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National Training
on
QUALITY SEED PRODUCTION OF CEREALS
(January16-20, 2023)

Training Manual

Organized by:

Government of India
Ministry of Agriculture & Farmers Welfare
Department of Agriculture & Farmers Welfare

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ON
QUALITY SEED PRODUCTION OF CEREALS
(JANUARY 16-20, 2023)

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राष्ट्रीय बीज अनुसंधान एवं प्रशिक्षण केन्द्र
कृषि एवं किसान कल्याण मंत्रालय
कृषि एवं किसान कल्याण विभाग
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सत्यमेव जयते
Government of India

GOVERNMENT OF INDIA
NATIONAL SEED RESEARCH & TRAINING CENTRE
Ministry of Agriculture & Farmers Welfare
Deptt. of Agriculture & Farmers Welfare
G.T. Road, Collectry Farm,
P.O. Industrial Estate, Varanasi-221106 (U. P.)

FOREWORD

Cereal grains are essential to our dietary needs, as well as for animal feeding and for industrial processing. The cereal species of agricultural significance are Paddy, Wheat, Maize, Sorghum and millets. More than 288 million metric tons of cereals were estimated to be produced in India at the end of financial year 2022. India is the second largest producer of rice and wheat across the world. Cereal crops provide essential nutrients and energy in the everyday human diet through direct human consumption. Cereals contain a higher percentage of carbohydrates than any other food plants as well as a considerable amount of protein, fats and Vitamins. During Financial year 2020-21, the actual availability of Certified/Quality Cereal Crop seeds is about 286.06 lakh quintals against requirement of 245.78 lakh quintals having a surplus of 40.28 lakh quintals.

National Seed Research and Training Centre, Varanasi has organized a National Training Programme on "Quality Seed Production of Cereals" during January 16-20, 2023. The prime objective of this training is to update the knowledge of all participants who are engaged in Cereals seed production, quality control and to provide a forum to discuss and exchange their knowledge to enhance the production and availability of quality seeds of Cereal crops amongst farming community across the country.

This training module consists of valuable information on various aspects of seed to seed system in Cereals. I hope this compilation will serve as a useful resource book and guide to all concerned.

Date : 20.01.2023
Place : Varanasi (U.P.)

(Manoj Kumar)
Director

National Training
on
QUALITY SEED PRODUCTION OF CEREALS
(JANUARY 16 - 20, 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,
- Center 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. The sanctioned staff strength is as follows:

S.No.	Name of Post	Staff strength
1.	Director	1
2.	Chief Seed Analyst	1
3.	Seed Processing Engineer	1
4.	Seed Technologist	3
5.	Sr. Seed Analyst	2
6.	Administrative/Accounts Officer	1
7.	Jr. Seed Analyst	5
8.	Private Secretary	1
9.	Stenographer	2
10.	Librarian	1
11.	Assistant (Administration/ Accounts)	1
12.	Caretaker cum Storekeeper	1
13.	Lower Division Clerk	1
14.	Laboratory Attendant	2
Total		**23**

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)
Director

Hybrid Seed Production Technology in Bajra

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Flowers of bajra are protogynous, therefore it is a highly cross-pollinated crop. In this condition stigma of the flower emerges first and mature before pollen shedding this condition of flower promote cross pollination. It poses high level of heterosis for grain yield so that most suited for hybrid breeding.

In the hybrid breeding, cytoplasmic-genetic male-sterility (CGMS) system is explored where three lines viz., male sterile line (A line), maintainer line (B line) and restorer line (R line) are used.

Basics of hybrid seed production

Bajra hybrid seed production is a highly commercial venture. It is essential to maintain an efficient level of crop management to maximize production at minimum cost. The guidelines for hybrid seed production are as follows:

Selection of area and field

Commercial seed production must be carried out systematically. Selection of areas and seasons free from disease and pests is very important before planning a bajra seed production programme. Hybrid seed production agencies have to identify suitable areas for efficient seed production through preliminary experimentation. Areas, endemic to serious disease and pests should be avoided. Areas that are prone to natural disasters such as floods, excessive rains, or high humidity during the grain filling stages of bajra could cause grain moulds, discolouration, weathering, and pre-harvest sprouting. All of these ultimately affect to the seed germination and seed quality. Days to 50% flowering of the hybrid parents, productivity vs cost, and climatic conditions, particularly during grain-filling stages, should be important considerations to select an area for seed production. If seed production is planned for the off-season, access to irrigation facilities is important. The seeds infested with pests and disease will lose their vigor and viability at a faster rate in storage and will become unfit for planting within a very short period. As successful disease and insect pest management are one of the most important factors in raising healthy seed production, seed plots of all categories should be raised from seed treated with proper fungicide and insecticide.

Isolation distance:

As pearl millet is a highly cross pollinated crop-recommended isolation distance should be followed strictly. The seed crop must be sufficiently isolated from nearby fields of the same crop as per the requirements of certification standards.

Sl. No	Contaminants	Minimum distance(mtrs)	
		Foundation	Certified
1	Fields of other varieties including commercial hybrid of the same variety	1000	200
2	Field of same hybrid (code designation) not conforming to varietal purity requirement for certification	1000	200
3	Field of other hybrids having common male parent and conforming to varietal purity requirement for certification	-	5
4	Field of other hybrids having common male parent but not conforming to varietal purity requirement for certification	-	200

Seed village approach is commonly followed for certified seed production to avoid isolation problem. Even after the seed crop is harvested, effective isolation of seed from different varieties is essential to avoid mechanical contamination

Land preparation:

Cultivation of field two times (cross ploughing) and harrowing once is sufficient to bring field to fine tilth. Use of plank tied behind the cultivator may be necessary to break large clods and more harrows may be required in case of fields infested with weeds.

Planting method:

Planting is done either by direct sowing of seed or transplanting the seedlings raised in nursery. Generally, tractor or bullock-drawn seed drills or bullock plough is used for sowing. A-lines are planted by machine-drawn seed drill and 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.

Transplanting:

Transplanting enables easy adjustment in flowering time of parental lines in case they have large differences for flowering time. Transplanting saves expenditure on weeding and irrigation. It also saves time when field is occupied with any other crop. 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 transplanted in the field when they are 18-20 days old. Transplanting of seedlings older than 20 days might result in reduced tillering and low seed yield.

Seed Multiplication of Bajra

In India, the seed multiplication is in four stages generation system.

1. Nucleus seed (NS)
2. Breeder seed (BS)
3. Foundation seed (FS)
4. Certified seed (CS)

The seed certification under the law is voluntary as per the Seeds Act of 1966 and applies to only notified kinds of varieties. However, as per Draft Seeds Bill, 2002, only registered kind of varieties that prove DUS and VCU are eligible to be permitted under seed trade and voluntary certification system. Apart from certified seed, the seed is also sold as a truthfully labeled (TL) seed. However, the certified seed has the advantage of the seed crop being monitored by an authorized agency to ensure high genetic and physical purity, freedom

from disease and pest, high germination, and seedling vigour. The seed of different classes is produced based on demand forecasting of annual certified seed requirement depending on seed multiplication ratio, seed replacement rate, and additional seed requirement.

1. Nucleus seed

The handful of initial seed obtained from selected individual plants of a particular variety produced by the originating breeder or the institute constitutes the nucleus seed. It is not covered under the purview of certification, is produced in small quantities on experiment stations by the breeder under his direct supervision, and forms the basis for further multiplication of breeder, foundation, and certified seed.

