus. In regions where rice is not grown year-round, inoculum is likely to come from collateral hosts, particularly wild rice. A supply of inoculum is also provided by the stubbles of the previous season's infected plants. Occasionally, grassy weeds like *Eleusineindica, Echinochloacolonum,* and*Echinochloacrusgalli*can become infected.*Nephotettixvirescens, Nephotettixnigropictus, Nephotettixparvus, Nephotettixmalayanus,* and *Recilia dorsalis* are the leafhoppers that spread the virus in a non-persistent way.

Management of the disease:

a) Destroy weed hosts of the virus and vectors.

b) Summer deep ploughing and burning of stubbles.

c) Grow disease resistant varieties (DRR Dhan 54 (IET 25653) (RP 5943-421-16-1-1-B) is resistant to RTD), moderately resistant varieties like 28S44 (IET 26549) (PHI-17108), Swarna SmriddhiDhan (IET 24306), Pant Dhan 18 (IET 17920) (UPRI 99-1) or tolerant cultivars like MTU

9992, 1002, 1003, 1005, Suraksha, Vikramarya, Bharani, IR 36, IET 2508, RP 4-14, IET 1444, IR50 and Co45.

d) Control the vectors in the nursery by application of any of the recommended insecticides including Ethofenoprox 10 % EC @500-750ml/ha, Fenobucarb (BPMC) 50 % EC @500-1500ml/ha, Fipronil 05 % SC @1000-1500ml/ha, Lambda-cyhalothrin 02.50 % EC @500ml/ha, Monocrotophos 36 % SL @625ml/ha.

B. Wheat (*Triticum sp.*)

1. Black or stem rust:

It is the most significant and harmful disease seen anywhere wheat is produced in the globe. Two million tonnes of wheat were destroyed by the rust epidemics that struck Maharashtra, Rajasthan, Uttar Pradesh, and Madhya Pradesh in 1946–1947. Rust was particularly bad in 1956–1957 in West Bengal, Bihar, and the eastern regions of Uttar Pradesh, which resulted in significant losses for the company and made the grain unfit for harvest in several places. Despite being widespread throughout India, the disease often only manifests as an epidemic in the central, southern, and eastern regions during the country's hot summer months. This rust can also affect barley crops, in addition to wheat.

Symptoms of the disease:

Flecking of leaves, leaf sheaths, culms, and floral structures is the first sign of infection. These flecks quickly grow into rectangular, reddish-brown uredopustules, also known as uredia. These oblong uredopustules sometimes merge together before eventually opening to reveal a mass of brown uredospores. The entire leaf blade and other affected areas appear to have a brownish tint when several uredia rupture and release uredospores, which is noticeable even from a distance. The same uredosori are used to create teleutosori, also known as telia, later in the season. The condition is named black rust because the lesions are observable, linear or oblong, dark brown to black in colour, and frequently combine with one another to form linear patches of black lesions.Upon reaching maturity, the telia opened out to reveal large clusters of dark brown teleutospores or teliospores. The afflicted tissues exhibit a mosaic of brown and black masses of spores throughout the transitional stage, which eventually dry up. Furthermore, unhealthy plants that have serious infections grow smaller, have tiny spikes, and either produce no grain at all or shrivelled grains.

Cause of the disease:

The disease-causing fungal pathogen is *Puccinia graministritici*. A heteroecious full cycle rust that exhibits all five spore stages is known as stem rust or black rust. Due to its heteroecious nature, it needs multiple host species from various families in order to complete its life cycle. The uredial and telial stages are found on wheat, barley, and some grasses, whereas the pycnial and aecial stages are found on the alternating hosts, Mahonia and Berberis (Barbery) species. The fungus has several physiological races and is extremely specialized (over 250). The most common races to be found in India's wheat-growing regions in virulent form are 11, 15c, 34-A, and 122. The primary source of infection is the barberry, or Berberis vulgaris.While these barberry plants are important to the fungus's survival in the USA, Europe, and Australia, they are not known to be so in India. The black rust inoculum originates in the south, specifically in

the Nilgiri and Pulney hills. The summer heat in the plains of North India makes it impossible for uredospores to survive. The fungus seems to have a good chance of surviving on ratoon tillers, self-sown wheat plants, late-season and off-season wheat crops, and some grasses growing in cool climates, especially in the northern Himalayan foothills, the southern Nilgiris, and the northern Pulney hills.

During the off-season, the fungus is harboured by the grasses, specifically *Briza minor, Bromuspatula, Brachipodiumsylvaticum, and Avenafatua*. The fungus is thought to overwinter on grasses and wheat plants in mountainous regions before migrating to the plains during the main wheat cropping season. *P. graministritici* begins to infect wheat crops in central Nepal in January after the crop is harvested in December after being sowed in August. This occurs in October. This could be an inoculum source for the major crop planted in the plains, which becomes infected every February.

Management of the disease:

a) Adjust the time of sowing to mismatch the load of inoculum with earlier stages of the crop.

b) Avoid late sowing.

c) Grow resistant varieties like GW 1339 (BANAS) (VD 2014-24), Chhattisgarh Genhu-4 (CG 1015), K-1317, MACS 3949 (d), PusaTejas (HI 8759), GW 499etc.

d) Eradication of self-sown wheat plants and weed hosts

e) Seed dressing with Plantavax@0.1% followed by two sprays with the same chemical.

f) Balanced application of nitrogenous fertilizers

g) Spray of any of the fungicides among Mancozeb 75% WP @1500-2000g/ha, Triadimefon 25% WP @1000g/ha, Kresoxim-methyl 44.3% SC @500ml/ha is helpful in reduction of the disease.

2. Leaf, brown or orange rust:

In the eastern and northern regions of India, it is the most prevalent kind of rust. It damages more in Punjab, Bihar, and Uttar Pradesh than stem/black rust. It can be found in crops cultivated in both plains and hills in South India.

Symptoms of the disease:

Small, spherical, orange sori that are sporadically found on the lamina and infrequently on the leaf sheath and stem are among the disease's earliest signs. When a sorus reaches maturity, its colour changes to brown. The telial stage may occur in the same sorus as the disease progresses. The host epidermis covers the tiny, black teliopustules that range in shape from oval to linear. The leaf sheath contains telia as well. A loss in yield is caused by severe leaf rusting.

Cause of the disease:

Puccinia recondita, a fungus, exhibits heteroecious behaviour as well. Wheat and certain other grasses have the uredial and telial stages, while other species of *Thalictrum* have the aecial and pycnial stages. The exact function of *T. flavum* and *Thalictrum javanicum* as substitute hosts in

India is unknown. Early January sees the rust become well-established in the southern plains of Tamil Nadu and Karnataka as well as in the foothills of the Himalayas. The initial inoculum build-up occurs in the Karnataka plains and proceeds northward to Madhya Pradesh and Maharashtra. The inoculum spreads to the northern plains from the foothills of UP and Bihar. Because of this, brown rust develops in North India's Western Hills a little later.When the rust populations in the north and south ultimately merge, they migrate in opposing directions and seriously infect the wheat-growing states.

Management of the disease:

a) Grow resistant varieties. Wheat variety DBW 303 (Karan Vaishnavi) is highly resistant to yellow and brown rusts. Other varieties like GW 1339 (BANAS) (VD 2014-24), GW 499, Chhattisgarh Genhu-4 (CG 1015), K-1317, PusaTejas (HI 8759), CoW 3, DBW 110, PBW 660, WB 2, PBW 1Zn, (HPBW 01) and HD 3171 are also resistant to yellow rust.

b) Seed dressing with Plantavax@0.1% followed by two sprays with the same chemical

c) Spray of any of the fungicides among Mancozeb 75% WP @1500-2000g/ha, Propiconazole 25% EC @500ml/ha, Triadimefon 25% WP @1000g/ha can be done for better management of the disease.

d) RH-124, an Indofil product is very specific to brown rust (or) spray dithiocarbamates like zineb@0.25% or Mancozeb@0.25%

3. Yellow or stripe rust:

The disease is limited to the nation's colder regions, specifically the Himalayan foothills, Punjab, Himachal Pradesh, Haryana, Uttar Pradesh, and sections of Rajasthan and Bihar. South India is completely devoid of it, with the exception of the Nilgiris and Pulney Hills. Although it occurs annually, the harm is only occasionally apparent.

Symptoms of the disease:

Mostly on the leaves, the uredia manifest as bright yellow pustules. They can also be visible on leaf sheaths in cases of severe diseases. Stripe rust gets its name from the elongated sori that are placed in linear rows between the leaf veins. The epidermal layer still covers most of these pustules, which are sub-epidermal. They only shatter when the crop reaches maturity. The teleutosori are likewise grouped in longitudinal rows and emerge late in the season. They are dark in colour, compact, and elongated. They stay beneath the skin of the host. They persist as black crust for a long time before breaking through the skin.

Cause of the disease:

The disease-causing fungus is called *Puccinia striiformis*. The pathogen produces yellow, round to oval uredospores with spiky walls. The teliospores have thick walls, two chambers, a dark brown colour, and a flat top. Its tenacity in India is unknown. At an elevation of roughly 1500 to 1800 metres in the Himalayas, it may spend the winter on volunteered wheat plants. Following a dormant phase, the uredospores sprout and provide an inoculum for an early-sown wheat crop. In Uttar Pradesh, the fungus causes more damage to early-planted crops than to late-planted ones. *Agropyronsemicostatum, Bromuscatharaticus, Bromus japonicus,* and*Hordeummurinum*

are among the weeds that are used as main sources of inoculum. Secondary infection is by wind borne uredospores. There are about 40 races in the world including 13, 14, 19, 20, 24 and 31 A which are widespread in India.

Management of the disease:

a) Removal and destruction of weed hosts may help reduce the survival of the pathogen in the areas of its overwintering.

b) Grow resistant varieties. Wheat variety HD 3298 has shown high level of resistance to yellow rust. Similarly, variety DBW 303 (Karan Vaishnavi) is highly resistant to yellow and brown rusts. WB 2, which is resistant to all the prevalent races of the pathogen. Variety PBW 660 andHim Palam Gehun 2 (HPW 368) have shown high degree of resistance to yellow/stripe rust. The variety PBW 1Zn (HPBW 01) has shown lower coefficient of infection (ACI) for leaf rust.

c) Spray of any of the fungicides among Propiconazole 25% EC (500ml/ha), Tebuconazole 25% WG (@750g/ha), Triadimefon 25% WP (@1000g/ha), Azoxystrobin 7.1% + Propiconazole 11.9% w/w SE-suspoemulsion (@750ml/ha), Azoxystrobin 11% + Tebuconazole 18.3% w/w SC (@750ml/ha), Picoxystrobin 7.05% + Propiconazole 11.7% SC (@750ml/ha), Pyraclostrobin 133 g/l + Epoxiconazole 50g/l SE (@750ml/ha), Tebuconazole 50% + Trifloxystrobin 25% WG (@300g/ha)can help reduce the losses from the disease.

4. Loose smut:

One of the main diseases affecting wheat is loose smut. The years 1970–1975 saw an outbreak of loose smut across Punjab, Haryana, and Western U.P. The incidence was between 5 and 6 per cent in Sonalika. The incidence is higher in India's north than in its south. The yield nationwide is lost by roughly 2 to 3 percent.

Symptoms of the disease:

Only until the panicle emerges from the boot leaf are the disease's symptoms visible. A panicle's entire spikelet mass is transformed into a mass of powdery, black spores. The spores of infected panicles are coated in a thin, silvery film, and they emerge two days before healthy ones do. The mass of black spores is revealed when this thin barrier bursts. The spores are easily dispersed from the naked rachis by wind.

Cause of the disease:

The fungus that causes the disease is called *Ustilago nuda tritici*. Wind-blown teliospores can germinate and infect the developing kernel embryo when they land on the blossoms of wheat plants. Till the kernel starts to germinate, the loose smut fungus's mycelium lies latent in the embryonic tissues of the kernel. The mycelium then grows alongside the plant's growth point and, when blooming time comes, replaces the spike's floral elements with large masses of black spores. Cool, humid weather promotes infection and disease growth and extends the host plant's flowering season. It is a systemic disease that is borne internally by seeds.The mycelium of the fungus remains latent within the seed. The dormant mycelium turns active and grows with the plant when the sown seed germinates. When the panicle is created, the mycelium reaches the ovaries and turns them into a mass of black smut spores. Smut spores carried by the

wind cause secondary spread. The healthy blooms get infected by the sporidia. The mycelium penetrates the ovary and stays latent within the seed.

Management of the disease:

a) Grow resistant varieties: HD 3171 and DBW 110 have shown fair levels of resistance to the disease.

b) Hot water treatment (Jensen, 1908): Soak the seed in cold water for 4 hours and then immerse the seed in hot water at a temperature of 132 0F or 520C for about 10 minutes. Dry the seed in shade before sowing.

c) Solar seed treatment (Luthra and Sattar, 1934): Soak the seed in water for 4 hours (8 AM to 12 Noon) and expose the seed to the hot sun for 4 to 5 hours (from 12 Noon to 5 PM) on cement or rocky surface. This can be practiced in the areas where the summer temperatures are high (42-440C)

d) Anaerobic seed treatment (USA): Soak the seeds for 2-4 hours in water between 60- 700F and keep the moist seeds in air tight containers for 65-70 hours and there after dry the seed.

e) Seed treatment with any of the systemic chemicals among Tebuconazole 5.36% FS @3.33ml/10kg seeds, Tebuconazole 5.4% w/w FS @3.0ml/10kg seeds, Carbendazim 25%+ Mancozeb 50% WS @30-35g/10kg seeds, Carboxin 17.5% + Thiram 17.5% FF @25-30g/kg seeds, Carboxin 37.5% + Thiram 37.5% WS @30g/10kg seed, Triticonazole 80 g/l + Pyraclostrobin 40 g/l (w/v) FS @1g/kg seed, Carbendazim 50% WP @2g/kg seed, Carboxin 75% WP @2-2.5g/kg seed can be effective enough to get relief from the disease.

5. Karnal bunt:

Mitra initially reported the disease in Karnal, Haryana, India (1931). Before the 1970s, the disease was relatively less severe, but with the use of high-yielding, nutrient-responsive, semi-dwarf cultivars, it began to take on more relevance in the early years of that decade. In certain regions of India, the disease was reported to be spreading epidemically in 1976, 1979, 1981–1983, and 1986.

Symptoms of the disease:

Usually, the infection is limited to a small number of unevenly arranged grains within the spike. There are situations where the infection may only affect a portion of the grains. In extreme circumstances, the grain becomes a black, glossy sac filled with teliospores. The bunted grains become visible as the grains ripen, with the outer glumes spreading and the inner glumes expanding. The pericarp initially encloses the bunt balls, but as it ruptures, the masses of bunt spores are revealed. The presence of trimethylamine is the primary cause of the unpleasant stench emanating from the severely afflicted plants. Since the disease often affects only a small number of kernels each spike, Karnal bunt is difficult to identify before harvest. After harvesting, diseasedkernels are easily identified visually: part of the endosperm is replaced by a mass of black teliospores, and the pericarp may be intact or broken. When crushed, diseased kernels release an unpleasant or fishy smell.

Cause of the disease:

Neovossiaindica is the fungus that causes the disease (formerly *Tilletiaindica*). Grain is reduced to a black, glossy sack of teliospores under extreme situations. There is no colonization of the embryo or endosperm. During threshing, the pericarp bursts, releasing teliospores that land in the soil and stick to the seed's surface. In vulnerable host types, moderate temperatures (19–230C), high humidity (>70%), cloud cover or precipitation during anthesis, and these factors all favour the development of disease.

Management of the disease:

a) Grow resistant/tolerant varieties, viz., Pusa Wheat 8805 (HI 8805), HD 3249, HI 1628, NIDW 1149, HI 1634 (PusaAhilya), HD 3298, DBW 110 and HD 3171.

b) Adjustment in the date of sowing

c) Use disease-free seed from apparently healthy crop for sowing

d) Seed treatment with Thiram 75% WS @3g/kg seed

e) Intercropping with Gram or Lentil

f) Use resistant sources like wild species of Aegilops and Triticum, HD 2329, HD 29 and HD 20 for breeding programme.

g) Follow strict quarantine measures to avoid its introduction to the newer areas.

h) Judicious application of nitrogenous fertilizers

i) Spray with Bitertanol 25% WP @2240g/ha, Propiconazole 25% EC @500ml/ha

6. Leaf blight:

In 1962, Prasad and Prabhu reported the disease from India. It is common in some areas of Uttar Pradesh, West Bengal, Bihar, and Maharashtra. Seedlings do not become diseasedeasily.

Symptoms of the disease:

Lesions that are small, chlorotic, oval- or elliptical-shaped initially emerge, and as they grow larger, they take on an uneven shape. The lesions' chlorotic margins may diffuse and change from light to dark brown in hue (See picture). It is challenging to differentiate lesions from those brought on by spot blotch. Although symptoms can appear on any section of the plant, the infection typically begins on the lower leaves. On immature seedlings, reddish-brown oval patches with a bright yellow border develop. In extreme circumstances, a number of spots combine to dry the leaves. Typically, the young leaves are not contaminated.Fields with heavy infection appear burned even from a distance. If the infection occurs at or before the boot leaf stage in certain cultivars, the drop in grain output can reach ninety per cent.

Cause of the disease:

The disease-causing fungal pathogen is *Alternaria triticina*. The pathogen spends the summer in soil and plant debris. Internally and externally borne seed-borne conidia are the main means of dissemination. Conidia carried by the wind are the main source of secondary infection. The

main hosts are durum and bread wheat, along with a few allied grasses. In the eastern and central regions of the Asian Subcontinent, the disease is widespread. High relative humidity and a temperature of 25°C are conducive to the disease.

Management of the disease:

a) Grow resistant/tolerant varieties like HD 3171, K0402 (MAHI), WH 1105, HD 3298, HI 1634 (PusaAhilya), WH 1270, HI 1628, HD 3249

b) Spraying the crop with any of the chemical fungicides among Kresoxim-methyl 44.3% SC @500ml/ha, Mancozeb 75% WP @1500-2000g/ha, Tebuconazole 38.39% w/w SC @600ml/ha, Zineb 75% WP @1500-2000g/ha can be helpful in effective management of the disease.

7. Powdery Mildew:

If powdery mildew infection happens early in the crop cycle and the environment continues to be conducive to its growth, high infection levels can be reached prior to heading, which can result in significant yield losses.

Symptoms of the disease:

White to pale grey, fuzzy or powdery colonies of mycelia and conidia on the upper surfaces of leaves and leaf sheaths (particularly on lower leaves), and occasionally on the spikes, are the initial noticeable symptoms of this disease on all hosts. Fungal tissue that is older is grayish-yellow. It is easy to remove this surface-level fungal stuff with your fingers. Underneath the fungal substance, the host tissue turns chlorotic or necrotic, and in cases of severe infection, the leaves can perish. Eventually, the mycelia may produce black, spherical fruiting structures called cleistothecia, which are visible without a magnifying glass.