Procedure to Maintain Nucleus Seed

The nucleus and breeder seed production is also called maintenance breeding, involves the purification of the following lines:

i. Cytoplasmic male sterile line (A line)
ii. Maintainer line (B line)
iii. Restorer line (R line)

Nucleus Seed Production of A and B lines

Seed quality with all its ramifications must be with cardinal virtue purity of commercial seed depends on genetic purity of parental line in the nucleus, breeder, and foundation seed class. The success, longevity, and productivity of the hybrids depend on the maintenance of genetic purity of parental lines.

Season I

Select the individual plants of A and B lines from a good quality breeder or foundation seed plots grown in a large area (0.25 to 0.5 ha) based on specific distinguishing morphological traits that enable genotype characterization.

Raise 200 to 300 rows (each 5 m length)each of A- and B- lines obtained by pooling seeds from selected ear heads.

1. Examine designated morphological traits especially those which are not influenced by genotype × environment interactions such as compactness of ear head from top to bottom. Tag the individual A and B- plants which are true to type plants. Self the individual tagged plants in B-lines and make the paired crosses between A- and B- at flowering. The ear heads of B-lines and A × B crosses should be labeled properly such as Al x Bl, A2 × B2, …. A200 × B200.Harvest the individual plants as per labeling. The A-lines should be harvested after B lines. After proper threshing and drying, store the properly labeled packets.
2. In the laboratory examine the seed of each plant carefully on the table for uniformity in colour, shape, and size of the seed. Discard the seed from Ear head not in conformity(deviating head) from the original true to type collection used as a seed source.

Season II

1. Raise plant to progeny rows such as B- line and A x B crosses from the selected 200 to 300 plants. Retain some portion of seed as remnant seed for all the B line plants and A×B crosses.
2. Observe the individual plants in progeny rows for diagnostic characters. Uproot the rows not confirming to the designated characteristics of the line. The A-lines showing pollen shedders and the corresponding B-lines should also be rejected.

3. Examine for seed morphological characters in the laboratory as per the parental line descriptors. Discard the seed of progeny row in case of doubtful deviants, if any.
4. Identify the best progenies (about 50) of A- and B- lines conforming to the designated characters of the parental lines. The remnant seeds of selected best progenies from the original A- and B- plants are identified and bulked separately (A and B lines), this forms the nucleus seed.

Nucleus Seed Production of R- line

Season I

1. Grow a large number of R- line plants.
2. At flowering, self about 1000 plants conforming to the designated morphological characters of the line.
3. Finally, select about 200 plants based on the field.
4. After harvest, rejection is also done based on deviations in seed colour, shape, size, etc.

Season II

1. Grow plants from about 200 panicles (row progeny of the selected plants) in two replications. Retain a portion of selfed produce as remnant seed from Season I.
2. Study progeny rows for the diagnostic characters. The lines not confirming to the characters of the parental line should be rejected. If an adequate number of progeny rows confirming to the lines are not found, selfing for one more generation will be required.
3. It is desirable to test selfed plants of R- lines for their restoration ability.
5. Evaluate the lines for economic traits and disease resistance characters as well.
6. Identify the best progeny rows (about 50) based on the diagnostic descriptors of the R-line.

Season III

1. Grow the bulk seed of remnant seed from Season I fraction in isolation.
2. Ensure adequate pollination during flowering.
3. Bulk the seed of all the plants after the harvest.
4. This forms the nucleus seed of the R-line.

2. Breeder seed

It is the progeny of the nucleus seed. It bears a golden yellow tag issued by the producing breeder. Its production is organized by the ICAR through the ICAR institutes, Agricultural Universities, and seed corporations based on indents received from the Department of Agriculture, Ministry of Agriculture, Government of India. Breeder seed production also does not come under the purview of certification. However, production and genetic purity are monitored by the monitoring team consisting of the Project Coordinator, nominees of National Seed Corporation, State Seed Corporation, and State Seed Certification Agency.

The hybrid seed production chain needs three basic seed lines:

i. Male sterile line (A-line),
ii. Maintainer line (B- line) and
iii. Restorer line (R- line).

The seed of the A-line is produced by planting A- and B lines side by side in an isolated field. This process will give the A-line seed perpetually. The B- and R- lines can be reproduced easily like any other cross-pollinated variety. The seed obtained from a breeder is normally in small quantities (up to a few kilograms). Breeder seed plots should be at least 1000 m away from another bajra field,

Breeder Seed Production of A-line

Breeder seed of A- line is produced with the breeder stock seed derived from nucleus seed. Breeder seed field is jointly monitored by a team consisting of producing breeder, project coordinator and nominees of National Seeds Corporation, State Seed Corporation, and State Seed Certification Agency.

Breeder seed production of A-line
4:2 planting ratio of female (A) and male (B) line

Crop management practices:

1. The breeder seed field should be clean, fertile, leveled and with proper irrigation and drainage facilities. Bajra should not have been grown in the previous year in that field. This is to ensure that no volunteer from the previous crop interferes with breeder seed plants. The seed plot should be isolated by 1000 m from other bajra fields.
2. A planting ratio of 4:2 (A: B) is recommended for better pollen dispersal. The row spacing should be sufficient to permit the examination of plants in rows for a possible mixture of off-types.
3. The seed rate of 3 kg A-line and 2 kg B-line per ha is recommended for A-line seed production.
4. To facilitate rouging operations, a spacing of 50 × 20 cm is most suited. Precautions should be taken to avoid accidental admixing of parental lines.
5. Start rouging before off-types, volunteers, or pollen-shedders in the female row starts shedding pollen. The sterile types show only the stigma or a few abortive anthers exserted. These should not be mistaken for normal fertile plants. Normal fertile plants show rich yellow anthers, full of pollen in both the lobes. Upon shedding, these lobes rupture at the distal end to discharge pollen. The out of place plants, i.e., plants between the rows, male plants in female rows and vice versa should be strictly removed at the earliest opportunity. Special attention should be given at the periphery where the border rows and seed rows meet since there is a chance of admixed seed germinating. In both A- and B- lines, 100 per cent genetic purity should be ensured.
6. The breeder should offer the seed crop for joint inspection by the monitoring team during the crop growth stages approximately after 30-40 days of sowing, during flowering and at maturity (total 3 times).
7. Tapping the male plants or blowing the air over male panicles with an empty duster may be done to ensure uniform pollen transfer to the female panicles.

8. The B- lines should be harvested at appropriate maturity, dried, threshed, and stored under proper conditions. During harvesting and processing, the equipment used must be scrupulously cleaned and freed from mechanical mixtures. This standard of cleanliness should be extended during seed packing and transportation also.
9. The seed thus obtained should be properly labeled as A- and B- line seed and stored separately under clean and hygienic conditions.

Breeder Seed Production of B-line

The breeder seed production of B-line should be carried out independent of A-line seed production as per seed production norms.

1. Nucleus seed should be the source for the breeder seed production of the B-line.
2. General agronomic management practices as described should be adopted.
3. The field and isolation requirements are the same as in A-line breeder seed production (1000 m).
4. Before flowering, the out-row crosses can be identified with their height and colour differences. Rouging should be started before off-types or volunteers start shedding pollen. All rouges and volunteer plants must be cut at the ground level or better pulled out to prevent re-growth and subsequent contamination and disease and pest dispersal to seed crop.
5. Conduct inspections thrice by monitoring team at vegetative, flowering, and maturity stages.
6. Harvesting the crop at physiological maturity. Strict hygiene at harvesting, processing, transporting, and storage is a must.

Breeder Seed Production of R-line

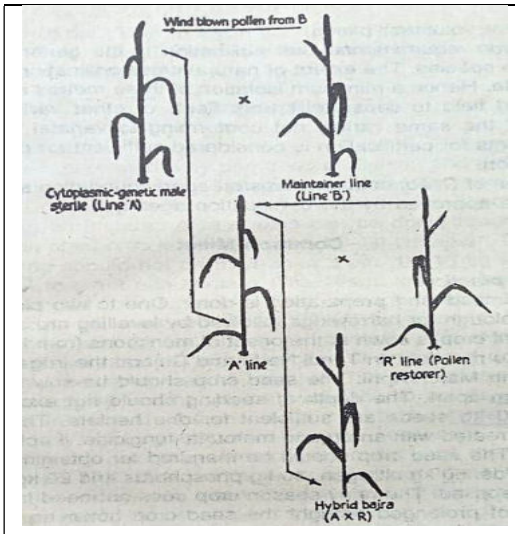
1. Breeder seed of R- line is produced from the bulked nucleus R-line seed source.
2. Seed crops should be isolated by 1000 m from all contaminants.
3. Best farming procedures and rouging operations should be followed. Before flowering, the outcrosses can be identified with their height and colour differences. Start rouging before off-types and volunteers start shedding pollen. All rouges and volunteer plants must be cut at ground level or preferably pulled out to prevent re-growth or spread of disease and pest to seed crop. The R-line seed plots should be well monitored to required standards
4. After harvest at physiological maturity, the seeds from all plants should be bulked, dried, threshed, packed, and stored hygienically.

Foundation seed

It is the progeny of breeder seed. It is genetically and physically pure, satisfying the minimum certification standards. Foundation seed is produced by National Seed Corporation, State Seed Corporations, State Farms Corporation of India, State Agricultural Universities, and designated public and private sector agencies. The foundation seed shall be the source for the production of certified seed and produced following the practices and procedures same as breeder seed. Foundation seed bears a white tag on certification. The breeder seed alone should be used to plant the foundation seed plots isolated from other bajra fields at least 1000 m. Before flowering, the grower should search for and destroy all volunteer plants on ditches, and in nearby fields lying within the isolation distance. Obvious off-types are roughed out before flowering to meet foundation seed standards. The off-types permitted at the final inspection depend on the seed certification standards and normally genetic purity should exceed 95 per cent.

3. Certified seed

Hybrid (A x R) seed is known as certified seed. Besides the state and national seed corporations, various private seed companies complement these public sector agencies in bajra hybrid seed production. Some private companies' market both private and public sector hybrids. To produce hybrids, the foundation seed of A- and R- lines are used by certified seed growers. This seed is normally certified by a team of specialists from the State Seed Certification Agency, scientists of the research station, and State Seed Corporation. Certified seed bears a blue tag. Approved foundation seed alone should be contiguous blocks with the isolation of at least 200 m from other bajra fields. Rouging can be practiced to remove off-types. The permitted off-types at the final inspection depend on the seed certification standards, normally off-types should not exceed 0.1 per cent.



Seed production of hybrid bajra

Procedure for Hybrid Seed Production

The hybrid seed is produced as certified seed under the vigilance of state seed certification agencies on a very large scale by private agencies, seed farms, experienced growers, and other extension organizations. Bajra hybrids involve A × R seed production and are carried out according to the prescribed standards of production and processing in terms of isolation distance, genetic purity, and seed quality.

Seed certification and seed law enforcement agencies have an important role to play in certified hybrid seed production and distribution because the crop performance is dependent on the quality of the certified seed used. Although the production of hybrid seed can be carried out by small individual growers, it is convenient to grow it in large compact blocks of 100-150 ha in a single or cluster of adjoining villages to avoid isolation problems. The quantity of certified seed produced depends upon the projected demand for the seed of a particular cultivar; normally an excess of 20% over the demand is produced. The requirements of isolation distance must be satisfied by a negotiated contract between a contract grower or group of farmers living in a community (seed village) and the seed firm, the seed companies train supervisory staff who will, in turn, advise and assist the seed growers in hybrid seed production across critical crop growth stages. Close communication between seed growers and the company supervisory staff during the entire hybrid seed production season facilitates quality hybrid seed production.

Determining the hybrid seed quantity targets

The quantities of hybrid seed demand should be roughly estimated on an annual basis in advance, depending upon the projected demand for the commercial hybrids under cultivation, it is desirable to maintain significant quantities of carry-over seed as insurance against unforeseen seed crop losses.

Planting ratio

Male sterile (A) and restorer (R) lines are sown in alternate strips of rows, normally in 8(A):2(R) ratio, depending on the experience of seed grower, success experienced over years, and the ability of the R-line to disperse the pollen. The eight borders of the R-line on all four sides of the hybrid seed production field are sown with the restorer (R) line to ensure an adequate supply of pollen and as a guard against contaminating stray-pollen. The ideal planting ratio between male and female lines is two male rows alternated by 6 to 8 female rows. The female rows for each pair of male rows can be increased to eight if the male lines have a larger ear head and longer span of flowering.

Plant height

Most of the bajra hybrid parental lines have matching heights in the *rabi* season facilitating an easy pollination process. The problem of height disparity can be avoided to some extent by planting the short parent on the raised ridges and the taller parent in the furrows below. Selective urea sprays that elongate the peduncle can also aid to increase the plant height to some extent.

Agronomic management

Seed rate:

The seed rate depends on planting method and row-to-row and plant-to plant spacing. General seed rate recommendation for foundation seed production is 3 kg/ha of A-line and 4 kg/ha for R-line and OPV. Seed rate of 3 kg/ha of A-line and 2 kg/ha of R-line is generally

Spacing:

Optimum population is 1,00,000 plants per hectare and hence it is recommended to follow 50 cm row-to-row and 20 cm plant-to-plant spacing in certified seed production. However, in nucleus and breeder seed production row-to row spacing of 75 cm and plant-to-plant spacing of 20-25 cm is followed to facilitate closer look at individual plants in order to identify and rogue out off-types, including pollen shedders in A-lines. Such spacing also allows better expression of plants and facilitates rouging extreme phenol types.

Fertilizer management:

Adequate amount of nitrogen, phosphorus and potassium is essential for proper growth and development of the crop. It is recommended to apply FYM @ 8-10 tons/ha and NPK @ 100:60:40 kg/ha. Basal dose of 40 kg N/ha is applied, and remaining nitrogen should be applied at tillering stage. Soils should also be analyzed for micronutrients, especially zinc, sulfur and boron, and those found deficient should be amended through proper micronutrient management.

Water management:

Most of pearl millet seed production is taken during off season (January to April) which is rain-free period. Therefore, access to irrigation is essential to obtain good seed yields. The most critical stages of irrigation are tillering, flowering and seed development.

The frequency of irrigation and amount of water supplied depend upon physical texture of the soil and crop requirements. Adequate soil moisture is also necessary for uniform seed germination in order to obtain good plant stand and high seed yields.

Weed control:

Production of high seed yield of high quality requires good weed control in the seed production plots. In addition to reduction in seed yield, weeds are often a source of contamination by way of admixture at the time of harvest. Weeds must not be allowed to flower or set seed in any case. Hand weeding, intercultural operations or chemical is necessary to control weeds.

Pre emergence spray of Atrazine @ 1g/litre controls broad-leaf weeds effectively. 10. Disease control: Effective control of all diseases is essential to produce a healthy seed crop. Diseases like downy mildew (Sclerospora graminicola (Sacc.) Schroet), blast (Pyricularia grisea (Cke.) Sacc.), and ergot (Claviceps fusiformis) cause heavy yield reduction and affect seed quality also.

Adoption of appropriate schedules of plant protection and rouging of diseased plants and panicles from time to time are essential to further check the spread of diseases. Following are the control measures for important diseases of pearl millet.