Cause of the disease:

The disease is brought on by the fungal infection *Blumeriagraminis sp. tritici* [teleomorph] Oidiummonilioides (Nees) Link [anamorph]. Cool (15–22^{o}C), overcast, and humid (75–100% relative humidity) weather are ideal for the growth of powdery mildew. The harmful fungus has a high level of host specificity. Only isolates that infect wheat do so; isolates that infect barley, oats, and rye seem to behave in a similar manner. Races represent another level of specialization. Everywhere that grains are grown—cool, humid, semiarid regions—powdery mildew develops.

Management of the disease:

a) Use of resistant/tolerant varieties is by far the most efficient measure of management of this disease. Varieties like PBW 1Zn (HPBW 01), DBW 110, WH 1105, HD 3298, NIDW 1149, WH 1270, HD 3249 can provide much respitefrom the disease.

b) Spray of any of the chemical fungicides among Sulphur 80% WDG @2500g/ha, Triadimefon 25% WP @260-520g/ha, Azoxystrobin 18.2% w/w + Cyproconazole 7.3% w/w SC @1000g/ha, Azoxystrobin 18.2% + Difenoconazole 11.4% w/w SC @0.1%aqueous solution, Tebuconazole 50% + Trifloxystrobin 25% WG @300ml/ha can give much relief from the disease.

8. Tundu disease or yellow slime disease

Hutchinson (1917) initially reported the disease from Punjab, India. It is brought on by a combination of two distinct species, a bacterium and a nematode.

Symptoms of the disease:

The condition is typified by the ear head deforming, the spikelets decaying, and a copious amount of yellow liquid seeping from the afflicted tissues. There are a multitude of bacterial cells in the ooze.

All by itself, the nematode distorts the leaves and stem, and produces tiny, circular galls on the leaves. It also causes the leaves to wink and twist. Compared to healthy plants, the infected plants are thicker and shorter. Instead of kernels, black galls are present in the deformed earheads. When the nematode and the bacteria are linked, the nematode and the bacteria work together to cause yellow ear rot, which worsens the disease's symptoms during the flowering stage. The earhead gets rough, and dark nematode galls that also carry the bacteria take the place of the kernels. Compared to healthy plants, infected plants produce more tillers.The early development of ears in nematode-infected plants—roughly 30 to 40 days earlier than in healthy plants—is another intriguing characteristic.

Cause(s) of the disease:

A combination of two taxonomically distinct species, *Anguinatritici* (a nematode) + *Corynebacterium tritici* or *Clavibactertritici*, is the cause of the disease (bacterium). The bacterial companion Corynebacterium has a single polar flagellum, is rod-shaped, and is Gram positive. The seeds that are admixed with nematode galls are the source of the disease. When these infested seeds are planted in the field, the soil retains moisture, which allows the larvae (young insects) to crawl up the young wheat plants escaping the galls. Nematodes penetrate the floral parts during flowering and develop into galls in the ovaries. The bacteria turn active and start to degrade after the nematode enters the ovarian tissues. Rain and wind favour the secondary spread of the disease, which is initiated by the yellow slime that emerges from the rotting earhead. It is likely that the nematode serves as a vector that carries the bacterium to parts of the host that would not otherwise be reachable. In the galls of A. tritici, the nematodes emit certain chemicals that, when present in the host bacteria, can remain alive for a minimum of five years. It has been shown that nematode galls can stay in the soil for up to 20 years, and that the bacteria can live for the same amount of time inside the nematode gall.

Management of the disease:

a) Sow gall-free seeds.

b) Separate the galls from the seed by floating in brine at 160 g of sodium chloride in liter of water.

c) Wheat, barley or oat should not be sown in the infested soil.

d) Spray the crop with streptocycline, 1g in 10 liters of water.

C. Barley Diseases:

1. Covered smut:

The disease is highly significant to crop agriculture and is externally seedborne. It is common in practically every area where barley is grown.

Symptoms of the disease:

The entire head of plants is replaced with masses of dark brown smut spores. At least some floral bracts and awns form, and spores are kept inside a membrane until the plant reaches maturity, at which point threshing dislodges them and allows the infection to spread to the seed. Their ebony ears that protrude from the leaf sheaths are what identify them. A diseasedplant has all of its ears, and a diseased ear has all of its grains infected. A continuous, tight, greyish-white membrane holds the masses of teliospores that are generated from all of the infected grains in a diseasedear in place.

Cause of the disease:

The primary fungal pathogen responsible for the disease production is *Ustilagohordei*. During threshing, the fungus, which is externally seedborne, might get to healthy seeds. Unless the membrane is accidentally torn, the covered masses of teliospores remain enclosed in their enclosing membranes until threshing time. Numerous teliospores are expelled during threshing when the diseased ears are split open. Many of these settle on sound kernels and don't sprout until the seed is planted (Externally seedborne). Infection of seedlings is favoured by warm, damp, acidic soil. Temperatures between 10°C and 21°C are when the most seedlings become sick.

Management of the disease:

a) Seed treatment is perhaps the most effective measure of management of the disease.
Treatment with Carboxin 75% WP @2-2.5g/kg seed can give good control of the disease.

b) Planting resistant/tolerant varieties is the first and foremost part of the strategy to manage the disease. BH 946 and VL Jau 118 (VLB 118), BH-902 have shown fairly good degree of resistance to the disease. Jawahar Barley-1 (JB-110) is tolerant and can be opted in the areas where the disease is not a big problem.

c) Removal of the smutted earheads from the field and avoidance of their entry in threshing process can be helpful in obtaining healthy seeds for the year to come.

Disclaimer: The material used in development of this literature has been taken from various sources including those from the internet. The author does not claim any of the information presented herein of his own and that, this has been compiled and edited for the benefit of the stakeholders.

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IoT and AI Tools Application in Storage Pest Management

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According to a USAID report from 2022, food security is defined as the ability to maintain a healthy and productive lifestyle by meeting dietary needs with both physical and economic access to sufficient food, ensuring that families do not live in fear of hunger. The issue of food insecurity is particularly prevalent in developing countries, whereas of 2020, approximately 800 million people globally go to bed hungry every night. Within this figure, around 690 million, including 144 million children, reside in developing countries where agriculture contributes to 40% of the GDP, and 54% of the population depends on agriculture for sustenance. To address the challenge of feeding an anticipated population growth to 9 billion people by 2050, there is a necessity to double the current food production, especially focusing on staple foods. Therefore, increasing staple food production at a lower overall cost and storing excess production is crucial for achieving food security (Ajisegiri et al., 2022).

The most common staple foods globally are cereal grains and tubers, with only 15 out of about 50,000 edible plants providing 90% of the world's energy intake. Rice, maize, and wheat constitute two-thirds of this, while other staples such as millet, sorghum, potatoes, cassava, and yams make up the remaining 33% (Resource Library, 2022). Efficient storage structures for these staple foods are imperative. As indicated by Hagstrum and Subramanyam (2006), storage structures are designed to protect grain from birds, rodents, fungi, mites, insects, and adverse weather conditions. Farmers face numerous challenges during the storage of agricultural products.

During storage, grain losses are estimated to be between 10–40% due to insect damage (Johnson, 2020). Insect infestation poses significant challenges and risks during storage, with cereal grains being susceptible to damage by various insect species, primarily beetles and moths. Insects can feed directly on whole or damaged grains in storage facilities, leading to rapid population growth, ranging from 20–60 fold increase per month, depending on the insect species, food type, and environmental conditions (Jian et al., 2016). If not managed appropriately, insects can cause extensive losses in stored grain quantity and quality, resulting in damaged grain, weight loss, spoilage, contamination, and quality degradation. The presence of insects can reduce the market value of the grain, rendering it unfit for human or animal consumption or processing. Identification of insects can be time-consuming, requiring special training or infrastructure, and current methods are human-centric, time-consuming, costly, and necessitate specialized equipment, infrastructure, training, or expertise (Johnson, 2020). Therefore, there is a pressing need for a system that can detect and identify stored product insect species in real-time and an automated manner, particularly in high-risk areas of a food facility.

In recent years, reduced hardware costs and a substantial increase in computational power have paved the way for utilizing and exploring artificial intelligence-based solutions,

particularly deep learning techniques (Badgujar et al., 2023). Artificial Intelligence, the intelligence exhibited by machines, involves the development of computer systems capable of performing tasks that typically require human intelligence (Audu and Aremu, 2021). The Internet of Things (IoT) provides a secure solution for real-life applications, enabling the connection of 'things' to the internet, facilitating data exchange between objects, devices, and systems.

Advancements in imaging technology, both hardware and software, have enabled the capture, collection, processing, and interaction with visual information on objects of interest at varying scales, domains, environments, and lighting conditions. Deep learning (DL) based computer vision methods have demonstrated state-of-the-art performance in terms of accuracy, robustness, and speed for object detection and identification in images or videos (Redmon and Farhadi, 2018). Supervised DL-based techniques involve extracting object feature maps from images using a deep neural network trained on a large amount of labeled data, allowing for automated, real-time object detection and identification.

Researchers such as Baranwal and Pateriya (2016) developed an IoT smart wireless security system for identifying rodents, alerting farmers, and repelling rodents in grain storage. Ding and Taylor (2016) utilized the Sliding Window method and a 5-layer convolutional neural network to detect moths. Shen et al. (2018) developed a method for detecting and identifying stored-grain insects using a deep neural network. Badgujar et al. (2023) created an RGB image-based stored product insect species identification and detection system for insect monitoring in various environments. While these advancements show promise, machine vision has some drawbacks, including the complexity of designing and implementing systems, the cost of development and implementation for specialized applications, sensitivity to lighting conditions, limited contextual understanding, and a limited range of applications beyond image analysis (Mendoza et al., 2023).

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Water Management practices during seed production with special reference to cereals Crops

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Abstract
A seed is an agricultural commodity that is raised and harvested under optimum conditions and processed with state-of-the-art technologies to maximize its viability and subsequent crop productivity. The seed is the basic ingredient of successful crop production which guarantees the highest yield potential of any crop variety. The use of good-quality seeds under highly productive systems can increase yields by 5–20%. Every stage of seed production from field selection, nutrients management, weed management, pest management, and water management is crucial for cereals seed production. Water is one of the most important inputs essential for the cereal's seed production. Plants need water continuously during their life. It profoundly influences photosynthesis, respiration, absorption, translocation and utilization of mineral nutrients, and cell division besides some other processes. Both its shortage and excess affect the growth and development of a plant directly and, consequently, its yield and quality.

Key Word: Water management, Agriculture, Productivity, Yield Potential, Photosynthesis, Respiration, Nutrients.

Introduction

The seed production system is a vital ingredient for high farm production and guarantees sustainable supplies of food and feed production. Quality seed utilization acts as an aid to enhance yield to ensure the food security of a nation. It ensures efficient utilization of resources such as water and nutrients. The importance of high-quality seed production is well understood by all entrepreneurs in agriculture. It is essential to sway seed production, which is the first part of the food chain to sway the food production of the world. The good-quality seed has significant potential of increasing on-farm productivity and enhancing food security, but seed production is a challenge under global environmental change. The quality of seed is ensured through better crop raising and husbandry techniques such as maintaining optimum water management, nutrition, pest control, better weed management, and stray plants and seed production steps such as harvesting, processing, and storage. Due to population growth, urbanization, and climate change, competition for water resources is expected to increase, with a particular impact on agriculture. Water is a perilous input for agricultural production and plays an important role in food security. Irrigated agriculture represents 20 percent of the total cultivated land and contributes 40 percent of the total food produced worldwide. Water management in seed production is a critical input.

Water management in the cultivation of rice seeds

The water requirement of rice seed production is higher than that of any other crop of a similar duration, assured and timely supply of irrigation water has a great influence on the yield of the

crop. In the life cycle of a rice plant, there are certain critical stages when the water requirement is high. The water requirement is high during the initial seedling period covering about 10 days. Tillering to flowering is the most critical stage when a rice crop should not be subjected to any moisture stress. Ensure enough water from the panicle initiation stage to flowering (heading). Flooding is not necessary if weeds can be controlled economically through chemical means or by manual weeding before the plants become vegetatively strong. The application of small quantities of water at short intervals to keep the soil saturated is more effective and economical than flooding at long intervals. Flooding is not necessary if the soil is saturated with water and biofertilizers have not been used. However, flooding suppresses weed growth. It increased the availability of many nutrients, particularly phosphorus, potassium, calcium, iron, and silica. Until the transplanted seedlings are well established, water should be allowed to stand in the field at a depth of 2 to 5 cm. Thereafter about 5 cm of water may be maintained up to the dough stage of the crop. Water should be drained out from the field 7 to 15 days before harvest depending on the soil type to encourage quick and uniform maturity of grain.

Water management in the cultivation of Wheat seeds

Adequate soil moisture is required for the normal development of wheat seed production at all stages of growth. The crown root initiation stage and heading stage are critical stages when the plant suffers the most due to moisture stress. The following schedule of irrigation should be followed for dwarf varieties of wheat. In the case of dwarf high-yielding varieties, pre-sowing irrigation should be given and crop sown when the field becomes fit for operation.

First Irrigation

The first irrigation to the standing crop could be given 20-25 days after sowing, i.e., at the crown root initiation stage. In cooler regions like hilly tracts and late-sown wheat, it is desirable to apply first irrigation approximately 25-30 days after sowing. Delay in giving this irrigation should be avoided as it would result in upsetting the synchronous tillering in these varieties, subnormal heads, poor root system, and finally poor grain yield. It is the most critical stage for irrigation.

Second Irrigation

At tillering stage, within 40-45 days after sowing.

Third Irrigation

At the late jointing stage, within 70-75 days after sowing.

Fourth Irrigation

At the flowering stage, within 90-95 days after sowing. Irrigation at this stage is also important because during this period plants suffer most from soil moisture deficiency. The grainnumber and grain size are reduced considerably.

Fifth Irrigation

At the dough stage, within 110-115 days after sowing. The total number of irrigations required will vary depending on soil type, winter rainfall, and amount of water applied per irrigation. Under a limited supply of water, the following schedule of irrigation should be adopted for the best utilization of the available quantity of water.

1. Where only one irrigation is possible, give it at crown root initiation CRI stage, i.e., 20-25days after sowing.
2. Where two irrigations are available, first irrigation should be given at the CRI stage and second at the flowering stage.
3. Where three irrigations are possible, first irrigation should be given at the CRI stage, second at the late jointing (boot) stage, and third at the milk stage. These recommendations strongly stress the importance of irrigation at the CRI stage. It has been found that each week's delay in the first irrigation from the CRI stage results in a yield reduction of 2-3 quintals/ha.

Water deficit during the yield formation period results in reduced grain weight and hot dry wind in combination with water deficit during this period causes shriveling of gain. In the case of light soil and undulated topography, the sprinkler method of irrigation should be used.

Water management in the cultivation of Barley seeds

Barley is a drought-tolerant winter-season crop and thus requires less irrigation. Besides pre-sowing irrigation for crop establishment, the crop also requires irrigation at 3 critical stages viz. active tillering (30-35 DAS), flag leaf (60-65 DAS), and milking stages (80-85 DAS). Under limited water resources, the crop should be irrigated at the active tillering stage. If water is available for two irrigations crop should irrigate at the crown root (20-25 days after sowing) and second at the panicle emergence stage (65-70 days after sowing) if water is available for the third irrigation, it should be given at grain formation stage (90-95 days after sowing). In saline soils, frequent irrigations are given to dilute the impact of salts. Heavy irrigation in March should be avoided to prevent lodging. Hull-less barley needs additional irrigation at the grain filling stage for proper grain filling and to overcome hot wind damage. Crop grown for malt purpose seed should not suffer from moister at any stage and three to four irrigations ensure better yield, grain uniformity, and malting quality. Fodder barley requires irrigation and top dressing of nitrogen immediately after the first cut (55 DAS). Heavy irrigation should be avoided as it causes lodging, severe yellowing as well reduction of tillering.

Water management in the cultivation of Maize seeds

Maize is very susceptible both to excess water and moisture stress. Never allow water to stand in a maize field at any stage of its growth. Water stagnation even for six hours continuously sufficiently damages the crop. Maize can tolerate heavy rains, provided water does not stand in the field for long periods. Therefore, drain away excess water by making a drain of adequate capacity at the lower end of the field. A good crop of maize requires about 460 to 600 mm of water during its life cycle. Do not allow maize plants to wilt due to water shortage at any stage of the life cycle. Tasselling to the silking stage is critical. At this stage water shortage even for 2 days can reduce maize yields by about 20%. The same for 6-8 days can pull down the yield by 50%. Irrigate the crop whenever it is needed.

Water management in the cultivation of Sorghum seeds

Sorghum is grown as a rainfed crop. The irrigation should, however, be provided whenever rains are not received. At the time of flowering and grain filling stages, the crop requires more water. If enough moisture is not there in the soil at the time of flowering and grain filling, it should be irrigated at once. At no stage, the plants should be allowed to wilt. Suitable drainage conditions should be provided for the removal of excess rainwater from the field.

Water management in the cultivation of Pearl millet seeds

As Pearl millet is a rainfed crop, there is hardly any need for irrigation. Irrigate the crop if there is no rain. Generally, two irrigations during the growing period of the crop are enough. If moisture is limited irrigation must be done at the time of ear head emergence because it is the most critical stage for moisture stress. Pearl millet does not tolerate Water logging. So, do not allow rainwater to stand in the field for more than a few hours. Proper arrangements for draining the excess water must be made.

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Post-Harvest Management for Seed Quality Assurance in Cereal Crops

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ABSTRACT

As a recent period's demanding enterprise, there is always a need for healthy seeds in order to provide a good yield in next season. In order to preserve a crop with a high yield, seeds must be safely and scientifically stored. Numerous biological and non-biological processes cause significant losses of seeds during storage. Since they eventually have an impact on the market price and seed quality, examining the causes of these crop losses is necessary. The quality of seeds can be maintained through careful post-harvest management techniques. Designing the most suitable processes for assessing process losses is required to minimise loss and maintain the seed's quality and safety.Producing high-quality seeds that meet both national and international requirements and could perhaps satiate the supplier's needs is the aim. This manuscript emphasises the post-harvest techniques and elements that are used to maintain the quality assurance of the seeds. A full examination of more efficient, cost-efficient, useful, and productive methods is provided; it is centred on the needs of developing countries but also applies to more industrialised countries.

Keywords: Assurance, drying, management, post-harvest, quality, seed, storage

Introduction

Better seed quality and post-harvest storage methods are what allow the seed industry to continue to exist. A high achievement and quality assurance are sought after by this seed quality programme. One of the most demanding industries in the modern era is seed quality. The bulk of small-scale farmers' seeds, particularly those for cereals and legumes, are grown and kept on the farms. By using efficient storage strategies, the main issue—damage caused by biological elements like insects and moulds can be reduced (Delouche and Caldwell, 1960 & Woodstock, 1966). The prevention of crop losses and the storage of seeds and grains is the top priority of farmers. Due to the risk of crop loss, farmers frequently buy new seeds or grains from the market to create the next harvest for a higher yield. The development of efficient seed storage methods that can confirm improved crop yields and lower the likelihood of storage losses is required (Gregg and Billups, 2010).

The value of the seeds enables farmers to grow high-yielding crops from healthy and high-quality seeds. The ability of a seed to produce desirable quality, healthy, and high-yielding crops at low planting rates is referred to as seed quality (Gregg and Billups, 2010). Seed quality cannot be achieved automatically or through an ongoing process. The quality of the seeds is under strain from the environment. To provide farmers with the highest quality seeds, efforts are being made. Any stage of handling or production has the potential to degrade the seed's quality. All seed activities must be managed technically carefully in order to reduce these losses (Boxall et al., 2002).

Seed Storage Principles

When stored at ambient or natural temperatures, seeds react quickly to changes in temperature, the presence of oxygen, and relative humidity. By adjusting the humidity, temperature, and oxygen levels, one can influence the metabolic activity, age, and longevity of seeds (Mohammed, 2014). Prior to storage, the seed's moisture content must be reduced up to an acceptable level because desiccation could cause damage to the seed. Due to the lower humidity, seeds can be kept for a longer amount of time. As a general rule, if the seed moisture level is between 5 and 14 percent, reducing the moisture content to 1 percent doubles the life of the seed. Seeds need to be stored in a cool environment since higher temperatures have a greater impact on higher moisture content. When the temperature is lowered by 5°C, the life of the seed doubles and is applicable between 0 and 50°C. Hermetic storage in a sealed container allows for the regulation of oxygen levels, reducing both the physiological ageing of the grains and the physical harm caused by insects and microbial development (Harrington, 1972).

Postharvest techniques of seed storage

1. Drying

Cereal and legumes reach physiological maturity at moisture contents between 35 and 45 percent, depending on the crop. When seeds have a moisture level between 10% and 14%, temperature has an impact on how long they can be stored. Timely harvesting and drying of crops are essential for a high-quality yield.In most cases, fungal infection and insect and other pest attacks cause biologically active seeds to degenerate quickly. Reduced respiration in seeds is the primary goal of drying (Boxall et al., 2002 &Kiaya, 2014). The procedure also prevents quality loss brought on by pest insects and other fungus. The process of drying itself may have an impact on the seeds' quality. The seed may suffer if it is dried extensively at a high temperature. Simple drying techniques are utilised in the summer by exposing clothing to the sun and getting enough wind. To deal with higher output or harvesting during the wet season in multi-cropping, different drying methods have been developed for high-yielding varieties and enhanced agricultural practises and irrigation (López et al, 2010 & Mujumdar and Law, 2010).

2. Sun-drying

In emerging tropical nations, seeds are typically dried by sun exposure. When the crop is ready for harvest, the procedure is used. Some seeds, like maize, can be sun dried, but crops become more susceptible to pest attacks like insects, rodents, and birds, as well as mould damage, throughout the drying process.Although it is a typical occurrence, spreading threshed seed to dry on sheets or a tray runs the danger of contaminating it with dirt or stones. For instance, paddy is available in big quantities at rice mills (Boxall et al., 2002). On specially constructed drying floors that make it simple for rainwater to drain off, rice is dried. To aid in drying, the seeds are spread out in thin layers, flipped at regular intervals, and covered at night with sheets. The technique has some drawbacks because temperature is an unpredictable variable.High temperatures in paddy rice can stress or break the seeds, which results in significant damage during milling. Dust, air pollution, insect infestation, and human or animal disturbance are all potential sources of yield contamination (Boxall et al., 2002 &Kiaya, 2014).

3. Solar drying

It is a version of solar drying in which solar rays are gathered in a unit created especially for the removal of air in a sufficient ventilation system. The device uses less time and has a temperature that is 20–30° greater than open drying (Chen and Mujumdaer, 2008). In solar dryers, air is heated using solar collectors and then let to travel to the seed beds. It has two fundamental designs: forced convection dryers force air through solar collectors and seed layers, while natural convection dryers exploit thermal gradients. These dryers are appropriate for use on farms. The old design of the Asian Institute of Technology in Bangkok, which consists of a drying bin, a solar chimney, and a solar collector, has formed the basis for other convection dryers (Boothumjinda et al., 1983). The solar collector is made of a layer of burned rice husk or a black polythene sheet and is covered with a clear polythene sheet.In the drying bin is a pedestal with holes in it. The following are the procedure' drawbacks: a high structural profile, stability issues in windy conditions, and the requirement for routine replacement of polythene sheets (Boxall et al., 2002).

3.1 Mechanical dryers

Mechanical dryers use the same drying technique as forced convection solar dryers; the air is forced through the seed bed and heated with the aid of a flat plate as opposed to conventional methods. Drying occurs at one of two points in a modern automated storage system: either in pre-storage dryers (before seeds are loaded into freestanding loading containers) or in store dryers (after seeds are loaded into the final storage compartment) (Kiaya, 2014). Continuous flow dryers used in pre-storage dryers employ ambient air, and a thermostatically regulated furnace, powered by electricity, diesel, or gas, produces heat. Heat can be delivered directly or indirectly. Because the combustion product has a separate outlet and does not go through seeds, the indirect method is recommended. While grains are flown into the system and collected at the correct moisture level in continuous flow dryers, seeds are supplied into properly defined batches in batch dryers (Boxall et al., 2002).

3.2 Tray dryers

Batch dryers having flat beds called tray dryers. To thoroughly dry the seeds, they are spread out on the mesh tray at a depth of 600–700 mm. Warm, dried air is then pushed through the seeds (Boxall et al., 2002).

4. Radial drying bins

Two vertical metal mesh cylinders with one within the other make up the radial drying bin. Between these two cylinders, seeds are loaded, and air is forced into the inner cylinder and transferred from the inner to the outer mesh cylinder. You can remove air from the central cylinder by forcing air through seeds in the opposite direction. Seeds in the inner cylinder that are in direct contact with the hot air run the danger of being overdried. At the exit side, near the outside, the air is cooler and wetter (Boxall et al., 2002).

5. Continuous flow dryers

The moisture content of the seeds can be reduced by sucking or blowing hot air through the system from top to bottom. A bin and cooling system are located at the bottom of the drying

portion. Seed beds can be vertical, sloping, or horizontal. Conveyors, scrapers, vibration, or gravity are used to transfer seeds. The speed, size, and rate of flow of the dryer's outlet belt all affect how much moisture is removed. The relative orientation of the air stream and seed flow alters the continuous flow dryer (Radajewski et al., 1987). Below are descriptions of several continuous flow dry processes.

5.1 Cross flow

The two perforated sheets allow air to move horizontally through the seeds, allowing the seed to pass through and into the column. The dryer's advantage is that the moisture gradient can be established at any point during the drying of seeds (Boxall et al., 2002). Cross-flow dryers have been employed extensively recently.

5.2 Counter flow

Seeds are discharged from a spherical bin using an upward airflow. Even when the hottest air flows through the driest seeds, little evaporative cooling occurs.

5.3 Concurrent flow

When air is moving through a seed bed concurrently, the wettest seeds are exposed to the warmest air. High temperatures increase drier efficiency and chill the seeds by evaporating moisture (Heid, 1980).

5.4 Mixed flow

Mixed-flow dryers have advantages over cross-flow dryers. The combination of contemporaneous, counter, and cross flow dryers in mixed flow dryers offers the major advantage of efficient fuel use. The largest obstacle to the adoption of mixed flow drying, however, is the decrease in yield caused by uneven seed flow, which causes uneven drying (Boxall et al., 2002).

5.5. Mixed flow tower

They are made up of tall rectangular storage bins, and horizontal triangle ducts run the length of the dryer's breadth. The remaining ducts are used to remove dampened and cooled air, while half of the ducts are utilised to introduce warm air. It has several air and seed flow directions (Heid, 1980).

5.6 Fluidized bed dryer

The seeds are dried by hot air that is blown over them after passing through several types of batches. The cross-flow dryer theory underlies how the dryers operate. The degree of drying determines the speed and depth of the drying beds. Conveyor dryers and cascade dryers are the two primary dryer designs. Cross-flow dryers with gravity feeding are the cascade dryers. Roller dams control the seed depth, while output elevators control the speed. Changes can be made to the dryer's design to alter its length. In a conveyor drier, air is forced onto the seeds through an inclined fluidized bed, with heavy duty, roller chain, and variable speed conveyors controlling the seed flow. These dryers can be unidirectional, bidirectional, or

multidirectional; the directional change helps with waste material removal and dryer size reduction (Boxall et al., 2002).

6. Store-based or in store drying

In this alternative drying procedure, seeds are loaded into bins or bulk floor storage before being dried in stores (Chung, 1986).

6.1. Large-scale floor storage

They are made with particularly reinforced walls that can support the weight of seeds. The seeds are stacked at a constant depth. The plenum chamber runs in the middle of the store or walls with perforated lateral ducts, below or above the floor level under the majority of seeds, and the fan is located at one side of the building for aeration purposes (Boxall et al., 2002).

6.2 Bin drying

One or more bins are used for drying, and other bins are used for storage in this form of drying. Due of the decreased handling, dryers decrease the possibility of physical harm. The drying process is faster and safer thanks to the shallow layer of seed around the bins. The semi-dried batches, which consist of ventilated floors or lateral ventilation systems around 0.5 m above the base, free up room for incoming seeds.

6.3 Bag dryers

It is challenging to dry seeds in bags because there is inadequate protection against air passing through the seeds. In fan blowers, hot air is blown from the floor apertures and sacks are put on them, as opposed to sack platform dryers, which blow air through the air duct's floor. In the moisture extraction unit, larger bags are placed in the middle of the tunnel. Hot air is circulated through the air ducts with the aid of a fan. To prevent uneven drying, proper dimensioning must be observed. However, because of short circuits in some places, this technique is not suitable for even drying seeds(Boxall et al., 2002).

Storage losses

According to reports, harvest-related agricultural losses amount to a total of 30%. However, this is the "worst case" estimate to use for the crops in the development priority area. Before harvest, storage losses cannot be estimated. Crop losses can result from a variety of biological, climatic, handling, harvesting, storing, and distribution, as well as social and cultural reasons. 50 percent of post-harvest and storage losses can be distributed with appropriate handling. There is no way to determine the precise sum of such damages. There has been work done to identify the trustworthy baseline techniques for calculating crop loss activities. To calculate the standardised post-harvest losses for different crop operations, a methodology has been developed (Harris and Lindblad, 1978). The Food and Agricultural Organization (FAO) of the United Nations has encouraged loss assessment and loss reduction programmes. The goal of these projects was to prevent the decline of staple food crop production. Even though there was no set approach for evaluating storage losses, the methodology for assessing seed loss during harvest was summarised (Boxall, 1986). The loss assessment phenomenon is non-generalizable, particularly for perishable commodities, due to sampling methodologies, different handling

and storage products, and irregular batch movement. An acceptable, cost-effective, and relevant technique should be carefully designed with positive goals in mind. Due to their distinct nature, perishable goods require a variety of procedures, whereas grain seeds require rather standard methods. It is possible to compare the weight loss of undamaged and damaged seeds in order to determine standard moisture content and dry matter. Storage is used to prevent yield losses on a biological and economical level. We needed to be aware of what was causing these losses in order to prevent them (Kiaya, 2014).

1. Damage and loss

Damage and loss are sometimes used interchangeably, which can be confusing. Loss is defined as a quantifiable drop in the quality or quantity of food. The term "superficial deprivation of commodities" refers to damage where physical decay causes loss of the product. Although a damaged good can still be used, a loss represents a permanent deterioration. (Mohammed, 2014).

2. Classification of storage losses

The stored seeds are directly impacted by the main cause of losses. Economic effects can be attributed to qualitative or quantitative storage loss categories. Physical weight or volume loss, which is regarded as a quantitative loss, is easily calculable. By judging a commodity and comparing it to goods of similar quality, one can estimate quality losses. Changes in flavour, texture, appearance, nutritional value loss, and the presence of pollutants can all cause consumers to reject a commodity. To illustrate the agricultural storage losses, the following categories can be listed (Boxall, 2002): They could have a biological, chemical and biochemical in nature.

2.1. Natural catastrophes or biological losses

Rodents, insects, birds, and microorganisms (fungi and bacteria) are biological causes that cause crop deprivation. Crop weight loss, crop rotting, and other faults brought on by microbe growth on the crops lower the market demand for the produce. If produce is kept in storage for an extended amount of time, infestation development may become a problem. Birds, rodents, and microbiological (fungi and bacteria) attack in the field can worsen storage conditions and cause more severe damage or loss to wheat seeds. If the disease is only superficial, there will be a quality loss; if it spreads deeper into the seed layers, there may be a quantity loss. It is feasible to employ the remaining portion of the affected area when a superficial disease is present. Chemical losses result from pesticides and chemical interactions and include flavour, colour, texture, and nutritional value loss (Atanda, 2011). Due to enzyme-activated processes, biochemical losses can include softening, discolouration, and unpleasant flavour. Bruising, breaking, processing, and damage while handling or harvesting are all examples of mechanical losses. Climate conditions like low or high temperatures, unsuitable storage atmospheres, and high humidity are all related to physical losses. Chemical and metabolic losses can also be mediated by physical factors (Mohammed, 2014). Weight loss as a result of respiratory heat loss is considered a physiological loss. Infection and pathogen damage are more likely to occur during wilting, senescence, ripening, and wilting. In contrast to perishable crops, where losses are caused by mechanical, physiological, and microbial factors, biological and microbiological variables are significant in seed. Secondary crop losses caused by improper equipment, technology, and control handling are the variables that promote initial

crop losses. Lack of harvesting tools, expertise, packaging, handling, adequate containers, suitable transport, drying and storage conditions, correct processing technology, and competent management are the contributing factors (Kiaya, 2014).

3. Weight loss

Slimming down loss of weight is not always an indication of crop loss. Weight loss may be caused by a decrease in moisture content. Recognizing shrinkage factor is a useful technique in business transactions. If moisture loss is not taken into consideration when grading for price control, it might result in financial loss. Feeding birds, insects, rodents, and microbes can cause weight loss. By comparing the weight before and after being stored in the bag, weight loss can be calculated. Additionally, an increase in weight may result from an increase in moisture content brought on by water production in the seed brought on by insect infestation. Weight loss may be difficult to notice if insect infestation increases the moisture content of the seed or if insects devour the seed and leave behind dust (Boxall, 2001). A useful mass of infested and non-infested seeds is crushed into flour and their weights are compared in order to identify these losses. Infested mass will produce less flour than sound mass, as will be seen. Be on the lookout for unethical techniques that adulterate rocks, soil, sand, or water to compensate for weight loss. Therefore, it is necessary to evaluate both the amount of foreign matter present in the yield as well as variations in moisture (Grolleaud, 1997).

4. Quality decline or loss

Consumers place a high value on quality, and local merchants have various standards for judging it depending on the situation. Size, shape, and appearance are affected by biochemical elements such acidity, sugars, flavour, and fragrance. Contamination and the presence of foreign debris, such as bug pieces, rat hair, excrement, weed seeds, dirt, glass, and plant parts, can also cause quality degradation. Pesticides, oils, poisons created by fungi, soluble insect excrement, and dangerous organisms transferred by rodents are among the contaminants that are challenging to remove. Consumers boosting the standard norms will result in an increase in loss potential (Lipinski et al., 2013).

5. Nutrient loss

The loss is based on the qualitative and quantitative nutritional value lost to the human population, which has an impact on that people's nutritional state. This is primarily brought on by pests feeding on particular seed parts. Plodia and Ephestia consume the seed embryo selectively while removing the vitamin and protein content. Because so many pests consume cereal seed bran, the vitamin content is decreased. Selective feeding of Liposcelis spp. on rice bran and embryo. Weevil consumes endosperm and rejects the presence of carbohydrates (Grolleaud, 2002).

6. Reduction of seed viability

It is related to the decline in seed viability. Temperature, excessive respiration, moisture content, infestation, light, and infestation-control techniques could all be contributing factors to the losses. When compared to other insects, those that attack the embryo only suffer significant germination losses. Standard germination tests can be used to identify seed loss (ISTA, 1966).

7. Financial loss

Direct effects (the aforementioned causes) or indirect effects are both responsible for commercial losses (cost of preventive action or equipment). There could be a loss of reputation, financial loss, and loss brought on by legal action. Commercial loss might have an impact on international trade. With expertise and understanding, losses can be quickly minimised. Inappropriate storage is not always the cause of postharvest losses. The degradation of wheat seeds may be caused by biological, physical, or mechanical reasons. To get high-quality products from the farm to the market, it is necessary to expand the intervention approaches. For instance, Somalia and Malawi declined to accept the corn because of insect spread after the Tanzanian outbreak of pest in the maize crop (Tyler et al., 1990).

8. Damage based on temperature

Fresh goods rapidly decay when exposed to high-temperature sun radiation. The problem should be avoided by providing adequate ventilation and cooling for the crops. As temperature rises, respiration likewise rises. Similar to this, crops may suffer damage from low temperatures between 0 and 2°C. However, several plants from tropical and subtropical regions shown resistance to chilling injuries at 12–14°C. When a product is separated from its environment, chilling damage (skin pitting, discolouration, uneven or irregular ripening, and sensitivity to quick deterioration) become evident (Lipinski et al., 2013).

Estimation of losses

1. Estimation of seed losses in storage

Insects, rodents, and moulds are the main causes of seed loss during storage. Although many scientists have previously been interested in this topic, more effective methods must yet be developed in order to prevent insect-related seed loss. By boring or eating seeds, insects can cause both qualitative and quantitative loss; weight loss has received more attention (Boxall, 2002).

2. Insect related weight reduction

The evaluation is done by collecting samples of the seed at different points after storage and comparing the samples to see how they have changed. To estimate storage losses at various times, measuring amount loss with successive samples taken at various intervals will be employed. Each seed batch's sample collection and quantity loss are evaluated in accordance with this. Samples must be taken in bulk stores without disrupting the pattern of infestation. When further regular sampling is not practicable, three samples must be taken: the first at the beginning of storage, the second at the halfway point of the storage period, and the third at the end of the seed's storage duration. It is observed that utilised seed and quantity loss follow a pattern (Boxall, 2001).

3. Techniques for calculating weight loss

When additional sampling is possible, two techniques are employed to estimate the weight loss of the insects: the volumetric approach and the thousand grain mass (TGM) method. When further sampling is not practicable, count and weight procedures as well as converted percentage methods are employed (Boxall, 2002).