S.No	Name of disese	Causal organism	Control measures
1.	Downy mildew	Sclerospora graminicola (Sacc.) Schroet	Seed treatment with Apron 35 SD (2g a.i./kg of seed)
2.	Blast	Pyricularia grisea (Cke.) Sacc.	Three sprays of Nativo (tebuconazole 50% + trifloxystrobin 25% WG) @ 0.4 g/l or Tilt (propiconazole 25% EC) @ 1 ml/l at 10 days intervals were found most effective in managing pearl millet blast (Sharma et al., 2012)
3.	Rust	Puccinia substriata var. indica	One spray of Difenconazole @ 125 ml/ha) or Propiconazole @ 250 ml/ha at pre-flowering stage
4.	Ergot	Claviceps fusiformis	Ergot – Spray of Ziram 0.1% (300 ml/500litre of water)
5.	Smut	-	Sprays of Zineb (2 ppm) at flowering stage

Insect-pest control:

Major pests of pearl millet are armyworm (Spodoptera frugiperda), blister beetle (Psalydolytta fusca Olivier) and shoot fly (Atherigona soccata Rondani) that need proper control to avoid yield losses in production plots. The following control measures against each of these pests include:

Sl.No	**Name of pest**	**Control measures**
1.	Armyworm(Spodoptera frugiperda)	Dust 10% Carbaryl or spray Endosulphan 35 EC (300 ml/200 litre of water)
2.	Blister beetle (Psalydolytta fusca Olivier)	Use light traps and spray Carbaryl 50 WP (500 ml/200 litre of water)
3.	Shoot fly (Atherigona soccata Rondani)	Spray Rogor (300ml/200 l of water) at 10 days interval from seedling stage to flag leaf stage

Nicking and ensuring 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 stigmas emerge in the A-line. Synchronized flowering results in good seed set in A-line and higher yields in production plots. The A- and R-line may differ for flowering Synchronization of flowering of A- and R-lines can also be enhanced by

- by spray of urea- Hastening of flowering time by 6-8 days can be achieved by 3-4 sprays of 4% urea at 2-3 days interval at boot leaf stage.
- by staggered planting - If the difference in flowering time of parental lines is more, a practice of staggered sowing is followed. In which male parental line planted at different dates.
- by Jerking method- Removal of first tiller or ear of first tiller for synchronization of flowering of the parental line called Jerking.

Alternatively, selective irrigation of one parent and delayed irrigation of the other will also help in synchronizing the flowering dates of the parents but it is difficult in field conditions. Irrigation under a cool climate may further delay flowering.

Careful manipulation of nitrogenous fertilizer application, foliar spray of urea 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 an additional dose of nitrogen.

Roguing:

The process of removal of pollen shedders from A-lines and off-types from parental lines in seed production field is called roguing. Pollen shedders are male fertile plants in an A-line with similar morphology. Pollen shedders in A-line are results of mutations or mechanical mixtures. Off-type plants obviously differing in characteristics such as height, flowering time, colour of foliage, leaf size, shape, and orientation, tillering, panicle size, or any other morphological characteristic or diseased plants.

It may arise through mechanical mixture or out crossing and rarely as mutants. Adequate and timely rouging constitutes the most important operation in seed production. Rogues differing from normal plants in phenotypes should be pulled out and discarded at the earliest possible stage of plant growth, before flowering to avoid genetic contamination.

Roguing at maturity is also necessary to remove off-types not distinguishable earlier, and contaminants affecting the physical purity of seed. Roguing and sorting out of harvested panicles may be necessary in case of diseased panicles.

Field inspection:

Field inspection is a necessary monitoring protocol and is a prerequisite to ensure quality seed production. It involves recording cultivar identification, crop purity, disease incidence, general stand assessment, cultural practices, previous crop, dates and number of inspections, and roguing details. This is followed by recording of established plant population, species and cultivar purity and the establishment of rejection/selection criteria. A minimum of four inspections are made at different stage of seed production.

(i) The first inspection is made before flowering preferably within 30 days after planting in order to determine isolation, volunteer plants, outcrosses plants, planting ratio, any error in planting, incidence of downy mildew and other relevant factors.

(ii) The second and third inspections are made during flowering to check isolation, off-types, pollen shedders, downy mildew/ green ear and other relevant factors.

(iii) The fourth inspection is made at maturity but prior to harvesting in order to determine the incidence of downy mildew/green ear, ergot and smut and to verify true nature of plant and other relevant factors. When the seed production field does not meet the specified certification requirement, the options are whether whole field or part of the field is recommended for grow out test (GOT).

The area not meeting the requirements is harvested as seed of doubtful purity, kept separate, and final decision on the disposition of seed is made by observing genetic purity report. Plants of male line are chopped to avoid contamination. At least 25% of fields are inspected to validate the submitted male chopping report and to ensure that chopped male plants were properly destroyed or taken off the production field.

Harvesting and drying:

The appropriate time of harvest to ensure maximum seed yield and quality is of great significance. Fully mature seed is easily harvested and cleaned with minimal harvest losses. Delayed harvesting may result in increased losses due to lodging and seed shattering. Sun drying of seeds on clean threshing floor may be necessary to reduce moisture content, preserve viability and vigour and improve storage quality. Drying of seed to recommended moisture level of 12% is necessary to preserve its viability and vigour.

Harvesting: First male then female

Precautions:

- In 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.
- Panicles should be dried to 12% moisture level • Harvested material should be double checked properly.

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 a must to keep seed free from other seeds and Seeds should be cleaned before dispatching to processing plant by winnowing /using screens to remove chaffy /unwanted materials.

Seed certification:

Seed certification consists of several quality control measures that ensure supply of quality seeds to farmers. For this different following test were conducted

- For Genetic purity- Grow out test
- Germination test
- Physical purity test

Seed standards for Pearl Millet

Sl.No	Parameters	Permitted (%)	
		Foundation seed	Certified seed
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 (minimum) (%)	75	75
7.	Moisture content (%)	12	12

Field standards

Sl.No	Standard	Maximum permitted (%)	
		Foundation seed	Certified seed
1.	Off-types	0.05	0.10
2.	Pollen shedders	0.05	0.10
3.	Downey mildew diseased plants	0.05	0.10
4.	Ear heads affected by ergot	0.02	0.40

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Hybrid Seed Production Technology in Paddy

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What is hybrid rice? Like in other crops, the first-generation progeny (F1) obtained by crossing two genetically different varieties (parents) of rice is called 'Hybrid'. Since rice is self-pollinated, 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. It is generally referred to as 'R' line, and is used for hybrid seed production. The hybrid combines the desirable characters from CMS line and R line. They exhibit vigour for several quantitative characters including yield.

Grain quality of hybrids: The rice grain quality 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.