4. Volumetric approach

Bulk density method and standard volume weight (SVW) are two names for the volumetric approach. By using equipment, this is utilised to determine the bulk density of a clean sample. From the sample of seeds taken at the start of the storage period, SVW is calculated, and losses are calculated. Using a standard volume container, this method precisely measures the weight loss caused by grain boring insects and moisture variation over time. Moisture can be treated as a constant term and the crop as dry matter in the stand volumetric method to establish an appropriate ratio for moisture content and dry weight of seed. Changes in moisture content, however, can also have an impact on volume and frictional characteristics. Because there is a direct correlation between sample volume and moisture content, the seed should be packed loosely. Calculating the standard volume of dry matter at various moisture contents is important to keep the moisture constant. The procedure takes time, care, and a well-equipped laboratory (Adams, 1978). Weight of insecticidal dust, which sticks to the seed surface and increases the volume of seed and frictional character, is another factor that influences sample volume. The process of sieving can be helpful in removing dust. Volumetric phenomena, however, are less useful since losses are overestimated (FAO, 2013).

5. Using the mass in thousand grains

With a fixed number of seeds instead of a constant volume, this method varies from the volumetric method. This indicates that the weight of the seeds is multiplied by 1,000 and adjusted for dry matter. It is determined by weighing and tallying the seeds in a particular sample. Measurements are taken at the start of seed storage to establish a baseline reading, which is then used to compare future measurements(Reed, 1987).

6. The count and weight approach

When the baseline readings of seed storage are not collected at the beginning of the season, the method sometimes called "Gravimetric method" is used. This estimation makes use of a sample of 1000 seeds and a basic medium. After separating the damaged seeds, the weight and quantity of seeds in each sample fraction are calculated. The values are then entered into the ensuing equation to determine the outcomes:

$$\text{Wt. loss (\%)} = \frac{(UxNd)-(DxNa)}{U(Na+Na)}x100 \qquad (1)$$

Where,

U = weight of the undamaged seeds (g),

D = weight of the damaged seeds (g),

Na = the number of the undamaged seeds, and

Nd = the number of the damaged seeds

For a single sample, this approach does not require the moisture content of the distinct fraction, and the changes in assumptions are most likely negligible. The method does take into account concealed infestation in the damaged category, as well as insect-random seed infestation, which is not always accurate (Adams and Harman, 1977). For low levels of infection

and many infestations in large seeds, the approach can produce false findings. The technique is helpful for rapid estimating at extremes at the field level. Many improvements have been developed in order to overcome the biased estimation. For instance, different-sized seeds can have hidden infestations due to their varying moisture levels. Before counting and weighing, these seeds are categorised and graded according to size (Boxall, 1986); seriously harmed grains are segregated, and readings of hidden grains are collected after infestation appears (Ratnadass et al., 1994). The hidden infection can also be determined by dissecting seeds, however this procedure is time-consuming and runs the risk of changing the moisture content of the seeds due to calculations that must be conducted on dry matter.

7. Vertebral pest losses

It is impossible to measure the damage caused by vertebral pests because they remove the entire seed from the sample, like rats and birds do. By comparing the reference % of seed loss and average seed weight, the loss can be calculated (Boxall and Gillett, 1982). Than estimate the losses caused by pests and rodents, population studies and feeding experiments are used, although their accuracy is frequently inferior to that of increased efforts (Hernandez and Drummond, 1984). Pests only consumed stored grains as part of their diet; feeding experiments may overstate the loss of seeds that were kept in storage. It's debatable how much seed rodents actually destroy. When compared to losses to buildings, structures, personal property, and potential health issues, crop loss from rodents comes in last.

8. Weight loss by molds

Mold-infected seeds will lose weight, and the weight loss can be measured using the same technique as weight loss caused by insects. The weight loss from the mouldy seed increased as a result of moisture absorption, allowing for compensation of the mould loss. Due to the lack of obvious signs of infection on the surface, the procedure is not very effective in determining the actual loss of seeds, and the seeds may be mistaken for undamaged ones. Damaged seeds are distinguished from undamaged seeds in order to calculate the weight loss caused by mould. Moldy seeds are then distinguished from damaged seeds. Mold will cause a loss of weight that is equal to its own weight (Boxall, 2001).

9. Total seasonal loss

The losses listed above represent the starting losses for a particular period of time. The image might not be accurate; there must be a connection between the patterns of seeds used during a season. In an undisturbed stored crop, insects will be responsible for the majority of the loss if sample loss is 10% throughout the course of storage seasons. Due to insect exposure throughout various time periods during the season, the seeds will lose variable amounts at different intervals of time (Boxall, 2001). With time, as pest infestation grows, the percentage of seeds lost increases gradually. When the moisture content of the seeds has been taken into account, the loss in seeds can be estimated by weighing the seeds both when they are still in the store and when they are taken out. By deducting the loss brought on by other insects, the loss not caused by insect damage can be found. The actual seed losses after storage are far lower than the estimated amount. Numerous loss assessment procedures for businesses and farms have been reported (Boxall, 1986). To acquire the greatest assessment results, it's important to develop a process that works for each commodity. Small numbers of losses were reported for commercial operations, but none were reported for cooperative level storage. The situation is a

reflection of the quick purchasing and selling of seeds in developing nations. This paints an image of private sector involvement (market emancipation and parastatal marketing), but there is little data on storage loss. Entrepreneurs might keep a lot of seed in storage for a while. However, this level of farm storage has been raised by the private sector. To measure the storage losses in agricultural storage, a lot of time, energy, and money were expended, but the endeavour was not as successful as the prior initiatives. Additionally, the study ought to be conducted with the post-harvest industry as a whole, and exact measurements ought to be avoided. A social survey might be useful in identifying the farmers' issues so that loss estimation and the proper measuring methods can be used (Goletti and Wolff, 1999).

Harvest and maturity indices

Commodities that have been harvested or handled carelessly may have bruises and other injuries, which have a negative impact on their market value and render them unsightly. Injuries create a place for microbial attack that leads to rotting, increased respiration, and a reduction in storage life. Crop loss and serious seed damage might result from improper harvesting (FAO, 2011).

1. Harvesting and handling

The initial stage of postharvest and the final stage of crop production is harvest. The manner and state of the harvest have an impact on how the crops are handled, processed, and stored moving forward. Because of their high water content and premature harvest, seeds lose quality and degrade in storage. Crops that are harvested too early suffer biological and physical losses as a result of repeated watering and drying (Kiaya, 2014). After harvest, wet seeds must be promptly threshed and dried.

Different plant parts are harvested using different techniques: forage is harvested by trimming the entire plant; cereal seeds are harvested by threshing and cleaning a portion of the plant; and straw or chaff is harvested for further processing. Small-scale producers use threshing combines and harvesters (equipped by community organisations) to perform threshing and harvesting, but in developing nations, threshing and harvesting by hand is unlikely to cause harm to or degradation of stored crops. Mechanical harvester equipment is used by large-scale commercial growers, although its application is constrained by the growth of cash crops. Harvesting by hand lowers the danger of crop damage in storage after harvest. Threshing combines were used for small-scale production to perform the harvesting process (Kiaya, 2014). For the purpose of threshing, traditionally, seeds are thrashed with a stick or against a hard surface (wooden bar, log of wood, stone, and wooden metal or tub). The approaches may result in cracks or damage to the seeds, however walking on the seeds will be a less harmful method. Sorghum, millet, or wheat grain heads or ears are frequently bashed with sticks. However, hand harvesting is physically taxing and is not always the most cost-effective option. High-level damage is caused when maize cobs are pounded with sticks or shelled by hand. To lessen seed damage, mechanised threshers are designed; the models are quite complex.

Threshing, cleaning, or combine harvesters are used to harvest seeds in tandem with other processes. Mechanical machinery created specifically to collect grain seeds is used for large-scale harvesting (Boxall, 2002).

Seed storage facilities

Grains and seeds are hardy plants that typically only need straightforward storage arrangements.

1. On farm storage

The seeds must be protected against biological elements including microbes, birds, rodents, mites, and insects as well as physical harm from high temperatures, inclement weather, snow, and rain in order to store them safely outside or indoors. Many nations store the majority of their seeds using the agricultural storage method (Semple, 1992). The storage structure has a range of 100 kg to a few metric tonnes in terms of capacity. According to the weather, modifications to locally made storage structures could be made. There are a few conventional storage facilities. High-density and high-molecular-weight polyethylene, plywood, aluminium, ferro-cement, and other materials are frequently used to make the bins. Plywood is the most ideal material for storage structures, and hermetic storage underneath structures come in a variety of sizes and configurations. This increases the amount of carbon dioxide and decreases the amount of oxygen, which makes seed storage dangerous for insect and microbial attack (Shejbal and de Bioslambert, 1988). Although traditional approaches are less expensive, they are ineffective against microbial and pest attack. At the agricultural level, seeds are also kept in silos or metal bins.

2. Storage in bags

While silos for bulk storage, seeds elevators, and flat storage structures are utilised in rich countries, seeds are often stored in traditional warehouses in underdeveloped countries in gunny or woven polypropylene bags (Kennedy and Devereau, 1994). The procedure of bag storage is time-consuming and expensive, and there is a higher risk of biological losses and seed spilling. Due to warehouse flooring that isn't acceptable, there can be an issue with humidity and water seepage. Bags don't require any aeration equipment or fumigation facilities. The concept will not be viable in underdeveloped nations because of the tiny farm size and less expensive manual labour.

3. Bulk storage

There are two ways to store seeds in bulk: vertically (in silos or bins) or horizontally (on floor stores). Horizontal stores are made up of specifically built floors of warehouses with adequate ventilation on the floor and walls that are reinforced to support the weight of the seeds. Bins and silos are specially made storage units that can be circular or square, clustered or standalone, and include unloading and loading processes that typically include aeration systems. Belowground or partially belowground storage or enamelled, sealed silos for the storage of seeds with a high moisture content are further options for bulk storage. The procedure is suitable for handling or storing seeds in bulk (Bailey, 1992).

4. Hermetic storage

The seeds are protected from biological harm by the conventional techniques of storage in the natural oxygen build-up and lower oxygen levels. For seeds with lower moisture content and reduced infestation of insects per kilogramme of seeds, the conventional storage approach

is ineffective. In hermetic storage, the controlled environment treatment and fumigation must be augmented (Alvindia, 1994).

5. Outside storage

In the absence of permanent storage, this is the interim measure of storage. The stacks of seeds are covered with polyethylene covers, and the godowns and silos are constructed on plinths. In a week, the cover must be raised to the seventh or eighth layer in order to effectively aerate the stacks. For wheat and paddy, the cover and plinth (CAP) technique is frequently utilised. However, there is a danger that the cover will be damaged by wind or rain, making effective fumigation impossible (Semple, 1992).

6. Guidelines for quality seed storage

By specifically building the tiny stores to silos or warehouses that play a protective function against unfavourable temperature conditions, ground water, rain water, pests, and thefts, the quality of seeds may be maintained. The store's layout and contents need to be managed (Kiaya, 2014).

Moisture management

It is necessary to have a water disposal system and a well-designed roof (overhung or gutter) to stop water from flowing into the store. Water is moved away from the stores through drains. To stop water from dripping into the store, side-by-side connecting of shelves should be avoided in large warehouses. Water-resistant floors and walls protect against ground water, while a raised floor and efficient drainage systems reduce the risk of flooding. To regulate the humidity inside the storage structure, a suitable ventilation system is required (Boxall, 2001).

It is challenging to regulate temperature in storage structures; particular design components are required. The use of controlled ventilation can be used to measure temperature. Insulated shops can control temperature throughout the chilly night. Building stores in an east-west direction with reflective materials outside can be an efficient way to manage heat. The heat of the storage structure can be further reduced by thick walls and large roofs (for shade). To change the temperature in a store, heaters and refrigerators can be placed; the machinery works best in insulated stores. The degree of insulation in these storage structures, however, is dependent on the environment (Longstaff, 1988).

Controlled Atmosphere Storage (CAS) and Modified Atmosphere Storage (MAS)

To create a controlled atmospheric composition around seeds that differs from air (78.08 percent nitrogen, 20.95 percent oxygen, and 0.03 percent carbon dioxide), changed atmospheric conditions add or remove gases from the environment. This also entails a decrease in oxygen and an increase in carbon dioxide content. The degree of control between CAS and MAS varies, while CAS is more precise. The method is applied to make whole-store fumigation easier (Paster et al., 1991).

Transportation

Commodities being moved from fields to storage facilities may sustain some damage, which could subsequently result in produce degrading. The goal here is to keep the produce

dry and free of moisture. Seeds from the polluted container carry a residual risk of insect infestation. Vibration during transport, bad vehicle and road conditions, poor driving, unsafe container stacking, the use of inappropriate containers, and irresponsible handling can all result in mechanical injuries. Produce loses moisture due to overheating caused by the sun or a car's engine, which promotes natural decay and decomposition (Boxall, 2002).

Quality and safety

The class, degree, excellence, or superiority of a crop is determined by the quality of the product. The set of traits, qualities, and attributes that provide a commodity value as food or a source of the following crop's production collectively make up its quality. The marketing quality of the crop might be impacted by foreign material or high moisture content. In seeds, high moisture levels may promote shrinkage or biological and biochemical harm. Low moisture can break or harm the seeds in paddy rice and lentils. Broken and discoloured seeds have a lower marketable quality and are more susceptible to insect and microbial attack (Boxall, 2001). The fundamental goal of a farmer is to produce products that appear to be good and have few visible flaws. These products must also perform well in terms of yield, disease resistance, ease of harvest, shipping quality, and meeting national and international quality standards. The buyer or consumer places more value on looks; they are anxiously interested in good seed and long-term storage. For distribution to suppliers and the market, the product's safety must be guaranteed (Mohammed, 2014).

Future problems in postharvest technology of seeds

Demand for food has multiplied due to the growing urban population and changing lifestyle in developing nations. A unit called a seed is utilised to produce the following generation in addition to being eaten as food. Post-harvest management and seed quality preservation are the two viewpoints in seed biology that require the most focus. Though, significant progress has been made in recent years in the development of novel packaging, storage, and transport systems, pest control, and seed-borne disease management for market access. However, more study and technological advancement should be devoted to investigating genetic components of desirable qualities such stress resistance, resistance to postharvest illnesses, and pest management. Researchers ought to make an effort to develop integrated strategies for seed postharvest management. The discipline of nanotechnology is still developing, yet it is already producing amazing results in crop sciences. To preserve seeds for extended periods of time without affecting their genetic makeup, seed biologists should attempt to further their research in this area.

Conclusion

Quality of the seeds must be maintained for higher-quality harvests. Today, seed quality management is the biggest problem in developing countries. Improved post-harvest handling and seed storage methods need to be created in order to be more economical, useful, and efficient. The primary objective of research should be to translate knowledge into beneficial outcomes for agriculture. Factors affect seed quality, post-harvest seed storage methods, methodologies and safety precautions for their quality assessment to maintain good quality seeds to satisfy the requirements of developing countries, etc. are few important points for quality assurance of cereal seeds. A more advanced and sensitive technology might be used to do this, along with careful observation of how seeds interact with their surroundings.

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Determination of Moisture Content of Seed Lots

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Testing moisture content in Seed Sample is very important aspect of Seed Testing. The moisture content of a sample is the loss in weight when it is dried in accordance with the Seed Testing Rules. It is expressed as a percentage of the weight of the original sample. The submitted sample shall be accepted for moisture determination only if it is in intact, moisture - proof container from which as much air as possible has been excluded. The moisture determination of the seed sample must be started at earliest possible after receipt of sample.

Procedures:

Weighing shall be in grams to three decimal places. Seeds of larger size (Table 1.) are ground before drying unless its high oil content makes it difficult. After grinding, the sample is passed through different sizes of sieves (Table 2.). Pre-drying before grinding is required for samples having moisture content more than 17%. After pre-drying, the sub-samples are reweighed in their containers to determine the loss in weight.

I. Low constant temperature oven method:

The working sample must be evenly distributed over the surface of the container. Weigh the container and its cover before and after filling. Place the container rapidly, on top of its cover, in an oven maintained at a temperature of 103 ± 2°C and dry for 17 ± 1 hour. The drying period begins at the time the oven returns to the required temperature. At the end of the prescribed period, cover the container and place it in a desiccators to cool for 30-40 minutes. After cooling, weigh the container with its cover and contents. The relative humidity of the ambient air in the laboratory must be less than 70% at the time of final weighing. ISTA prescribes the low constant temperature oven method, for all tree species. Normally oilseeds are subjected to low constant temperature oven method while cereals and pulses are subjected to high constant temperature oven method.

II. High constant temperature oven method:

The procedure is the same as low constant temperature oven method, except that the oven is maintained at a temperature of 130-133°C, the sample is dried for a period of four hours for tree species and no special requirement pertain to the relative humidity of the ambient air in the laboratory during determination.

The moisture content expressed as a percentage by weight shall be calculated to one decimal place by means of the following formula:

$$\% = \frac{M2 - M3}{M2 - M1} * 100$$

Where,

M_1 - is the weight of the container and its cover (in grams),

M_2 - is the weight of the container & its cover (in grams) and its contents before drying and

M_3 - is the weight of the container, cover (in grams) and contents after drying.

If the material is pre-dried, the moisture content is calculated form the results obtained in the first (pre-dried), the second stages of the procedure. If S_1 is the moisture lost in the first stage, and S_2 is the moisture lost in the second stage, each calculated as above and expressed as a percentage, then the original moisture content of the sample calculated as a percentage is

$$S1 + S2 - \frac{S1 * S2}{100}$$

Table 1. Grinding requirements for Different Crop Seeds:

Crop	Grinding	Mesh size	
Paddy, wheat, maize, sorghum, cotton	Fine	50% ground material is passed through 0.5 mm mesh	10% ground material remain on 1.00 mm mesh
Pea, chickpea, soybean, lathyrus	Coarse	50% ground material is passed through 4 mm mesh	

Table 2 . Pre-drying requirements:

Crop	Moisture content	Temperature required for Drying (in °C)	Duration
Maize	>25%	>0	2 - 5 hrs
Rice	>13%	130	5 - 10 min
Soybean	>10%	130	5 - 10 min

III. Universal moisture meter:

Universal moisture meter is a popular and most dependable instrument for moisture estimation. The following are its essential parts:

1. Compression unit
2. Moisture meter dial
3. Thermometer
4. Compression knob
5. Cups of different volumes

Moisture estimation is made quick by the advent of digital moisture meters. The principle involved is that electrical conductivity of moist material is directly proportionate to the amount of moisture content in it. A representative sample of prescribed weight or volume (Table 3.) is taken and placed in the sample cup. It is fixed in the lower house of compression unit.

Meter is calibrated by pressing the button "CAL" and "BELL" with the help of calibration knob. Sample is compressed as per requirement with the help of compression knob and scale. At required compression the meter dial (M) is read by pressing the knob "Read" and bell. Temperature (T) is observed by the thermometer fixed in between meter dial and compression chamber. The reading M and T are intercepted on the corelator dial (moisture meter dial) by turning the temperature dial. On adjustment of both the reading mark of arrow on the outer reading of temperature dial indicates the moisture percentage. For some crops factor is also considered for estimation of moisture content.

Table 3. Determination of moisture content by universal moisture meter:

Crop	Sample size		Compression	Factor
	Weight (g)	Volume*		
	FIELD AND FODDER CROPS			
Barley	50	B	0.600	
Maize	60	B	0.560	
Oat	30	B	0.400	
Pearl millet	60	B	0.500	
Rice	50	B	0.550	
Sorghum	50	B	0.675	
Wheat	30	A	0.275	Add 1%
Moong and urid		A	0.275	Add 1.5%
Chickpea		C	0.500	Subtract 1%
Horse gram		A	0.275	
Lentil		A	0.250	x 0.7 + 3.5%
Pigeon pea, field pea		C	0.450	
Castor		C	0.500	Multiplied by 0.5
Groundnut	25		0.300	Multiplied by 0.6
Groundnut (kernel)	26		0.450	Multiplied by 0.56
Safflower	15		0.450	Multiplied by 0.66
Sesame			0.550	Subtract 0.5%
Soybean	60	C	0.575	Subtract 2.5%
Sunflower	30	B	0.500	Multiplied by 0.6
Rape seed and mustard			0.450	Multiplied by 0.6
Cotton (linted)	30	C	0.360	Subtract 5%
	VEGETABLES			
Kidney bean	50	B	0.400	
Okra		C	0.425	
Cabbage		A	0.260	Multiplied by 0.6
Cowpea		A	0.325	Multiplied by 0.8
Cucumber		B	0.525	Multiplied by 0.8
Lettuce		B	0.500	Multiplied by 0.9
Onion		A	0.250	Subtract 2.5%
Tomato	25	B	0.250	Multiplied by 0.8
Turnip	25		0.200	Multiplied 0.8
Watermelon		B	0.425	Subtract 3.5%
Coriander		C	0.325	Multiplied by 0.6

* A, B and C - Container size

The moisture content must be reported to the nearest 0.1% in the space provided on the Analysis Certificate. Seed lot with moisture content more than the minimum seed certification standards (Table 4.) are recommended for drying.

Table 4. Minimum seed certification standard for moisture percentage:

Crop	Sample in vapour proof container	Sample not in vapour proof bag
FIELD AND FODDER CROPS		
Castor, mustard, taramira	5	8
Groundnut, niger, sesame	5	9
Cotton	6	10
Rape seed	7	8
Linseed, horse gram, rajmash, safflower, sunflower, jute	7	9
Berseem, lucerne, Indian clover	7	10
Soybean	7	12
Moong, urid, chickpea, field pea, pigeon pea, lentil, lathyrus, kidney bean, rice bean	8	9
Buffel, Dharaf, Dinanath, guinea, marvel, setaria and stylo grass	8	10
Wheat, maize, sorghum, pearl millet, barley, triticale, oat, minor millets, teosinte, forage sorghum	8	12
Rice	8	13
VEGETABLES		
Rat tail radish, radish, turnip	5	6
Cole crops	5	7
All cucurbits	6	7
TPS, brinjal, tomato, chilli, capsicum, onion, fenugreek, lettuce, amaranth, asparagus	6	8
Carrot, celery, parsley	7	8
French bean	7	9
Cowpea, Indian bean, cluster bean, spinach, sugar beat	8	9
Okra	8	10

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Quality Seed Production Technology in Small Millets

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Small millets are nutri-rich, climate-resilient food and fodder crops. They include finger millet, proso millet, foxtail millet, little millet, kodo millet, browntop millet, and barnyard millet. They are self-pollinated crops and belong to the family Poaceae.Small millet cultivation is an ancient practice, with small millets being important staple crops in many regions.Quality seed production plays a crucial role in small millet cultivation as it ensures the availability of genetically pure and high-yielding varieties.

Benefits of Enhanced Quality Seed Production

- Enhanced quality seeds lead to higher yields and improved crop quality, contributing to food security.
- Resistance to pests and diseases is increased, reducing the need for chemical interventions.
- Uniformity and consistency in growth result in more efficient crop management.
- Enhanced seed production practices promote economic and environmental sustainability.

Challenges in Small Millet Seed Production

- Limited availability of quality seeds hampers the expansion of small millet cultivation.
- Maintaining varietal purity is essential to ensure the desired traits in small millets.
- Effective pest and disease management is crucial to mitigate crop losses.
- The lack of awareness and training among farmers about seed production techniques hinders progress.

Steps in Quality Seed Production

- Careful selection and maintenance of parent materials ensure the desired traits are passed on to the offspring.
- Controlled pollination and hybrid seed production techniques help maintain varietal purity and improve yields.
- Seed processing techniques such as cleaning, grading, and drying are crucial for ensuring seed quality and longevity.
- Seed quality testing and certification ensure that only high-quality seeds reach the market.

Best Practices for Small Millet Seed Production

To achieve high quality seed production in small millets, it is recommended to follow these practices:

1) Select healthy and disease free parent plants for seed production.
2) Implement proper isolation distance to avoid cross pollination.
3) Carry out timely and efficient harvesting to ensure seed maturity.
4) Properly clean and dry the harvested seeds to maintain their quality.
5) Use appropriate storage techniques, such as cool and dry conditions to prevent mold or insect infestation.

6) Regularly monitor seed quality through germination tests and seed health checks

FINGER MILLET

`Finger millet or Ragi*(Eleusinecoracana*)is one of the important minor milletsbelonging to the family Gramineae. Thisis widely grown in hilly and rainfed areas. It is atropical crop can be grown to an altitude of 2100metres. The best season for seed production isDecember – January. Pollination should notcoincide with rains for quality and effective seedsetting. The temperature of 37°c is favourableforseed setting.

Method of seed production:
Ragi is a self-pollinated crop and should beraised in isolation. The isolation distancemaintained between the varieties is 3 metresforboth foundation and certified seed production tomaintain the varietal purity.

Seed production stages
Breeder seed - Foundation seed –Certifiedseed

Land selection
Ragi can be grown in poor to fertile soil. The cropcan tolerate salinity better than any other crops.The selected land should be free from volunteerplants. The land should not be cultivated withsame crop in the previous season. Land shouldbe ploughed 2 - 3 times to get fine tilth andlevelled.

Seed selection and sowing
Ragi is a season bound crop and the best seasonto take up sowing is December - January andJune - July. Seeds used for seed productionshould be of good quality certified seeds from anauthentic source. Seeds should be healthy withrequired germination percentage. Recommendedseed rate is 2 kg/acre (5 kg/ha). Selectedseeds should be treated with Azospirillum@ 125gms/kg of seeds.

Main field preparation

The main field is prepared with 2 – 3 ploughingto make it a fine tilth and formed into ridges andfurrows. During final plough apply compost orfarmyard manure @ 5 tonnes/acre (12.5 tonnes/ha) and incorporate into the soil. 20 - 25 daysold seedlings transplanted to the main field. Twoseedlings per hill should be planted. Follow aspacing of 15× 15 cm.

Nutrient management

Before final ploughing compost or farmyard manure @ 5 tonnes/acre (12.5 tonnes/ha) should be applied and ploughed into the soil.

Weed management

The seed production field should be maintained weed free from the initial stage. The first weedingshould be done on 15th day after planting and followed by the second one on 30th day. Afterhand weeding allow the weeds to dry for 2 – 3 days.

Irrigation

The irrigation should be done once a week after life irrigation on the third day of sowing. Irrigationduring flowering and grain setting stages are very critical.

Pest and disease management

Ragi is affected by pests and diseases like pink stem borer, aphids, root aphids, earhead caterpillars, blast, brown spot, mottle streak virus etc., at different growth stages.

Field inspection

A minimum of two inspections should be done between flowering and maturity stages by the Seed Certification Officer. The first inspection is done at the time of flowering to check the isolation and off-types and the second done during the maturity stage prior to harvest to check theoff-types and to estimate the yield.

Harvesting and processing

Harvest is done once the earheads are physiologically mature. Physiologically mature earheads will turn from brown to green colour. Harvesting is done in two pickings since, the maturation of the earheadsare not uniform because of the tillering habit of the crop. Second harvesting should be done seven days after the first one. Mature earheads should be harvested and threshed with bamboo sticks. Threshed grains are further cleaned by winnowing.

Drying and storage

The cleaned seeds should be sun dried to attain a safe moisture level of 12%. Care should be takenwhile drying to avoid mechanical injury to the seeds and contamination. Seeds can be storedupto 13 months under proper storage conditions.

Field Standards for Seed Certification in Finger Millet

Field Standards	FS	CS
Minimum field inspection (number)	3	3
Minimum isolation distance (meters)	3	3
Maximum off-type (%)	0.05	0.05
Maximum objectionable weeds (%)	-	-
Maximum different crop plants (%)	-	-

Maximum objectionable diseases (%)	-	-

Seed Standards for Seed Certification in Finger Millet

Seed standards	FS	CS
Minimum physical purity (%)	97	97
Maximum inert matter (%)	2	2
Maximum other distinguishing varieties (number/kg)	-	-
Maximum other crop seed (number/kg)	10	20
Maximum other weed seed (number/kg)	10	20
Maximum objectionable weeds (number/kg)	-	-
Maximum objectionable diseases (percentage by number)	-	-
Minimum germination (%)	75	75
Maximum moisture (%)		
Ordinary container	12	12
Vapour proof container	8	8

KODO MILLET

Kodo millet *(Paspalumscrobiculatum)* is a well knownminor millet belonging to the familyGramineae. This coarse millet is highly resistantto drought and can also be cultivated in the areaswith 400 - 500 mm annual rainfall. It is grown in gravelly and stony upland poor soils to loamysoils. Seed production can be done in June – July and February – March. The pollination shouldnot coincide with rains for quality and effective seed setting.

Method of seed production

Kodo millet is a self-pollinated crop. The crop should be raised in isolation. The isolation distance maintained between the varieties is 3 metres for both foundation and certified seed production to maintain the varietal purity.

Seed production stages

Breeder seed - Foundation seed -Certified seed

Land selection
The selected land should be free from volunteer plants. The land should not be cultivated with thesame crop in the previous season. Land should be fertile with good drainage facility.

Seed selection and sowing
Seeds used for seed production should be of good quality certified seeds from an authentic source. Seeds should be healthy with required germination percentage. In North India, sowing should be done in mid June to mid July and in South India during September – December. Recommended seed rate is 4 kg/acre (10 kg/ha). Selected seeds should be treated with Azospirillum @ 60 gms/kg of seeds. Treated seeds should besown with a spacing of 30 x 10 cm. Seeds should be sown at the depth of 3 – 4 cm.

Main field preparation
The main field should be ploughed before the onset of monsoon to enable the soil to hold the moisture. At the onset of monsoon field should be ploughed for 2 – 3 times to make it a fine tilth and formed into ridges and furrows. During final plough apply compost or farmyard manure
@ 5 tonnes/acre (12.5 tonnes/ha) and incorporate into the soil. Seeds can be sown in the ridges witha spacing of 30 × 10 cm.

Nutrient management
Before final ploughing compost or farmyard manure @ 5 tonnes/acre (12.5 tonnes/ha) should be applied and ploughed into the soil.

Weed management
The seed production field should be maintained weed free from the initial stage. It is essential to control the weeds in the initial stages of plant growth especially upto 35 – 40 days after sowing. Generally two weedings at an interval of 15 days is sufficient. Weeding can be done with hand hoeor wheel hoe in line sown crop.

Irrigation
Kharif season crop does not require any irrigation, it is mostly grown as a rainfed crop. In the absence of rains one or two irrigation can be done. During heavy rains the excess water from the field should be drained out.

Pest and disease management
Kodo millet is affected by shoot fly pest and head smut disease at different growth stages.

Field inspection
A minimum of two inspections should be done between flowering and maturity stages by the Seed Certification Officer. The first inspection is done at the time of flowering to check the isolation and off-types and the second done during the maturity stage prior to harvest to check theoff-types and to estimate the yield.

Harvesting and processing
Harvest is done once the earheads are physiologically mature. Normally crop is ready for harvest in 100 days. Physiologically mature earheads will turn from brown to green colour. Plants are cut close to the ground level, bundled and stacked for a week before threshing. The

earheads are threshed by trampling under the feet of bullocks. The threshed grains are further cleaned by winnowing.

Drying and storage

The cleaned seeds should be sun dried to attain a safe moisture level of 12%. Care should be takenwhile drying to avoid mechanical injury to the seeds and contamination. Seeds can be storedupto 13 months under proper storage conditions.

Field Standards for Seed Certification inkodo Millet

Field Standards	FS	CS
Minimum field inspection (number)	3	3
Minimum isolation distance (meters)	3	3
Maximum off-type (%)	0.05	0.10
Maximum objectionable weeds (%)	-	-
Maximum different crop plants (%)	-	-
Maximum objectionable diseases (%)	-	-

Seed Standards for Seed Certification in Kodo Millet

Seed standards	FS	CS
Minimum physical purity (%)	97	97
Maximum inert matter (%)	2	2
Maximum other distinguishing varieties (number/kg)	-	-
Maximum other crop seed (number/kg)	10	20
Maximum other weed seed (number/kg)	10	20
Maximum objectionable weeds (number/kg)	-	-
Maximum objectionable diseases (percentage by number)	-	-
Minimum germination (%)	75	75
Maximum moisture (%)		
Ordinary container	12	12
Vapour proof container	8	8

FOXTAIL/ITALIAN MILLET

Foxtail millet ***(Setariaitalica)*** is a well known minor millet variety belonging to the family Gramineae. It is cultivated in both tropical and temperate regions. The crop can be grown upto an altitude of 200 meters. The crop can be grown successfully in areas receiving 750 mm of annual rainfall. Best season for seed production is June - July and February – March. The pollination should not coincide with rains for quality and effective seed setting.

Method of seed production
Foxtail millet is a self-pollinated crop and should be raised in isolation. The isolation distance maintained between the varieties is 3 metres for both foundation and certified seed production to maintain the varietal purity.

Seed production stages
Breeder seed -Foundation seed - Certified seed

Land selection
Foxtail millet needs moderately fertile soil for good yield. The selected land should be free from volunteer plants. The land should not be cultivated with same crop in the previous season. Land should be ploughed 2 - 3 times to get a fine tilth and levelled.

Seed selection and sowing
Seeds used for seed production should be of good quality certified seeds from an authentic source. Seeds should be healthy with required germination percentage. Recommended seed rate is 2 kg/acre (5 kg/ha). Selected seeds should be treated with Azospirillum @ 125 gms/kg of seeds. Treated seeds should be sown with a spacing of 30 x 10 cm at a depth of 3 – 4 cm.

Main field preparation
The main field should be ploughed for 2 – 3 times to make it a fine tilth and formed into ridges and furrows. During final plough apply compost or farmyard manure @ 5 tonnes/acre (12.5 tonnes/ ha) and incorporate into the soil. Seeds can be sown in the ridges at a depth 3 - 4 cm with a spacing of 30 × 10 cm.

Nutrient management
Before final ploughing compost or farmyard manure @ 5 tonnes/acre (12.5 tonnes/ha) should be applied and ploughed into the soil.

Weed management
The seed production field should be maintained weed free. Weeding can be done with a tyneharrow when the crop is 30 days old. Allow the weeds to dry for 2 - 3 days after hand weeding.

Irrigation
Kharif season crop does not require any irrigation. It is mostly grown as a rainfed crop. However, if the dry spell prevails for longer period, then 1 - 2 irrigations should be given to boost the yield. Summer crop requires 2 - 5 irrigations depending upon soil type and climatic conditions. During heavy rains the excess water from the field should be drained out.

Pest and disease management
Foxtail millet is affected by pests like army worm, cut worm, leaf scrapping beetle and shoot fly and diseases like blast and rust at different growth stages.

Field inspection
A minimum of two inspections should be done between flowering and maturity stages by the Seed Certification Officer. The first inspection is done at the time of flowering to check the

isolation and off-types and the second inspection is done during the maturity stage prior to harvest to check the off-types and to estimate the yield.

Harvesting and processing

Harvest is done once the earheads are physiologically mature. Normally crop is ready for harvest in 80 - 100 days after sowing. Physiologically mature earheads will start to dry. Plants are either harvested intact with earheads or earheads alone. The earheads are dried before threshing. The earheads are threshed bystone roller or trampling under the feet of bullocks. The threshed grains are further cleaned by winnowing.

Drying and storage

The cleaned seeds should be dried under the sun to attain a safe moisture level of 12%. Care should be taken while drying to avoid mechanical injury to the seeds and contamination. Seeds can be stored upto 13 months under proper storage conditions.

Field Standards for Seed Certification in Foxtail Millet

Field Standards	FS	CS
Minimum field inspection (number)	3	3
Minimum isolation distance (meters)	3	3
Maximum off-type (%)	0.05	0.10
Maximum objectionable weeds (%)	-	-
Maximum different crop plants (%)	-	-
Maximum objectionable diseases (%)	-	-

Seed Standards for Seed Certification in Foxtail Millet

Seed standards	FS	CS
Minimum physical purity (%)	97	97
Maximum inert matter (%)	2	2
Maximum other distinguishing varieties (number/kg)	-	-
Maximum other crop seed (number/kg)	10	20
Maximum other weed seed (number/kg)	10	20
Maximum objectionable weeds (number/kg)	-	-
Maximum objectionable diseases (percentage by number)	-	-
Minimum germination (%)	75	75
Maximum moisture (%)		
Ordinary container	12	12
Vapour proof container	8	8

PROSO MILLET

Proso millet *(Panicum miliaceum)* is a common and important minor millet belonging to the family Gramineae. This short duration millet variety is widely grown in India. The crop is able to evade drought by its quick maturity. Best season for seed production is June - July and February – March. The pollination should not coincide with rain for quality and effective seed setting.

Method of seed production

Proso millet is a self-pollinated crop and should be raised in isolation. The isolation distance maintained between the varieties is 3 metres for both foundation and certified seed production to maintain the varietal purity.

Seed production stages

Breeder seed - Foundation seed- Certified seed

Land selection

Proso millet can be cultivated in both rich and poor soils. Well drained loam or sandy loam soils rich in organic matter are ideal for cultivation. The selected land should be free from volunteer plants. The land should not be cultivated with same crop in the previous season.

Seed selection and sowing

Seeds used for seed production should be of good quality certified seeds from an authentic source. Seeds should be healthy with required germination percentage. Recommended seed rate is 4 kg/acre (10 kg/ha). Selected seeds should be treated with Azospirillum @ 60 gms/kg of seeds. Treated seeds should be sown with a spacing of 30 x 10 cm. Seeds should be sown in June – July onset of monsoon rains. Summer crop should be sown in the month of February – March. Seeds are broadcast manually or by seed driller in furrows at a depth of 3 – 4 cm

Main field preparation

The main field should be harrowed for 2 – 3 times to make it a fine tilth and levelled. The levelled field is formed into ridges and furrows. During final plough apply compost or farmyard manure @ 5 tonnes/acre (12.5 tonnes/ha) and incorporate into the soil. Seeds can be sown in the ridges at a depth 3 - 4 cm with a spacing of 30× 10 cm.