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 (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.

a. 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.

b. 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 5 m away from any rice variety.

c. 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: At present 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 Tamil Nadu are 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. Fifteen 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 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 raising. 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 may pollinate larger number of female rows.
c. Larger size of the inflorescence or panicle of the pollinator (R line), larger amount of pollen grains will be produced and 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 exserted, 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 exsertion 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. 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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Hybrid Seed Production Technology in Sorghum

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Breeding technique for Commercial production

Cytoplasmic genetic male sterility (CGMS)

Seeds produced in different stages

Nucleus seed stage	:	Maintenance of basic source by seed to row progenies.
Breeder Stage	:	A (AxB), Band R line are multiplied
Foundation Stage	:	A (AxB) and R line are multiplied
Breeder and foundation Seed stage	:	Multiplication of male sterile line or maintenance of A and B line
Certified seed stage	:	A xR–F1hybridproduced.
Certified seed stage	:	Production of hybrid seed

Stages of Seed Production

Breeder seed--->	A x B - B - R
Foundation seed--->	A x B - B - R
Certified seed--->	A x R

Popular hybrids of their parents: The first hybrid (CSH 1) was released in 1964. In 1969, the Coordinated Sorghum improvement Project was established. Now there are more than 30 hybrids. Some popular are

CSH1	CK 60AxIS84
CSH5	2077AxCS3541
CSH9	MS296AxCS3541
COH2	2219AxIS3541(KovilapattiTall)
COH3	2077AxCO21
COH4	296AxTNS30
CSH13R	296Ax RS29
CSH14	AKMS14AxAKR150
CSH16	27AxC43
CSH15(R)	104AxR585
CSH17	AKMS14AxRS673

Stages of seed multiplication	:	Breeder seed–foundation seed–Certified seed.
Foundation seed production	:	A and B lines are raised in4:2 ratios With 4 rows of B line as border row and allowed for cross pollination. The seeds from A line will be collected as A line seeds (multiplied).
Certified seed production	:	Hybrid seed production

Commercial in Hybrid seed production techniques

	Isolation distance	
	FS	CS
Normal	200	100
On presence of Johnson grass	400	400
On presence of forage sorghum	400	200
Hybrids	300	200

Johnson grass

Forage sorghum

Seed sand sowing

Seed rate	:	A line: 8 kg ha-[1]Rline: 4kgha^{-1}
Spacing	:	A line: 45 x30cm R line: 45 x solid row spacing.
Planting ratio	:	Foundation seed stage: 4:2 (A:B) Certified seed stage: 5:2(A: R)
Border rows	:	4 rows of male (either B or R line) to, supply adequate pollen.

Live markers :
- Live plants used for identification of male line live markers are used.
- It should have distinguishable morphological characters.
- Live markers can be sunflower, daincha etc.

Manure sand Fertilizers

Compost : 12.5t/ha
NPK : 100:50:50kgha^{-1}
Basal : 50:50:5kgha^{-1}
Topdressing : 25kgN after last ploughing
25kgN after boot leaf stage (45days)

Synchronization technique

1. Staggered sowing: Sowing of male parent and female parents are adjusted in such a way that both parents come to flowering at the same time.
   - ✓ CSH-5, MS2077A must be sown 10-15 days earlier to the male CS3541,
   - ✓ CSH6, the female parent MS2219A can be sown simultaneously with CS3541
   - ✓ CSH9, the female parent MS 296 A must be sown 7-10 days earlier than male CS3541 in November- December season.
2. Spraying growth retardant MH500ppm at 45DAS, delays flowering in advancing parent. MH won't dissolve in water and hence dissolve it in NaOH and then mix with water.
3. Urea spraying 1% to the lagging parent.
4. With hold one irrigation to the advancing parent.
5. Spraying CCC300ppm will delay flowering.

Rouging: Do it in both the parents.

Off types:

In female line remove : off types, wild types, pollen shedders, Rogues, partials, volunteer plants, diseased plants, R line, mosaic plants, late/Early flowering plant

In male line remove : Rogues, A line, Diseased plants, Late/ Early flowering plants, Wild types

Types of contamination

Presence of B line in A line called as pollen shedders
Presence of A line in B line called as off type Presence of
R line in B line called as rogue
Presence of B line in B line called as rogue
Presence of B line in R line called as rogue
Presence of B line in R line called as rogue
Pollen shedder sand off type cause physical contamination, whereas, rogue cause physical and genetic contamination.

Pollen shedders

Presence of B line plants in A linear called pollen shedders.

Partials

In certain A line plants, a part of the ear head-shed pollen due to the removal of sterility due to parental impurity (or) developmental variation or temperature.

Field Standards

	Isolation distance	
	FS	CS
Off-types(max)Varieties	0.05	0.10
Hybrids	0.05	0.10
Pollen shedders(max)	0.05	0.10
Designated diseased plants (max)(Ergot and smut)	0.05	0.10

Designated disease

1. Kernel smut
2. Head smut
3. Sugary disease of sorghum
   - ❖ It is specific to hybrid
   - ❖ Occur due to low seed set
   - ❖ Spray rogor 0.03%(or)
   - ❖ End osulfan0.07%

Method of harvesting

Male and female lines should be harvested separately. The male rows are harvested first and transported to separate threshing floor. Like that female rows are harvested and threshed separately.

Threshing

- ✓ At the time of threshing the seed moisture content should be reduced around 15-18%. Threshing can be done by beating the ear heads with bamboo sticks.
- ✓ While using the mechanical threshers, care should be taken to avoid mechanical damage.

Drying

Seed should be dried to 12% for short term storage and 8% for long term storage.

Processing

The sorghum seeds can be processed in OSAW cleaner cum grader using 9/64" round perforated metal sieve.

Seed treatment and storage

- ✓ The seeds are treated with captan or thiram @ 2 g/kg of seed and pack it in cloth bag at 12% moisture content for short term storage and 8% moisture content in 700 gauge poly ethylene bag for long term storage(or)
- ✓ The seeds can also be treated with halogen mixture @ 3 g/kg of seeds. The halogen mixture is prepared by mixing $CaOCl_2$ and $CaCO_3$+*Albizziaamara* at the rate of 5:4:1 and this mixture is kept in an air tight plastic container for 1 week. After one week the mixture is used for seed treatment.
- ✓ The treated seeds can be stored upto 12 months under open storage and upto 18 months in moisture vapour proof containers, provided it is not infested by the storage insects.

Seed yield : 3000kgha^{-1}

Seed standards

	Foundation seed	Certified seed
Physical purity Min.(%)	98	98
Inert matter Max. (%)	2	2
Other crop seed	5kg^{-1}	10kg^{-1}
Weed seed	10kg^{-1}	20kg^{-1}
Other distinguishable variety	10kg^{-1}	20kg^{-1}
Ergot disease by number	0.020%	0.040%
Germination Min. (%)	75	75
Moisture content		
Moisture pervious container	12	12
Moisture vapour proof container	8	8

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Quality Seed Production Technology in Small millets

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Millets comprising of sorghum, pearl millet and small millets or minor millets have been the traditional food in India especially in the marginal environments of the dry lands. Small millets include finger millet, foxtail millet, little millet, kodo millet, barnyard millet and proso millet. Because of their adaptation to hot and dry environments, millets have the potential to provide food and fodder security in the challenging environments of arid and semi-arid regions. The incentives and policies in favour of production and consumption of wheat and rice since 'Green Revolution' had put millets in a significant disadvantage. The cultivation of millets has declined by 70 per cent in the last seven decades. Fortunately, their production has not been affected as the productivity was enhanced by more than 2.5 times during the same period. The diversion of area under millets to other crops requiring more water has resulted in over-exploitation of groundwater and reduction in the on-farm diversity, making agricultural production system more vulnerable to ever-changing climate.

Currently, there is renewed interests in millets due to their in-built tolerance to water stress and supra-optimal temperatures, and capacity to grow well and produce good yields on soils with low fertility. Moreover, millets being highly nutritious, have an important role in achieving nutrition security. Therefore, Government of India declared millet crops as 'Nutri-Cereals'. The year 2023 has also been declared as the 'International Year of Millets' on India's call, which is supported by 70 countries in the world to promote cultivation and consumption of millets. The demand of nutri-cereals are increasing day by day, therefore, the great scope of seed business of its improved cultivars are arising.

Land requirements

Land for seed production all the small millets shall be well drained and free of volunteer plants.

Isolation requirements

Self pollination is the general rule in all these species. The extent of natural cross pollination is rather negligible. Hence a minimum isolation of three meters all around the seed field to separate it from fields of other varieties and fields of the same variety not conforming to varietal purity is the requirements for certification is considered sufficient for pure seed production.

Source of Seed: Generation system has to be followed, therefore, obtain nulleus, breeders and foundation seed as a source approved by the certification agency.

Finger millet (*Eleusine coracana* L. Gaertn)

Local name: Finger millet, Ragi, Mandua, Nagli, Kapai, Madua and Marua Hindi name: Ragi or Mandua

Finger millet is grown in all the cropping seasons i.e. *Kharif, Rabi* and *Zaid* in different parts of the country. However, 90 per cent of the area is under rainfed conditions, grown during Kharif season.

Climatic requirements: Finger millet is a crop of tropical and subtropical climate and can be sown successfully from sea level upto an altitude of 2100 meters on hill slopes as well as plains.

Rainfall: It is grown in areas having annual rainfall between 50 to 100 centimeter. Optimum temperature: It is a heat loving plant and for its germination, the minimum temperature required is 8-10° C. A mean temperature range of 26-29° C during the growth is best for proper development and good crop yield.

Soil requirements: Finger millet can be grown on a wide variety of soils ranging from. very poor to very fertile soils. The best soils are alluvial, loamy and sandy soils with good drainage.

Topography: Finger millet can be grown successfully from sea level to an altitude of 2100 meters on hill slopes as well as plains.

Time of sowing: As a rainfed crop, finger millet is sown in June-July in Tamil Nadu. Karnataka and Andhra Pradesh; during June in Maharashtra, Orissa, Madhya Pradesh and Gujrat; and in April-May in hills at higher altitudes of Himachal Pradesh and Uttarakhand.

Seed rate and seed treatment (Bio- fertilizer, chemical etc.): Finger millet seeds are very mall (400 seeds/g) and the recommended seed rate of 10 kg/ha contains 4 million seeds. However, the recommended seed rates for different method of are:

Line sowing	8 to 10 kg/ha
Broadcast method	10 to 12 kg, and
Transplanted	4 to 5 kg/ha

Seed treatment Azospirillum brasilense (N fixing bacterium) and Aspergillus awamori (P solubilizing fungus) @ 25 g/kg seed is beneficial. If seeds are to be treated with seed dressing chemicals, treat the seeds first with chemical and then with bio fertilizers at the time of sowing.

Procedure for inoculating seeds with biofertilizers: 1. culture specific to the crop is to be used @ 25 g per kg of seed.

Application of 7.5 th FYM+ 10% of the recommended dose of N gives better results than 100% NPK in the form of inorganic fertilizers.

Irrigation/water management: Finger millet grown in *Kharif* does not require any irrigation. When irrigation facilities are available, at tillering and flowering stages, if rains stop for a long spell, then irrigation would be required to obtain good yield.

Critical stage of crop/plant for irrigation: Tillering and flowering stage Method of irrigation: To facilitate irrigation, ridges and furrows must be made before transplanting of crop. Number of irrigation routines: For irrigated crop, depending on soil type, weather condition and duration of variety, 8-14 irrigations are required. Irrigate the crop once in 6-8 days in light soils and once in 12-15 days in heavy soils.

Crop stage for irrigation: Tillering and flowering stage.

Disease management: For control of blast spray dithane Z-78 twice or thrice at 2kg/ha at an interval of 10 days.

Roguing: Rogue out off-type plants at flowering and maturity stage. Harvesting and threshing. The crop is cut close to the ground and loose sheaves laid on ground to dry for several days, then tied and placed in small stacks to dry until dewy season is over and ears are removed from the stacked sheaves. In the case of Irrigated crops, the ears may also be gathered as they mature, heaped for a few days to cure and then threshed. Seed is threshed with sticks. If threshed with threshers care is necessary to avoid cracking of seeds. Seed separates easily from the straw.

Weed management: Some of the important weeds viz. *Galinsoga parviflora* (Pardesi), *Polygonum capitatum* (kukaria), *Digitaria ciliaris* (Malsa), *Setaria glauca, Cyprus rotundus* (Dub grass), *Oxalis latifolia* (Tipatia), *Cyprus rotundus* (Motha), *Commelina brnghalensis* (lonia grass) are found in the fields of finger millet

Control measures

Mechanically:

Method: Two to three inter-cultivations and one hand weeding in line sown crop. However, in broadcast crop two hand weedings can effectively manage weed problem in field. Weed free up to 35 days or two weedings up to 35 DAS are recommended for weed management

Chemically:

Name of chemicals their doses and stage of application: In irrigated areas, spraying of 2,4-D sodium salt @ 0.75 kg a.i./ha after crop emergence. Alternatively Isoproturon @ 0.5 kg/ha as pre-emergence spray is also effective. In assured rainfall and irrigated areas Oxyflurofen @ 0.1 liter a.i. /ha as pre-emergence is also effective in weed control. Pre-emergence application of Isoproturon @ 0.5 kg a.i./ha mixed with sand with two intercultivations and one hand weeding effective in giving weed control.

Harvesting and threshing: The crop matures in about 120-135 days depending on the tract and the variety. Harvesting is generally done in two stages. The earheads are harvested with ordinary sickles and straw is cut close to the ground. Earheads are heaped for three to four days to cure and then threshed with hand or bullocks. At some places under rainfed conditions, the whole plant with panicle is cut, heaped and then threshed.

Yield: With improved package and practices, it is possible to harvest 15-20 quintals of seed per hectare

Barnyard millet (*Echinochloa frumentacea*)

Local name: Sawan, Jhangora, Madira, Kudraivali and Oodalu Hindi name: Sawan or Jhangora. Season (s) in which the crop is grown: The crop is sown in Rabi, Kharif and Zaid, in different states of the country

Uses and nutrient values: Its grains are consumed just as rice. They are used in making nice pudding (kheer). Grains contain 7.2 per cent protein, 9.8 per cent crude fiber, 65.5 per cent carbohydrates, 4.4 per cent ash. The digestibility of protein is 40 per cent. The grain is eaten mostly by poor classes but sometimes it is brewed for beer. It is also used as feed for cage birds. The straw makes good fodder for cattle. Its green fodder is very much relished by cattle.

Area and distribution: Barnyard

millet is grown in India, China, Japan, Malaysia and East Indies. In China and Japan it is said to be grown as a substitute crop when the rice crop fails. It is also grown to some extent in Africa and United States of America. In India it is grown in Madhya Pradesh, Uttar Pradesh, Uttarakhand and Tamil Nadu.

Climatic requirements: Barnyard millet is drought tolerant and hence it is grown as rainfed crop. The ideal temperature for the better growth is 26-29^{o}C.
Soil requirement: Barnyard millet is generall cultivated in soils of marginal fertility. It can be grown in partially water logged soils such as low lands. But it thrives best on sandy loam to loam soils having sufficient amounts of organic matter.
Preparation of field: Since, the barnyard millet crop is cultivated in very limited and marginal soils. The land is given only limited preparatory cultivation. Although fine tilth is required but only two ploughs are needed. Some where farmers using with local plough or harrowing followed by planking are sufficient to prepare seedbed for barnyard millet.
Time of sowing: In Tamil Nadu, rainfed crop is sown in September October and imgated crop in February March. In hills of Uttarakhand and North Eastern states, sowing in April-May is ideal.
Seed rate and seed treatment (Bio-fertilizer, chemical etc.): 6 to 8 kg/ha
Method of sowing: The sowing of Barnyard millets is done as line sowing However, transplanting is also done in some places in Maharashtra but in case of seed production single plant per hill is recommended.
Spacing and depth: Optimum spacing of 25 cm between rows and 10 cm between plants is optimum. However, sowing of seeds in 3-4 cm depth is ideal.