Nutrient management

Before final ploughing compost or farmyard manure @ 5 tonnes/acre (12.5 tonnes/ha) should be applied and ploughed into the soil.

Weed management
The seed production field should be maintained weed free at least upto 35 days after sowing for retaining the soil moisture and nutrients. Subsequent weeding should be done at an interval of 15 – 20 days. Weeding can be done with a handhoe or wheel hoe.

Irrigation
Kharif season crop does not require any irrigation. However, if the dry spell prevails for longer period 1 - 2 irrigations should be given at the tillering stage to boost the yield. First irrigation should be given 25 - 30 days after sowing followed by the second one at 40 – 45 days after sowing. Summer crop requires 2 - 4 irrigations depending upon soil type and climatic conditions. During heavy rains the excess water from the field should be drained out.

Pest and disease management
Proso millet is commonly affected by shoot fly and there is no other remarkable disease incidence.

Field inspection
A minimum of two inspections should be done between flowering and maturity stages by the Seed Certification Officer. The first inspection is done at the time of flowering to check the isolation and off-types and the second inspection is done during the maturity stage prior to harvest to check the off-types and to estimate the yield.

Harvesting and processing
Harvest is done once the earheads are physiologically mature. Normally crop is ready for harvest in 65 - 75 days after sowing. The crop should be harvested when two thirds of the seeds are ripe. The harvested earheads are threshed by hand or trampling under the feet of bullocks. The threshed grains are further cleaned by winnowing.

Drying and storage
The cleaned seeds should be sun dried to attain a safe moisture level of 12%. Seeds can be stored upto 13 months under proper storage conditions.

Field Standards for Seed Certification in Proso Millet

Field Standards	FS	CS
Minimum field inspection (number)	2	3
Minimum isolation distance (meters)	3	3
Maximum off-type (%)	0.05	0.10
Maximum objectionable weeds (%)	-	-
Maximum different crop plants (%)	-	-
Maximum objectionable diseases (%)	-	-

Seed Standards for Seed Certification in Proso Millet

Seed standards	FS	CS
Minimum physical purity (%)	97	97
Maximum inert matter (%)	2	2
Maximum other distinguishing varieties (number/kg)	-	-
Maximum other crop seed (number/kg)	10	20

Maximum other weed seed (number/kg)	10	20
Maximum objectionable weeds (number/kg)	-	-
Maximum objectionable diseases (percentage by number)	-	-
Minimum germination (%)	75	75
Maximum moisture (%)		
Ordinary container	12	12
Vapour proof container	8	8

LITTLE MILLET

Little millet (Samai) (Panicum sumatrense) belongs to the family Gramineae. The crop can grow well in drought conditions and considered as a good famine food as it can produce some grain even under severe drought conditions when all the other crops fail to produce. It is a typical dryland crop suitable for the areas with low rainfall and poor soils. Seed production can be done during June – July and February – March. The pollination should not coincide with rains

for quality and effective seed setting.

Method of seed production

Little millet is a self-pollinated crop and should be raised in isolation. The isolation distance maintained between the varieties is 3 metres for both foundation and certified seed production to maintain the varietal purity.

Seed production stages

Breeder seed - Foundation seed - Certified seed

Land selection

Little millet can be cultivated in both rich and poor soils. Well drained loam or sandy loam soils rich in organic matter are ideal for cultivation. The selected land should be free from volunteer plants. The land should not be cultivated with same crop in the previous season.

Seed selection and sowing
Seeds used for seed production should be of good quality certified seeds from an authentic source. Seeds should be healthy with required germination percentage. Recommended seed rate is 4 kg/acre (10 kg/ha). Selected seeds should be treated with Azospirillum @ 60 gms/kg of seeds. Treated seeds should be sown with a spacing of 30 x 10 cm. Seeds should be sown in June – July at the onset of monsoon rains. Summer crop should be sown in the month of February – March. Seeds are broadcast manually or by seed driller in furrows at a depth of 3 – 4 cm.

Main field preparation
The main field should be harrowed for 2 – 3 times to make it a fine tilth and levelled. The levelled field is formed into ridges and furrows. During final plough apply compost or farmyard manure @ 5 tonnes/acre (12.5 tonnes/ha) and incorporate into the soil. Seeds can be sown in the ridges at a depth 3 - 4 cm with a spacing of 30 × 10 cm.

Nutrient management
Before final ploughing compost or farmyard manure @ 5 tonnes/acre (12.5 tonnes/ha) should be applied and ploughed into the soil.

Weed management
The seed production field should be maintained weed free at least upto 35 days after sowing for retaining the soil moisture and nutrients. Subsequent weeding should be done at an interval of 15 – 20 days. Weeding can be done with handhoe or wheel hoe.

Irrigation
Kharif season crop does not require any irrigation. However, if the dry spell prevails for longer period at least one irrigation should be given at the tillering stage to boost the yield. First irrigation should be given 25 - 30 days after sowing followed by the second one at 40 – 45 days after sowing. Summer crop requires 2 - 4 irrigations depending upon soil type and climatic conditions. During heavy rains the excess water from the field should be drained out.

Pest and disease management
Little millet is commonly affected by shoot fly and there is no other remarkable disease incidence.

Field inspection
A minimum of two inspections should be done between flowering and maturity stages by the Seed Certification Officer. The first inspection is done at the time of flowering to check the isolation and off-types and the second inspection is done during the maturity stage prior to harvest to check the off-types and to estimate the yield.

Harvesting and processing
Harvest is done once the earheads are physiologically mature. Normally crop is ready for harvest in 80 - 85 days after sowing. The crop should be harvested when two thirds of the seeds are ripe. The harvested earheads are threshed by hand or trampling under the feet of bullocks. The threshed grains are further cleaned by winnowing.

Drying and storage

The cleaned seeds should be sun dried to attain a safe moisture level of 12%. Seeds can be stored upto 13 months under proper storage conditions.

Field Standards for Seed Certification in Little Millet

Field Standards	FS	CS
Minimum field inspection (number)	3	3
Minimum isolation distance (meters)	3	3
Maximum off-type (%)	0.05	0.10
Maximum objectionable weeds (%)	-	-
Maximum different crop plants (%)	-	-
Maximum objectionable diseases (%)	-	-

Seed Standards for Seed Certification in Little Millet

Seed standards	FS	CS
Minimum physical purity (%)	97	97
Maximum inert matter (%)	2	2
Maximum other distinguishing varieties (number/kg)	-	-
Maximum other crop seed (number/kg)	10	20
Maximum other weed seed (number/kg)	10	20
Maximum objectionable weeds (number/kg)	-	-
Maximum objectionable diseases (percentage by number)	-	-
Minimum germination (%)	75	75
Maximum moisture (%)		
Ordinary container	12	12
Vapour proof container	8	8

BARNYARD MILLET

Barnyard millet (Echinochloafrumentacea) is an important minor millet grown in India. This millet crop belongs to the family Gramineae. The crop is able to evade drought by its quick maturity. Best season for seed production is September – October and February – March. The pollination should not coincide with rains for quality and effective seed setting.

Method of seed production
Barnyard millet is a self-pollinated crop and should be raised in isolation. The isolation distance maintained between the varieties is 3 metres for both foundation and certified seed production to maintain the varietal purity.

Seed production stages
Breeder seed- Foundation seed -Certified seed

Land selection
Barnyard millet can be cultivated in both rich and poor soils with variable texture. Well drained loam or sandy loam soils rich in organic matter are ideal for cultivation. The selected land should be free from volunteer plants. The land should not be cultivated with same crop in the previous season.

Seed selection and sowing
Seeds used for seed production should be of good quality certified seeds from an authentic source. Seeds should be healthy with required germination percentage. Recommended seed rate is 4 kg/acre (10 kg/ha). Selected seeds should be treated with Azospirillum @ 60 gms/kg of seeds. Treated seeds should be sown with a spacing of 30 x 10 cm. Seeds should be sown in September - October at the onset of monsoon rains. Summer crop should be sown in the month of February – March. Seeds are broadcast manually or by seed driller in furrows at a depth of 3 – 4 cm.

Main field preparation
The main field should be harrowed for 2 – 3 times to make it a fine tilth and levelled. The levelled field is formed into ridges and furrows. During final plough apply compost or farmyard manure @ 5 tonnes/acre (12.5 tonnes/ha) and incorporate into the soil. Seeds can be sown in the ridges at a depth 3 - 4 cm with a spacing of 30× 10 cm.

Nutrient management
Before final ploughing compost or farmyard manure @ 5 tonnes/acre (12.5 tonnes/ha) should be applied and ploughed into the soil.

Weed management
The seed production field should be maintained weed free at least upto 35 days after sowing for retaining the soil moisture and to get high yields. Subsequent weeding should be done at an interval of 15 – 20 days. Weeding can be done with a handhoe or wheel hoe.

Irrigation
Kharif season crop does not require any irrigation. However, if the dry spell prevails for longer period at least one irrigation should be given at the tillering stage to boost the yield. First irrigation should be given 25 - 30 days after sowing followed by the second one at 40 – 45 days after sowing. Summer crop requires 2 - 4 irrigations depending upon soil type and climatic conditions. During heavy rains the excess water from the field should be drained out.

Pest and disease management
Barnyard millet is commonly affected by shoot fly and three types of smut diseases at different growth stages.

Field inspection

A minimum of two inspections should be done between flowering and maturity stages by the Seed Certification Officer. The first inspection is done at the time of flowering to check the isolation and off-types and the second inspection is done during the maturity stage prior to harvest to check the off-types and to estimate the yield.

Harvesting and processing

Harvest is done once the earheads are physiologically mature. Normally crop is ready for harvest in 75 - 90 days after sowing. The crop should be harvested when two thirds of the seeds are ripe. The harvested earheads are threshed by hand or trampling under the feet of bullocks. The threshed grains are further cleaned by winnowing.

Drying and storage

The cleaned seeds should be sun dried to attain a safe moisture level of 12%. Seeds can be stored upto 13 months under proper storage conditions.

Field Standards for Seed Certification in Barnyard Millet

Field Standards	FS	CS
Minimum field inspection (number)	3	2
Minimum isolation distance (meters)	3	3
Maximum off-type (%)	0.05	0.10
Maximum objectionable weeds (%)	-	-
Maximum different crop plants (%)	-	-
Maximum objectionable diseases (%)	-	-

Seed Standards for Seed Certification in Barnyard Millet

Seed standards	FS	CS
Minimum physical purity (%)	97	97
Maximum inert matter (%)	2	2
Maximum other distinguishing varieties (number/kg)	-	-
Maximum other crop seed (number/kg)	10	20
Maximum other weed seed (number/kg)	10	20
Maximum objectionable weeds (number/kg)	-	-
Maximum objectionable diseases (percentage by number)	-	-
Minimum germination (%)	75	75
Maximum moisture (%)		
Ordinary container	12	12
Vapour proof container	8	8

CONCLUSION

Enhancing small millets through quality seed production technology holds immense potential for farmers and agricultural chemistry. With careful scaling up and the adoption of advanced techniques, we can meet the demand for small millet seeds, improve food security and stimulate economic growth in rural areas. Looking ahead, continued research and investment in seed production technology will further unlock the secrets to maximizing the potential of small millets.

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Agronomic practices for quality seed production

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Introduction

Quality seed plays a pivotal role, since crop productivity as it directly related to the genetic potential of the seed planted. It is estimated that the direct contribution of quality seed alone to the total production is about 15–20% depending upon the crop and it can be further raised up to 45% with efficient management of other inputs. Seed production is a biological process, which involves multiplying small quantities of nucleus/breeder/parental lines seed into larger quantities (certified/truthful labelled seed/hybrids) for commercial distribution, following specified stages over successive cropping seasons. Since seed is living, it is subject to the natural phenomena of aging and death. Besides, the growth of plant and the quality of seed production are strongly influenced not only by genetic factors but also by the environmental condition. Therefore, careful handling and monitoring is essential starting from field preparation to seed harvesting or during transportation and storage. Although, the package and practices of seed production technology vary from location to location and from crop to crop. But a general recommendation can be adopted for vegetable seed production. Ideally, quality seed should have following characters: 1. It should be true to its type (genetically pure). 2. It should be free from ad mixture of other variety of seeds. 3. It should have high percentage of germination. 4. It should be free from seed borne diseases.

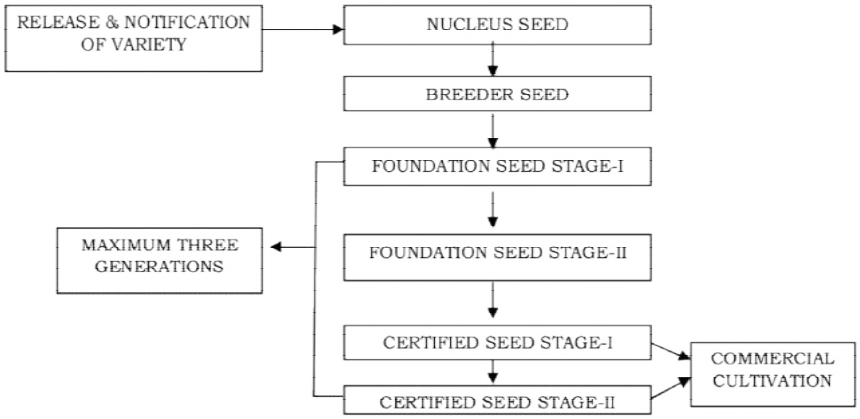
Modern seed supply systems are primarily dependent on improved varieties,which are developed and released by crop breeding institutions. The seeds of thesevarieties should be multiplied in large quantities for distribution to the farmers in amanner to maintain the genetic purity. At the time of release of a variety, smallquantity of seed, normally known as Nucleus Seed, is available with the plant breeder.Tofacilitateasystematicincrease,seedmultiplicationisundertakenfollowingGeneration System, which is nothing but the production of a particular class of seedfrom a specific class of seed up to the certified seed stage. The choice of a proper seed multiplicationmodelisthekeytothesuccessofaseedprogrammethatdependson:

- Therateofgeneticdeterioration
- Seedmultiplicationratioand
- Totalseeddemand

Based on these factors different seed multiplication models may be derived foreach crop and the seed multiplication agency should decide how quickly the farmerscan be supplied with the seed of newly released varieties, after the nucleus seed stockhas been handed over to the concerned agency, so that it can spread quickly, replacingthe old varieties. In view of the basic factors, the chain of seed multiplication modelscouldbe:

Three-generation model: Breeder seed - Foundation seed - Certified seed (adoptedforcross-pollinated/open cross pollinated crops)

Four-generation model: Breeder seed - Foundation seed (I) - Foundation seed (II) - Certifiedseed (adopted for self-pollinated crops)



Generations/steps in seed multiplication programme

Classes of Seed

1. *Nucleus Seed*: It is produced by the Breeder and it is genetically pure seed. 2. *Breeder Seed*:It is produced by the breeder from Nucleus Seed. Golden yellow colour tag is affixed by the breeder. 3. *Foundation Seed*: It is produced by the breeder seed under the supervision of the concerned seed Certification Agency. White colour tag certified by the certification agency is affixed. 4. *Certified Seed*: It is produced from the foundation seed. Certified seed may be the progeny of certified seed provided this reproduction does not exceed three generation beyond foundation seed stage I. It is determined by the seed certification agency. Certification tag shall be of azure blue colour for certified seed class.

Table-1 Genetic purity standard for different class of seeds and hybrids

Class of seed	Genetic purity required
Breeder seed	100
Foundation seed	99.5
Certified seed	99
Certified hybrid seed	95
Certified hybrid seed developed by Hand emasculation	90

General principles of seed production

Extreme attention is needed to the maintenance of genetic purity and other qualities of seeds at the time of hybrid seed production in order to exploit the full yield potential of developed hybrid. In other words, hybrid seed production must be carried out under standardized and well-organized manner. Basically, there are two types of seed production principles.
(A) Genetic principles (B) Agronomic principles.

(A) Genetic Principle – It involves all the factors which may lead deterioration of genetic purity (true to type) of a crop variety. In negligence of genetic principles during seed production programme leads deterioration of the varieties. The important factor for varietal deterioration is listed by Kadam (1942):
(1) Developmental variation: When the seed crops are grown in difficult environment, under different soil and fertility conditions, or different climate conditions, or under different

photoperiods, or at different elevation for several consecutive generations. The developmental variation may arise sometimes as differential growth response. To minimize the opportunity for such shifts to occur in varieties it is advisable to grow them in their areas of adaptation and growing seasons.

(2) Mechanical mixtures: Mechanical mixtures may often take place at the time of sowing, harvesting, processing, grading and packaging. If more than one variety is sown with same seed drill or volunteer plants of the same crop present in the seed field or different varieties grown in adjacent fields may cause mechanical mixing. Often the seed produce of all the varieties are kept on same threshing floor, grading is done with same grader and packaging is done in the old gunny bags etc. these practices may also cause mechanical mixing. To avoid mechanical contamination, it would be necessary to rogue the seed fields timely and practice the utmost care during the seed production, harvesting, threshing and further handling of seeds for grading and packaging.

(3.) Mutations: This is not a serious factor of varietal deterioration. In the majority of the cases it is difficult to identify or detect minor mutation.

(4) Natural crossing: In sexually propagated crops, natural crossing is another most important source of varietal deterioration due to introgression to genes from unrelated stocks which can only be solved by prevention.

Natural crossing occurs due to following reasons: Natural crossing with undesirable types, natural crossing with diseased plants and natural crossing with off- type plants.

Natural crossing occurs due to following factors: The breeding system of species, isolation systems, varietal mass pollinating agent, size of the pollen grains, and duration of pollen viability.

(5) Minor genetic variations: Minor genetic variations may exist even in the varieties appearing phenotypically uniform and homogeneous at the time of their release. During later production cycle some of this variation may be lost because of selective elimination by the environment.

(6) Selective influence of diseases: New crop varieties often become susceptible to new races of diseases often caused by obligate parasites and are out of seed programmes. Similarly, the vegetative propagated stocks deteriorate fast if infected by viral, fungal and bacterial diseases. During seed production it is, therefore, very important to produce disease free seeds/stocks.

(7) Techniques of plant breeders: In certain instances, serious instabilities may occur in varieties due to cytogenetical irregularities not properly assessed in the new varieties prior to their release. Other factors, such as break down in male sterility certain environmental conditions and other heritable variations may considerably reduce the genetic purity.

Maintenance of genetic purity during seed production: The various steps suggested by Hartmann and Kester (1968) for maintaining genetic purity. Minimum genetic purity standard is given in table-4.

a. Providing adequate isolation to prevent contamination by natural crossing or mechanical mixtures (Table-2).
b. Use of approved seed only in seed multiplication by adopting generation system (In India three generation system of seed production is followed i.e. starting from breeders seeds then foundation seed and then certified seed).
c. Rouging of seed fields, prior to the stage at which they could contaminate the seed crop.
d. Periodic field inspection at critical stages for verification of genetic purity, detection of mixtures, weeds, and for freedom from noxious weeds and seed borne diseases etc. Avoiding genetic shift by growing crops in areas of their adaptation only (Table-2).

e. Certification of seed crops to maintain genetic purity & quality seed through seed certification agency.
f. Grow-out tests: This is mandatory for hybrids produced from hand emasculation and pollination method because there are chances of presence of female selfed seed.