Nutrient management: The recommended doses of fertilizers vary from state to state as well as for rainfed and irrigated crop.

State	Recommended doses of fertilizers
Andhra Pradesh	20:20:20
Bihar and Tamil Nadu	40:20:20
Uttar Pradesh	40:20:0
Uttarakhand	40:20:20
Other states	20:20:0

Time and method of application: All the fertilizers should be added in the soil at the time of sowing but in case of irrigation facilities are available, half dose of the nitrogen should be top-dressed in standing crop after 25-30 days of sowing.
Integrated nutrient management: In addition to fertilizer, application of 5 to 10 tonnes of farmyard manure per hectare is also beneficial in boosting the yield of crop.

Irrigation/water management: Generally barnyard millet does not require anyimgation. However, if dry spell prevails for a long period, then irrigation is required.
Critical stage of crop/plant for irrigation: Panicle Initiation stage.
Number of irrigation routines: One irrigation is required, if dry weather prevails for long period.
Crop stage for irrigation: Panicle formation stage.
Weed management: In the barnyard millet only 2,4-D can be applied as in finger millet and mechanical weeding is preferred for effective control. Only two inter-cultivations and one hand weeding in line sown crop are enough. However, in broadcast crop two hand weedings can effectively manage weed problem in field. Weed free up to 30 days or two weedings up to 30 DAS are recommended for weed management
Roguing: Rogue out off-type plants at the time of flowering and at maturity. Besides off-types also remove plants affected by diseases. Harvesting and threshing. The crop is harvested when the ears turn golden brown, either by cutting the whole plant or the ears separately.
Harvesting and threshing: the crop should be harvested when it is ripe. It is cut from the ground level with the help of sickles and stacked in the field for about a week before threshing. Threshing is done by trampling under the feet of bullocks.

Yield: With improved package of practice, it is possible to obtain 12-15 quintals of seed.

Little millet (*Panicum sumatrense*)

The cultural practices, roguing, harvesting and seed yields are similar to barn yard millet. It can however withstand both the water-logging and drought.

Foxtail millet (*Setana italica* (L) Beauv)

Local name: kakun, kangani, navane, tenai, korra, , kauni and rala
Season (s) in which the crop is grown: It is grown in *Rabi, Kharif* and *Zaid* in different states of the country
Uses and nutrient values: The grains of Kakun are cooked like rice. In some areas the grains are ground to flour and used in the form of 'chapatis'. Kakun grains contain 12.3 per cent protein, 4.7 per cent fat, 60.6 per cent carbohydrates and 3.2 per cent ash. The grains are fed to cage birds. The straw is stemmed and is liked by cattle.
Area and distribution: Foxtail millet is grown in India, China, Eastern Europe, Southern Parts of Russia and to some extent in African and American countries. In India it is cultivated in Karnataka, Andhra Pradesh, Madhya Pradesh, Uttar Pradesh and Uttarakhand.
Climatic requirements: foxtail millet cultivated in tropical as well temperate regions. It can be grown successfully in areas receiving 50-75 centimeter rainfall.
Optimum temperature: It is grown in warm regions and can tolerate temperature of 35 to 40°C.

Soil requirements: Foxtail millet requires a fairly soil for good yields, although it can be grown in poor soils. Light soils including red loams, alluvials and black cotton soils are all suitable for its cultivation but it thrives best on rich, well drained loam soils.
Topography: Foxtail millet can be grown up to an altitude of 2000 meters.

Preparation of field: Before the onset of monsoon the field should be ploughed once with mould board plough. With the onset of monsoon the field should be harrowed or ploughed with a local plough twice in Northern India or with blade harrow in South India, planking should be done for making the field smooth and well leveled.
Time of sowing: Optimum time of sowing for rainfed crop is August - September in Tamil Nadu, July-August in Karnataka, first fortnight of July in Andhra Pradesh and second and third week of July in Maharashtra. In Tamil Nadu, *kharif* irrigated crop is planted from the beginning of June to end of July and summer irrigated crop in January. For plains of Uttar Pradesh and Bihar, middle of June is optimum sowing time.
Seed rate: In line sowing 8 to 10 kg/ha
Seed treatment: Seeds should be treated with Thiram at the rate of 2.5 g/kg of seed.

Method of 33 from 5-10 q/ha and of irrigated crop 10-16 q/per hectare depending upon the management practices.

Proso millet (*Panicum milliaceum* L.)

Local name: Cheena broom corn millet, hog millet, hershey millet, panivaragu, variga, baragu
Season (s) in which the crop is grown: It is grown in *Rabi* and *Kharif* different states of the country.
Area and distribution: It is grown extensively in India, Japan, China, Egypt, Arabia and Western Europe. In India cheena is largely grown in Madhya Pradesh, Eastern Uttar Pradesh, Bihar, Tamil Nadu, Maharashtra, Andhra Pradesh and Karnataka. In Uttaranchal, the crop is grown as catch crop during April-May after the harvest of *Rabi* crops and is harvested before transplanting of rice.
Climatic Requirement: Proso millet is acrop of warm climate. It is extensively cultivated in warm regions of the world. It is highly drought resistant and can be grown in areas where there is scanty rainfall. It can withstand water stagnation to also to some extent. It can tolerate temperature of 35-40^{o}.
Soil Requirement: Proso millet can be grown both in rich and poor soil, having variable texture, ranging between sandy loam to clay of black cotton soils. Coarse sandy soil is not suited for proso millet cultivation. Well drained loam or sandy loam free from volunteer plants and rich in organic matter are ideal for proso millet cultivation. The proso millet is grown in sporadic patches from Himalyas in North to Tamil Nadu in south.
Preparation of field: Soon after harvesting of the previous crop, the field should be ploughed to expose the soil to sun and enable it to retain more moisture. With the onset of monsoon, the land should be harrowed two to three times and then finally leveled. The seed bed should be prepared by running harrow or desi plough thrice followed by planking. Cheena needs a firm and clean seedbed but does not respond to deep ploughing.
Time of sowing: As a *Kharif* crop, proso millet should be sown in the first fortnight of July with the onset of monsoon rains and as a summer crop it should be sown by the middle of April. During summer, it would be desirable to sow cheena as soon as the harvesting of *Rabi* crop is over.
Seed rate: Proso millet can be sown by broadcasting or by drilling seeds in furrows. Depending on method of sowing, 8-12 kg seed is required for one hectare of land.