(B) Agronomic principles-

1. Selection of agro-climatic region: Growth of the plant and production of good quality seeds are strongly influenced by both genetic and environmental factors. For good seed crop, a crop variety to be grown for seed production in an area where it must be adapted to the photoperiod and temperature conditions prevailing in that area.
2. Selection of seed plot: The plot selected for seed crop must be free from - volunteer plants weed plants, soil borne diseases & insects pests and have good soil texture and fertility.
3. Isolation of Seed crops: The seed crop must be isolated from- Other nearby fields of the same crop and the other contaminating crop as per requirement of the certification standards (Table-2).
4. Selection of variety: The variety of seed production must be adapted to the agro-climatic conditions of the region and it should possess some trait such as disease resistance, earliness, grain quality and higher yield.
5. Seed treatment: Depending upon the requirement, seed should be treated by chemical (fungicide & insecticide), biocontrol agent (PGPRs) and by dormancy breaking chemicals.
6. Time of planting: The seed crops should invariably be sown at their normal planting time. Depending upon the incidence of diseases and pests, some adjustments, could be made, if necessary.
7. Seed Rate: Lower seed rates than usual for raising commercial crop are desirable because they facilitate rouging operations and inspection of seed crops.
8. Method of sowing: The most efficient and ideal method of sowing is by mechanical drilling.
9. Rouging: Adequate and timely rouging is extremely important in seed production. Rouging in most of the hybrid crops may be done at vegetative / pre-flowering stage, flowering stage and Maturity.
10. Supplementary pollination: Provision of honey bees in hives in close proximity to the seed fields of crops largely cross pollinated by the insects, ensure good seed set thereby greatly increase seed yields.
11. Weed control: Weeds may cause contamination of the seed crop, in addition to reduction in yield by enhancing competition.
12. Disease and insect control: Successful disease and insect control is another important biotic factor in raising healthy seed crops. Apart from reduction of yield, the quality of seeds from diseased and insect damaged plants is invariably poor.
13. Fertilizer application: In the nutrition of seed crops, nitrogen, phosphorus, potassium, and several other elements play an important role for proper development of plants and seed. It is, therefore, advisable to know and identify the nutritional requirements of seed crops and apply adequate organic fertilizers.
14. Irrigation: Irrigation can be important at planting for seed crops on dry soils to ensure good uniform germination and adequate crop stands. Excess moisture or prolonged drought adversely affects germination and frequently results in poor crop stands.
15. Harvesting of Seed crops: It is of great importance to harvest a seed crop at the time that will allow both the maximum yield and the best quality seed.
16. Storage of seeds: The seed should be stored properly in air tight container after drying at optimum moisture content level. Optimum moisture content is given in table-3 as per IMSCS.

Table:2 Seed certification standards of different crops for seed production as per the IMSCS-2013. (FS-Foundation seed, CS-certified seed, FI field inspection)

Vegetable crop	Isolation distance		No of FI	Stage of field inspection
	FS	CS		
Rice (Hybrids)	200	100	4	1st before flowering, 2nd& 3rd during flowering and 4th at maturity
Rice (Varieties)	3	3	2	Flowering to harvest
Wheat	3	3	2	Flowering to harvest
Barley	3	3	2	Flowering to harvest
Maize (Inbred line, single crosses and hybrids)	400	200	4	1st before flowering and three during silking stage
Maize (Composites, synthetics and open pollinated varieties)	400	200	2	1st pre-flowering and 2nd during flowering
Hybrid Sorghun,	400	300	4	1st before flowering, 2nd and 3rd during flowering & 4th during pre-harvesting
Hybrid Bajra	1000	200	4	1st before flowering, 2nd and 3rd during flowering & 4th during pre-harvesting
OP varieties of Sorghum	1000	200	3	1st pre-flowering, 2nd during Flowering & 3rd during pre-harvesting.
OP varieties of Bajra			3	1st pre-flowering, 2nd during Flowering & 3rd during pre-harvesting.
Brinjal	300	150	4	1st before flowering 2nd& 3rd at flowering 4th at mature fruit stage and prior to harvesting
Chilli	500	250	3	1st before flowering 2nd at flowering 3rd at mature fruit stage and prior to harvesting
Okra	500	250	3	1st before flowering 2nd at flowering 3rd at mature fruit stage and prior to harvesting
Tomato	200	100	4	1st before flowering 2nd& 3rd at flowering 4th at mature fruit stage and prior to harvesting
Bitter gourd	1500	1000	4	1st before flowering 2nd& 3rd at flowering 4th at mature fruit stage and prior to harvesting
Bottle gourd	1500	1000	4	1st before flowering 2nd& 3rd at flowering

				4th at mature fruit stage and prior to harvesting
Cucumber	1500	1000	4	1st before flowering 2nd& 3rd at flowering 4th at mature fruit stage and prior to harvesting
Muskmelon	1500	1000	4	1st before flowering 2nd& 3rd at flowering 4th at mature fruit stage and prior to harvesting
Watermelon	1500	1000	4	1st before flowering 2nd& 3rd at flowering 4th at mature fruit stage and prior to harvesting
Pumpkin	1500	1000	4	1st before flowering 2nd& 3rd at flowering 4th at mature fruit stage and prior to harvesting
Spoung gourd	1500	1000	4	1st before flowering 2nd& 3rd at flowering 4th at mature fruit stage and prior to harvesting
Ridge gourd	1500	1000	4	1st before flowering 2nd& 3rd at flowering 4th at mature fruit stage and prior to harvesting
Summer squash	1500	1000	4	1st before flowering 2nd& 3rd at flowering 4th at mature fruit stage and prior to harvesting
Winter squash	1500	1000	4	1st before flowering 2nd& 3rd at flowering 4th at mature fruit stage and prior to harvesting
Cauliflower, Broccoli, Knol-Khol	1600	1600	3	1st before flower stalk development 2nd during flowering 3rd at maturity and prior to harvesting
Onion	1200	600	3	1st before flowering 2nd& 3rd at flowering 4th at mature fruit stage and prior to harvesting
True potato seeds	-	50		1st before flowering 2nd& 3rd at flowering 4th at harvesting
Carrot	1000	800	4	1st before flowering 2nd& 3rd at flowering 4th at mature fruit stage and prior to harvesting
Radish	1600	1600	4	1st before flowering 2nd& 3rd at flowering 4th at mature fruit stage and prior to harvesting

Table:3 Seed standards of different crops for seed production as per the IMSCS-2013. (GP%-germination percentage, PP-Physical purity, mc%- Moisture content, VPC-vapour proof container)

Vegetable crop	GP%	PP%	mc%	
			Max. mc%	VPC%
Rice	80	98	12	8
Wheat	85	98	12	8
Barley	85	98	12	8
Maize	90	98	12	8
Sorghum	80	98	12	8
Bajra	75	98	12	8
Oats	85	98	12	8
Brinjal	70	98	8	6
Chilli	60	98	8	6
Tomato	70	98	8	6
Okra	65	99	10	8
Bitter gourd	60	98	6	7
Bottle gourd	60	98	6	7
Cucumber	60	98	6	7
Muskmelon	60	98	6	7
Watermelon	60	98	6	7
Pumpkin	60	98	6	7
Spoung gourd	60	98	6	7
Ridge gourd	60	98	6	7
Summer squash	60	98	6	7
Winter squash	60	98	6	7
Cauliflower, Broccoli, Knol-Khol	70	98	5	7
Onion	70	98	6	8
True potato seeds	80	98	6	8
Carrot	60	95	7	8
Radish	70	98	5	6

Hybrid seed production

Seed production of vegetable can be categorized into self-pollinated, cross-pollinated open-pollinated, F_1 hybrid and clonally propagated cultivars. Among them the acceptance and demand of using F_1 hybrid in vegetable production is increasing rapidly due to their yield potential, resistance, quality attributes and storability. Hybrids varieties have been developed in those crops/vegetables which manifest distinct hybrid vigour. Most of the seed of crops including rice, maize, tomato, chilli, brinjal, cucumber, squash, pumpkin, melon, watermelon, brassicas such as cabbage, cauliflower, broccoli, and radish, and onion are of F_1 hybrid cultivars. From the breeder point of view, it is a fast and convenient way to combine desirable characters of a vegetable together, for example fruit size and colour, plant type and disease resistance, and as a mean to control intellectual property rights through control and protection of the parental lines by the breeders. In F_1 hybrid seed production, cropss can be divided into two groups: the hand-pollinated and the gene-control pollinated species. The genetic control system can be due

to the self-incompatible system where pollen of the same plant or flower cannot pollinate itself or to the male sterile genetic system where a female plant has no male organ, deformed organ or no functional pollen to pollinate itself. When no such genetic control system is found or when it is not introduced into inbred parental lines, tedious hand-emasculation and pollination have to be used to produce F_1 seed. In both the gene-control system and hand-pollinated species sufficient field or female flower isolation have to be maintained to obtain high seed genetic purity.

The success of hybrid seed production technology primarily depends on genetic purity, timely availability and the affordability of hybrid seed costs to the farmers. The production of pure hybrid seed at affordable price in vegetables, is a highly skill oriented activity. A good hybrid may not reach a large number of farmers, unless it is feasible to commercially produce the seed on large scale economically. There are different methods for hybrid seed production in crops such as:

The gene-control pollination F_1 (hybrid seed production system- There are two systems.

a. Self-incompatibility system-based hybrids: These hybrids are developed for Crucifereae family crops which includes mustard,*Brassica oleracea* (Brussel sprouts, cabbage, cauliflower, broccoli, kohlrabi and kale), *Brassica rapa* (Chinese cabbage, turnip and a range of Asian leafy brassicas) and *Raphanus sativus*. Maintenance of self-incompatible line is very difficult task. Different methods are available for temporary suppression of self-incompatibility *viz,*Bud pollination, CO_2 gas (CO_2enrichment) or sodium chloride, tissue culture using meristem, sodium chloride sprays, removal of stigmatic surface or whole stigma, high temperature treatment, and double pollination etc.

b. Male sterility-based hybrids: Hybrid seed production of rice, maize, sweet corn, carrot and onion are based on male sterility gene system and the genetic control can be either just clear-cut male sterility genes or the interaction of a male sterility gene with a cytoplasmic factor. In this system parents are maintained till foundation seed production by selfing or by crossing with maintenance line while for certified seed production male/restorer line and female parent are crossed to obtain hybrid seed.

The hand-pollinated F_1 (hybrid) seed production system

The method involves the manual emasculation of the pollen-producing organ (anthers) followed by hand pollination with pollen of the male parent and then preventing other pollen from contaminating the pollinated flowers. However, it is labour intensive and requires a team of skilful growers and many dedicate pollinators with good eye-sight, gentle hands, a lot of patience and commitment, and able to follow instructions accurately. To be cost-effective, this system only works in species where a single pollination of a female flower will produce many seeds e.g. solanaceous crops (tomato, brinjal) and cucurbits (bitter gourd, bottle gourd, summer squash, winter squash, pumpkin etc.).

Removal of anthers

Hand Pollination

Covering with cotton

Fig-1: Hand emasculation and pollination in tomato, Pollination in bitter gourd

Table-4: The most commonly utilized mechanisms/methods for developing commercial hybrids in vegetables (Kumar *et al.,* 2005)

Mechanism	Commercially exploited in:
Hand emasculation + HP	Tomato, eggplant, sweet pepper, okra, hot pepper
Pinching of staminate flowers + HP	Cucurbits (bitter gourd, bottle gourd etc.)
Male sterility + HP	Tomato, hot pepper, sweet pepper
Male sterility + NP	Onion, cabbage, cauliflower, carrot, radish, muskmelon, hot pepper
Self-incompatibility + NP	Most of the cole vegetables like broccoli, cabbage etc.
Gynoecism + NP	Cucumber, muskmelon
Pinching of staminate flowers* + NP	Cucurbits including bitter gourd, summer squash etc.
PGR and pinching of staminate flowers* + NP	Summer squash, winter squash etc.

HP = hand pollination; NP = natural pollination; PGR = plant growth regulator
* Genotypes with increased proportion of pistillate flowers are desirable for hybrid development.

Hybrid are advantageous over the varieties due to heterosis (high yield, earliness, quality) but hybrid seed production is laborious, time consuming and costly. It is not possible to develop hybrids in each crops. In legumes the small number of seeds per flower/pod and floral biology prevents hand-pollination to be efficient and thus no hybrid in pea and beans to date have been produced. In this case the use of gene-control pollination has to be exploited. Similarly, if a good gene-control pollination system is available in tomato and pepper their seed production could be transformed into less intensive large field production system as in the brassicas and sweet corn.

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Quality Seed Production Technology in Wheat

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Quality seed plays crucial role in realising true genetic potential of the any variety and transferring genetic gain to the farmers. New varieties developed by breeders backed by apt seed production programme leads to rapid spread of new varieties at farmers' doorstep. It is well proven fact that, use of quality seed of improved varieties contributes towards 15-20% increase in agricultural productivity. Therefore, it is imperative that quality seed production at farmers' field to be strengthened and maximum number of farmers to be encouraged for quality seed production at own farm. These will result in assured seed supply of newly released varieties at faster pace and genetic gain achieved by plant breeding can be effectively transformed up to farmers' field. However, farmer's awareness towards use of quality seed needs to be improved in order to achieve higher Seed Replacement Rate (SRR) and varietal Replacement Rate (VRR) of the country. Efforts are being made by various Govt. agencies, State Department of Agriculture, ICAR Institutes and SAU's to engage farmers through participatory seed production programme and extension programme and disseminate know- how of quality seed production at faster rate. Seed is considered as a vital input, having a crucial role in assuring food security. Seed always decides fate of all other agricultural inputs *viz*., land, irrigation, fertilizer, labour etc. and efficacy of all above inputs revolves around viability and vigour of the seed. It becomes imperative to use quality seeds of improved varieties by the farmers to assure uniform field establishment and potential yield.

Seed Multiplication Chain

The Indian seed production system primarily has three categories of seed i.e. breeder seed followed by foundation seed and certified seed. The breeder seed is primarily produced by the concerned breeder/concerned institute or an authorized breeder. The genetic purity of the breeder seed determines the purity of foundation and there by certified seed that is supplied to the farmers. In India annually, approx.15000 quintals of breeder seed of wheat is produced to meet the seed demand of the country. Seed production plays a crucial role in ensuring sustainable agriculture and biodiversity. It involves the science, techniques, and methods used to produce high-quality breeder and subsequent generations of seed for seed producers as well as for farmers, ensuring the availability of desirable plant varieties.

Following package of practices may be followed for quality seed production of wheat

Source of Seed: Quality seed supplied by ICAR Institutes, SAU's, KVK's, State Department of Agriculture, State Seed Corporation/National Seed Corporation of following wheat varieties under north western plain zone conditions;

A. Varieties recommended for North western plain zone

Name of variety	Duration (Days)	Average Yield (q/ha)
Irrigated Early Sown (25th Oct.-5 the Nov.)		
DBW-303	156 days	81.2
DBW-187	150 days	72.1
DBW-327	155 days	79.4
DBW-332	156 days	78.3
DBW-370	151 days	74.0
DBW-371	150 days	75.9
DBW-372	151 days	75.3
WH 1270	156 days	75.85
PBW 872	152 days	75.2
Irrigated Timely Sown (01st Nov.-25th Nov.)		
DBW-222	145 days	61.3
DBW-187	150 days	61.0
HD 3226	142 days	57.5
HD 3086	143 days	54.6
PBW 826	146 days	63.0
Irrigated late sown conditions (10th Dec. – 25th Dec.)		
DBW 173	122 days	47.2
PBW 752	120 days	49.7
Irrigated Very late sown conditions (25th Dec. – 15th Jan.)		
PBW 757	104 days	36.7
HD 3298	103 days	39.0
Restricted irrigation Timely sown conditions (25th Oct.-20th Nov.)		
HI 1620	146 days	40
HD 3237	145 days	40

DBW-187

DBW-222

DBW-303

B. Varieties recommended for north eastern plain zone:

Name of variety	Duration (Days)	Average Yield (q/ha)
Irrigated Timely Sown (01st Nov. -25th Nov.)		
PBW 826	123 days	49.7
HD 3411	127 days	46.8
DBW222	121 days	48.9
DBW187	120 days	48.8
Irrigated late sown conditions (5th Dec. – 15th Dec.)		
DBW 316	114	41.0
PBW833	115	42.75
Restricted irrigation Timely sown conditions (25th Oct.-20th Nov.)		
HD 3171	122	28.0
HD 3293	129	38.9
HI 1612	125	37.6

C. Varieties recommended for Central Zone:

Name of variety	Duration (Days)	Average Yield (q/ha)
Irrigated Early Sown (01st Nov. -10th Nov.)		
DBW 303	123	58.5
DBW 187	124	60.3
DBW 327	125	65.0
Irrigated Timely Sown (10th Nov. -20th Nov.)		
HI-1650	124	57.2
MACS 6768	116	56.6
GW513	119	58.5
HI1636	119	56.6
Irrigated late Sown (5th Dec. -15th Dec.)		
HD3407	109	46.5
HI 1634	108	51.6
CG 1029	110	52.1

Field selection: For seed production of wheat, plot needs to be selected where wheat crop is not grown or cultivated in previous year. This is will prevent contamination from other varieties or volunteer crops. Selected field should be fertile, levelled and well drain type for quality seed production of wheat.

Isolation distance: Wheat is self pollinated type crop and it is mandatory to maintain 03 meter of isolation distance between adjacent wheat seed/ grain production plot to avoid any mechanical mixture or contamination from other varieties. However, for loose smut infected plots, it is recommended to maintain 150 meters of isolation distance.

Preparation of field: After harvesting of *kharif* crop, it is recommended to plough the selected land and at least two- three times harrowing to be done for optimum sowing conditions.

Seed treatment: For control of seed borne disease, seed treatment with Tebuconazole @ 1 gram/kg of seed for control of loose smut may be done.

Sowing: It is very essential practice to know germination of seeds before sowing of seeds in the field. 400 seeds may be selected for germination test in germination paper (paper towel method) or newspaper under moist condition for 8 days at room temperature. After completion of 8 days, number of seeds germinated needs to be counted. If germination percentage is above 85 % in wheat seeds, then the seed lot is considered as fit for sowing.

Sowing technique: Row sowing is always preferred during seed production as it facilitates inspection and ease in rouging. Row spacing of 20-22 cm is recommended for wheat seed production. Depth of sowing in wheat is crucial for proper field establishment as deep sowing delays the seed germination and damages the emerging coleoptiles of the seedling. Therefore, wheat seed should be placed at depth of 5- 6 cm to ensure proper field stand. Timely sowing of seeds is always preferred for seed production of wheat.

Irrigation: In the wheat seed production plot, normally six irrigations are recommended at following stages of crop growth;

Irrigation schedule	**Days after sowing (DAS)**	**Stage of Crop**
1st Irrigation	20-25	Crown root initiation
2nd Irrigation	40-45	First node formation
3rd Irrigation	60-65	Jointing stage
4th Irrigation	90-95	Boot stage
5th Irrigation	110-115	Milk stage
6th irrigation	120-125	Dough stage

However, crown root initiation and flowering stages are the most critical to moisture stress in wheat crop. If rainfall occurred at any of the above stages, then irrigation for that stage may be skipped.

Rouging of seed production plot: Term rouging refers to the selective removal of undesirable plants *viz*., other varieties plants, diseased plants, off types, other crop plants or weed plants, and volunteer plants from the seed production plot. Rouging is carried out in order to maintain genetic purity,physical purity and disease-free attributes of seed plot. In the wheat crop, rouging is advised at heading and maturity stage, as most of the off types and other varieties plants are easily identified during these stages of crop growth. It is recommended that, inseparable other crop plants *viz*., Barley, Oat, Triticale and Gram should be rouged out from wheat seed plot. Similarly, Wild oat/Gulidanda (*Phalaris minor*) and Wild morning glory/ Hirankhuri (*Convolvulusarvensis* L) are considered as a objectionable weeds in wheat seed production, therefore efforts needs to be mounted to rogue out above mentioned weed plants. Diseased plants and offtype may be carefully removed and dumped or destroyed in isolated place.

Rouging

Identification of diseased plants/ offtypes **Rouging of wheat seed plot**

Off types may differ from the variety in the following characteristics:

1. Plant Height: Tall/Short

2. Leaf Characters: Leaf length, width, orientation

3. Spike Type: Awned/awnless/tapering/parallel/Club shaped

4. Flowering Time

5. Maturity Time

6. Any other DUS feature different from the original variety

The timing of rouging is important aspect in the process of removal of off types. It should be done from vegetative to maturity stage to ensure that all possible mixtures are removed before harvesting. At vegetative stage, take note of the plant height and the colour of the leaf blades and leaf sheaths. At reproductive stage, check for the flag leaf angle and the date and degree of panicle exertion. At ripening/maturity stage, look for differences in size, shape and colour of grains as well as the presence or absence of awns.

To obtain maximum benefits from this operation, following practical points should be followed:

1. The crop should be grown in such a way that plants can be seen individually. Paired row system of planting may be followed so that it is easy to walk between rows or give gap of one row after 8-9 rows as in case of wheat and barley. It facilitates easy movement in the field and detection of undesirable plants.

2. Walk systematically through the rows so that each plant of the crop is easily seen. Uproot the whole off-type plant and do not simply remove the fruits showing undesirable character because the remaining flowers on the off-type plant will still contribute to the material in the next generation.

3. Move in the field in such a way that the sunlight is on the back as it is difficult to examine plants with the sunlight in front of your eyes.

4. Do not delay field inspection. The undesirable plants should be removed before flowering as far as is possible.

5. Remove cross-compatible weeds and wild relatives. Remove all diseased plants and related infected weeds.

Roguing under wheat breeder Production plot at ICAR-NDRI, Karnal

Fertilizer application: For quality seed production of wheat, timely sowing of seeds is preferred to avoid any losses due to weather vagaries during harvesting and threshing of the crop. For timely sown conditions following fertiliser dose is recommended under North Western Plain Zone conditions, well decomposed compost @ 4-5 ton per ace may be applied well before 15- 20 days of sowing. Further, fertilisers may be applied as per following schedule,

Stage	**Nitrogen/ acre**	**Phosphorous/ acre**	**Potash/acre**
Timely sown and irrigated condition	60 kg N	24 kg P	16 kg K
To fulfil above recommend dose, 52.0 kg DiammnouimPhoshapte (DAP) per acre; 109.0 kg Urea and 27.0 kg of Murate of Potash (MOP) per acre is required. Out of this 43.0 Kg Urea is applied at first and second irrigation respectively. Whereas, 24.0 Kg urea, 52.0 Kg DAP and 27.0 Kg MOP are applied as basal dose at the time of sowing.			

Weed management: Weed seeds free seed production is pre-requisite for producing quality seeds and avoid further contamination in seed multiplication chain. Among various methods of weed control, chemical method is considered as the most effective and based on weed flora following herbicides can be applied for effective control of weeds.

Weed types	**Herbicide**	**Product dose (ml or gram per acre)**	**Time of application**
Broad and Grass type of weeds	Pendimethalin	1250 ml	As pre-emergence (Up to 03 days of sowing)
Grasses type *Phalris minor* (Mandus/ Kanaki) Wild oat/ JangaliJau etc.	Sulfosulfuron or Isoproturon	13 gram 500 gram	30-35 DAS 30-35 DAS
Broad leaves type *Chenopodium album* (Bathua); *Convolvulusarvensis* (Hirankuri); *Anagallis arvensis* (Krishnaneel) and *Melilotusindica* (Metha) etc.	2,4-D (38 EC) or Metsulfuron	500 ml 08 gram	30-35 DAS 30-35 DAS

Disease and Pest management:

1. **Loose smut of wheat:**

Loose smut is seed borne disease in wheat and needs to be effectively control during seed production to avoid further spread of disease in new areas. For this, seed treatment with Carbendazim (50 WP @ 2.5 gm/kg seed) or Tebuconazole (2DS @ 1.00 gm/kg seed) is recommended.

2. **Karnal bunt:**

Karnal bunt infection is not desired in the seed production plot of wheat and seed standard are being suggested under Indian Minimum Seed Certification standards, 2013. Therefore following measures may be taken for effective control of karnal bunt disease.

- One spray of Propiconazole 25EC @ 0.1 per cent using 200 litre of water at 50% flowering. If conditions are favourable for the disease then repeat at an interval of 15 days to control the disease.
- In KB prone areas, the seed crop can be given one spray of Propiconazole or two sprays of *Trichoderma viride* at tillering and ear head emergence stage.

3. **Yellow Rust:**

Spraying the crop with Propiconazole (0.1 per cent), or Tebuconazole (@ 0.1%) at stripe rust initiation using 200 litre of water/ha is recommended. Usually, it is done in the first half of February.

4. Aphids:

For the management of aphids, foliar spray of Imidacloprid 200SL @20g a.i./ha is recommended.

Harvesting, threshing and storage: Generally, in India, harvesting is carried out manually however recently combine harvesters are being deployed for ease in harvesting and threshing. Therefore, it is essential to clean properly all combine machines to avoid any admixtures/ mechanical mixtures of different varieties. It is recommended that seeds should be dried properly for proper storage before storage to avoid storage losses due to high moisture. Seed crop is subjected to sun drying for 3- 4 days to reduce the moisture content at safe level i.e., less than 12 %. It is suggested that, always use new bags for storage of seed to avoid mixture or if using old jute bags then clean the bag thoroughly and spray the bags with 50 EC Malathion to avoid any infestation. While storing the seed bags, it is recommended to use wooden pallets to avoid take up of moisture by seeds from floor.

Seed Harvesting

Seed Storage

Seed Certification: As per Indian seed Act, 1966, seed certification is voluntary whereas labelling is compulsory. Seed certification is allowed in those varieties which are notified under Section 5 of the Indian Seed Act, 1966. As per Indian Minimum Seed Certification Standards, 2013 published by Central Seed Certification Board, Ministry of Agriculture Cooperation and farmers Welfare, Govt. Of India, following field and seed standards to be followed for production of foundation and certified seed of wheat.

A. Field Standards

Class of seed	Minimum		Maximum permissible level (%)			Remarks
	Isolation (meter)	No. of field inspections	Off types	Inseparable other crop plants	Plants/heads affected by designated diseases	
FS	3 (150)*	2	0.05	0.010	0.10	*Fields of wheat , triticale and rye with infection of loose smut in excess of 0.10% and 0.50% for
CS	3 (150)*	2	0.20	0.050	0.50	

						FS and CS

B. Seed Standards

Class of seed	Minimum		Maximum permissible level (%)			Remarks
	Purity (%)	Germination (%)	Total weed seed (No./kg)	Objectionable weed seeds (No./kg)	Seeds infected by disease	
FS	98	85	10	2	0.050*%	* karnal bunt
CS	98	85	20	5	0.25 %	

Conclusion: By adoption of techniques for quality seed production of the recent wheat varieties farmers can produce healthy seeds for their own use and reduce dependency on external sources for seed input.

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Hybrid Seed Production Technology in Bajra

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Botanical Name :*Pennisetumglaucum*
Family : Gramineae
Origin : West Africa
Chromosome No: 2n=14
Distribution: In India, over 10 million hectare are under pearl millet cultivation and more than half of this is in **Rajasthan, Maharashtra and Gujarat.**

Nutritional Value per 100g Of Pearl Millet:

Carbohydrate	68 g
Protein	12 g
Minerals	1.9 g
Dietary Fibre	2.5 g
Fat	4 g
Iron	11.5 mg
Calcium	43 mg

Area and Distribution

- **AREA –** 6.93 million Hectares
- **PRODUCTION –** 8.61 million Tonnes
- **Average Productivity –** 1243 kg/hectare
-

WHAT ARE THE ADVANTAGES OF PEARL MILLET HYBRIDS?

- Higher grain yield
- Uniform growth
- Foliage is leafier and remains green after grain harvest
- Profuse tillering
- Stems are succulent and sweet
- Generally better in fodder quality

Floral Biology

- The spike emerge about 10 week after sowing.
- Stigma remains receptive for 12-24 hours
- The anther emergence starts from middle of the spike and proceed upwards and downwards.
- Anthesis occurs throughout the day and night with the peak between 8:00 PM – 2:00 PM
- The plant is thus markedly protogynous and cross pollination normally occurs

Method of Hybrid Seed Production

- Cytoplasmic genetic male sterility system (CGMS)
- Three specific parents are required to produce a hybrid male sterile line.

i) Male sterile line/A line
ii) Maintainer line/B line
iii) Restorer line/R line

- An A line is maintained by pollinating with B line.
- B and R lines are maintained separately.
- The first report on CGMS line was made by Burton and his coworkers at Tifton Georgia USA.
- The line is **Tift 23A**

Stages of seeds production :

Nucleus Seed	**By ear to row method**
Breeder Seed	**A×B line** **B and R multiplied under isolation**
Foundation seed	**A×B line** **R line under isolation**
Certified seed	**A×R line** **To produce hybrid**

Isolation distance parameters:

Contaminator	**Minimum isolation distance (m)**			
	Foundation/Breeder seed		**Certified seed**	
	Hybrid parents	**OPV**	**Hybrid**	**OPV**
Fields of other hybrids/varieties	**1000**	**400**	**200**	**200**
Field of the same hybrid/variety not conforming to varietal purity requirements for certification	**1000**	**400**	**200**	**200**
Fields of other hybrids having common male parent but not conforming to varietal purity requirements forcertification		**NA**	**200**	**NA**

Fields of other hybrids having common male parent and conforming to varietal purity requirements for certification		**NA**	**5**	**NA**

Selection of Site:

- Isolation standards requirement
- Any pearl millet or its relative should have been cultivated/ grown during the previous season on the plot selected for seed production (and preferably within the prescribed limit of isolation distance especially for nucleus and breeder seeds)
- Production site should have adequate irrigation, good soil(clay-loam-sandy) with proper drainage and good fertility level.
- The soil of the selected plots should be comparatively free from soil borne diseases and pests.
- The plot should be free from volunteer plants, weeds and other crop plants.
- The plot must be leveled and should have isolation as per the requirement of certification standards.
- Compact blocks should be selected for better supervision.
- Progressive farmers with good seed production skills are always helpful.
- High yield/unit with low cost of production.

Planting Method

1. **Direct Sowing**

- A-lines are planted by hand sowing, machine drawn seed drill
- R-lines are planted manually by hand dibbling in rows marked with stakes.
- Sowing equipment needs to be thoroughly cleaned to avoid contamination during sowing

2. **Transplanting**

- Transplanting requires 30-40 % less seed than direct sowing and proper plant stand is achieved with required spacing.
- The parents of hybrid are sown in a nursery bed raised 10 cm above the ground level.
- Seed should be sown 1.5 cm deep to facilitate better germination and safe uprooting of seedlings for transplanting.
- Seed is sown in rows spaced 10-15 cm apart
- Seedlings are planted when they are 18-20 days old and it it exceed 20 days then it might result in reduced tillering and low seed yield

Row Ratio and Spacing

- Row ratio depends on male and female parent height and pollen producing ability of pollinator line.
- Standard row ratio is 8:2 due to ease of management.
- To ensure longer duration of pollen availability staggered planting or male parent at more than one date is planted with minimum gap of 3 days between 2 male plantings.
- All sides should be covered with 2 rows of male

Spacing:

- Optimum plant population: 1,20,000/ha
- Row-to-row spacing- 45 cm
- Plant-to-plant spacing- 15 cm

Manure and Fertilizer Management

FYM: 8-10 tons/ha
Nitrogen- 100 kgs/ha
Phosphorus- 60 kgs/ha
Potassium- 40 kgs/ha

- Fertiliser dose splits into two- basal dose of 40 kg of N and all the P and K at the time of planting
- Remaining nitrogen for top dressing in two equal splits- tillering and panicle emergence stage.

Male and Female Synchronization

- Synchronization of flowering of A-line with R-line in certified seed production plots is essential in order to ensure pollen availability in the R-line when stigma emerge in the A-line.
- Synchronized flowering results in good set in A-line and higher yields in production plots.
- The A- and R-line may differ in flowering due to their inherent genetic differences for this trait as well as due to their differential photo-thermal sensitivity.
- Male flowering should be 2 days early to female flowering.

Pollination Process

Pollination takes place in two phases:
1st Stage

- Stylet starts protruding 2-3 days after panicle emergence.
- Stylet emergence begins from upper middle region of panicle and proceeds upward and downward.
- Complete stigma emergence completes in 2-3 days and remain receptive for 2-3 days.
- Emergence of 1st anther takes place after 3-4 days of 1st stigma emergence

2nd stage

- Staminate flowers become functional from upper part of panicle soon after completion of 1st stage.
- Pollen shredding for this stage will last for 3-4 days.

Water Management

- Every 10-12 days intervals irrigations should be provided.
- The most critical stages of irrigation are:-

1) Tillering
2) Floweing
3) Seed development

- The irrigation should be stopped at hard dough stage or about 10-12 days before harvesting time to ensure dried conditions for harvesting.

Field Inspection Protocol

Field inspection: Process of inspecting crop at critical stages to meet quality assurance.

Stage of inspection- Pre-flowering, flowering and pre-harvesting

Key observations: Isolation distance, Shredder, Off type, Volunteers

Unwanted factor	Maximum permitted (%)
	Certified
Off-types in seed parent at any one inspection at and after flowering	0.10
Off-types in pollinator at any one inspection at and after flowering	0.10
Pollen shredding heads in seed parents at any one inspection after flowering	0.10

Harvesting and Drying

- Harvest indicator- Seed should come out when ear heads are pressed with fingers.
- In case of certified seed production, R-line should be harvested first.
- Field should be thoroughly checked before harvesting A-line to avoid mixture.
- Ensure that the drying yard is clean and free from any pearl millet or other crop seed.
- Avoid making big heap at high moisture as it may deteriorate seed vigour.
- Panicle should be dried to 12% moisture level.

Threshing

- Care must be taken during threshing operations to avoid any chance of mechanical mixture. Threshing should be done lot wise.
- Checking and cleaning of threshers before use is must to keep seed free from other seeds. Recommended RPM should be followed to minimize mechanical damage to seeds.
- Seeds should be leaned before dispatching to processing plant by winnowing/using screens to remove chaffy/unwanted materials

Disease Control

Downy mildew-Seed treatment with Apron 35 SD (2g a.i/kg of seed)

Blast -Three sprays of Nativo (tebuconazole 50% + trifloxystrobin 25% WG)

Rust - One spray of Difeconazole @125 ml/ha or Propiconazole @250 ml/ha at pre-flowering stage

Ergot - Spray of Ziram 0.1% (300ml/500l of water)

Smut - Sprays of zineb (2 ppm) at flowering stage

Insect-Pest Control:

Armyworm (*Spodopterafrugiperda)* - Dust 10% Carbaryl or sprayEndosulphan 35 EC (300 ml/200 l of water

Blister beetle *(Psalydolyttafuscaolivier)* - Use light traps and spray carbaryl 50 WP (500 ml/200 l ofwater)

Shoot fly *(Antherigonasoccatarondani)* - Spray rogor (300 ml/200 l of water) at 10 days interval from seedling stage to flag leafstage.

Minimum Seed Standard for Various Seed Classes in Pearl Millet:

S.No	Parameters	Permitted (%)	
		FS	CS
1	Physical purity (minimum)	98	98
2	Inert matter (maximum)	2	2
3	Other crop seed by number (maximum)	10/kg	10/kg
4	Weed seed by number (maximum)	10/kg	10/kg
5	Ergot effected seed by number (maximum)	0.020%	0.040%
6	Germination (%)	75	75
7	Moisture content (%)	12	12

Minimum Field Standard in Pearl Millet:

S.No	Standard	Maximum permitted (%)	
		FS	CS
1	offtypes	0.05	0.10
2	Pollen shedders	0.05	0.10
3	Downy mildew diseased plant	0.05	0.10
4	Ear heads affected by ergot	0.02	0.40

Conclusion:

The adoption of Bajra hybrid seeds promotes sustainable agriculture by reducing the need for chemical inputs, conserving water, and mitigating environmental impact.Bajra hybrid seed production contributes to the economic empowerment of farmers by enhancing crop productivity, ensuring food security, and generating income diversification.The increasing demand for Bajra hybrid seeds is driving the expansion of production facilities and the establishment of seed banks to meet the growing needs of farmers.Ongoing research and development initiatives are crucial for continuous improvement in Bajra hybrid seed production, leading to the development of new varieties with enhanced traits.Efforts to disseminate knowledge and best practices in Bajra hybrid seed production through training programs and extension services are essential for empowering farmers and promoting adoption.Addressing challenges such as pollen contamination, seed purity maintenance, and regulatory compliance is vital for ensuring the sustainable growth of Bajra hybrid seed production.The advancements in Bajra hybrid seed production technology have implications for global food security and sustainable agriculture, contributing to the attainment of UN Sustainable Development Goals.The future of Bajra hybrid seed production holds promise for further advancements in yield potential, stress tolerance, and nutritional quality, contributing to global food sustainability.Encouraging widespread adoption and scaling up of Bajra hybrid seed production is crucial for food sovereignty, rural development, and enhancing agricultural resilience.Hence, bajra hybrid seed production technology represents a transformative approach towards achieving agricultural sustainability and enhancing global food security.

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