Method of sowing: of proso millet is done by drilling seeds in furrows.
Spacing and depth: Row to row distance should be kept 25 centimeter and plant to plant 10 centimeter. The depth of seeds should be 3-4 centimeter.
Nutrient management: To get a good crop, general fertilizer recommendations under irrigated conditions are 40 kg nitrogen, 20 kg phosphorus and 20 kg potash per hectare. However, in rainfed conditions the fertilizer doses should be reduce to half of the irrigated crop. If organic manure is available, it may be added to the soil about a month before sowing at the rate of 5 to 10 tonnes per hectare.
Time and method of application: Apply half of the nitrogen and whole amount of phosphorus and potash as a basal at the time of sowing. The remaining half of the nitrogen should be applied at the time of first irrigation,
Irrigation or water management: The *kharif* sown crop generally does not require any irrigation. However, at tillering stage, if dry spell prevails for longer period, then one irrigation must be given to boost yields. Summer crop, however, would require two to four irrigations depending upon soil type and climatic conditions. Give first irrigation at 25- 30 days after sowing and second irrigation about 40-45 days after sowing.
Weed management: For getting high yield and minimizing loss of soil moisture and nutrients, the field should be kept weed free up to 35 days stage. Two weeding at an interval of 15-20 days would help control it. Weeding may be done with hand hoe or wheel hoe.
Roguing. Rouging in the seed crops is the most important practice before the harvesting. Therefore, rogue out off-type plants at the time of flowering and at maturity. Besides off-types also remove plants affected by the diseases. Harvesting and threshing. The crop is harvested when the ears turn golden brown, either by cutting the whole plant or the ears separately.
Harvesting: Proso millet crop matures to harvest 65-75 days after sowing. The crop should harvested when it is about to mature. The seeds in the tip of upper heads ripe and shatter before the lower seeds and latter panicle get mature. Therefore, the crop should be harvested when about two thirds of seeds are ripe. Crop is threshed by hand.
Yield: With improved package of panicle it is possible to harvest 18-22 q seeds per hectare.

Kodo millet (*Paspalum scrobiculatum*)

Cultural practices
Only limited land preparation is done. One to two harrowings followed by levelling is desirable for seed crop. The crop is nor- mally sown in June-July. In Andhra Pradesh and Tamil Nadu it is

sown in Sept.-Oct. also. Seed crop is sown in rows 25-30 cm apart. The depth of seeding should not be more than 3 cm. 10-15 kg seed per hectare is sufficient. Seed crop should be manured at 60 kg nitrogen, 40 kg phosphorus and 20 kg potash per hectare. The rainy season crop does not need irrigation. In case of prolonged drought 1-2 irrigations may however be given. The water should not be allowed to stagnate in the field. The insect control is similar to that described for common millet. For control of smut treat the seed by immersing them in 1.5 per cent copper sulphate solution.

Roguing. Rogue out off-type plants at the time of flowering and at maturity. The smutted plants should also be removed before harvesting the crop.

Harvesting and threshing: The plants are cut close to the ground, bundled and stacked for a week and threshed by tram-pling by cattle.

Seed yield. The seed yield ranges from 8-14 q/ hectare depending upon crop management

Seed Standards for Small Millets

Sl.No	Parameters	Permitted (%)	
		Foundation seed	Certified seed
1.	Physical purity (minimum)	97	97
2.	Inert matter (maximum)	2	2
3.	Other crop seed by number (maximum)	10/kg	20/kg
4.	Weed seed by number (maximum)	10/kg	20/kg
5.	Objectionable disease effected seed (%)	0.020	0.040
6.	Germination (%)	75	75
7.	Moisture content (%)	12	12

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Quality Seed Production Technology in Wheat

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Generally, after harvest of the wheat crop, the farmers preserve a part of the harvested grain and use that as seed for the next season. For them, there is no difference between grain and seed. But in reality, we use grain as our food for which we never care for the quality or germination percentage of it. But, seed is a living grain which can produce a living plant and is used for crop production. Therefore, lot of importance is given on its physical purity, germination capacity, seed moisture and genetic purity of seed; and it is emphasized that, "every seed is a grain, but every grain is not a seed".

However, when we talk about quality seed, then a quality seed is physically pure, healthy, true-to-the-type and genetically pure, which leads to a good production. Quality seed should have the following qualities:

- ✓ It should be genetically pure with the exact varietal features. It should be physically pure; that means physical impurities like soil particles, small stones, broken seeds etc. should not be there.
- ✓ Seed should be fully matured, healthy and of uniform size. Seeds of weedy grasses, other varieties or other crop should not be found mixed with it.
- ✓ Seed should be free from diseases.
- ✓ Seed should not be affected by insects
- ✓ Seed should have a maximum of 12% moisture content
- ✓ Seed should have a minimum of 85% germination. Higher the germination percentage better is the seed quality.

Why to use Quality Seed?

It is an established fact, supported by the research and field data of the agriculture scientists, that among different factors responsible for a good crop production, quality seed alone can contribute for 5-20% higher yield, Among all the factors contributing to higher yield, quality seed alone contributes the maximum; and without this the contributions of other factors become negligible. Therefore, lot of importance has been given on use of quality seed for achieving higher yield in wheat. Generally, the advantages of use of quality seed are:

- ✓ Genetic purity as per varietal features is obtained
- ✓ Number of off-type plants becomes less
- ✓ Requirement of seed quantity remains within the prescribed seed rate because of high germination percentage
- ✓ Healthy seeds give rise to healthy seedlings which compete well with the weed/grasses
- ✓ Less disease and insect incidence are marked
- ✓ Crop stand becomes uniform that flowers and matures uniformly and helps in higher yield

Land Requirements

Land to be used for seed production of wheat shall be free of volunteer plants. In addition, the field should be well drained, free of weeds, and the soil neither too acidic nor too alkaline. Fairly long intervals between crops of wheat are desirable in rotation, to reduce disease contamination of seed from diseases such as, karnal bunt.

Previous cropping

The crop should be planted on a field with a known history to avoid contamination from volunteer plants, noxious weeds and soil-borne diseases that are potentially seed transmitted. A wheat seed crop should never immediately follow wheat, unless the wheat crop in the previous season was of the same variety and of the same or higher generation. Two year rotation for flag smut and seed gall nematode is suggested where applicable.

Isolation Requirements

Wheat is normally a self-pollinated crop, but natural cross-pollination sometimes occurs. The extent of cross-pollination varies from one to four per cent. It is usually sufficient to isolate seed fields with a strip of 3 metres all around which is planted with a non-cereal crop, or left uncropped. In cases where variety is susceptible to diseases caused by *Ustilagospp*. (e.g. loose smut) an isolation distance of 180 metres between seed field and other L fields of wheat is recommended. The Indian minimum Seed Certification Standards require only 150 metres isolation from other wheat fields wherein loose smut infection is in excess of 0.1 per cent in the case of foundation seed production, and 0.5 per cent in the case of certified seed production.

Brief Cultural Practices

1. **Preparation of land**. Bring the soil to a fine tilth by deep ploughing with a soil turning plough and by running before the presowing irrigation. Presowing irrigation is a must for uniform good germination. Give a light shallow ploughing or discing after presowing irrigation. Levelling is an important part of seed bed preparation. Keep the seed bed free of weeds.

Broadcast BHC 10 per cent dust at 25 kg per hectare just before the last harrowing or ploughing. It may be added to the fertiliser and applied. This will prevent white ant and Gujhia weevil attack.

2. **Time of sowing**: a. long duration varieties like C 306 should be sown during the first fortnight of November. b. short and medium duration varieties like Sonalika, HD 1982 should be sown during the second fortnight of November.

3. **Source of seed:** Obtain breeder/foundation seed from a source approved by the certification agency.

4. **Method of sowing**: The seed crop is sown in rows with seed drill, or behind the plough in furrows. The depth of seeding should be 5 cm. Seed drill should be thoroughly cleaned and checked before use. Sowing of one variety should be completed before taking up another variety, to avoid mixture. If, for any reason, it has to be used for another variety, it should be thoroughly cleaned and checked so that not even a single seed of the previous variety is left.

5. **Seed and sowing**: If seed of more than one variety is being sown for seed production, the different varieties should be kept separately. Before putting the seed in the seed drill, check the individual bags and tags for that variety.

6. **Spacing**: The row distance for seed crop should be kept at 20 to 22.5 cm to facilitate rouging and inspection work. 6. Seed rate: The recommended seed rate for seed crop is 85-100 kg per ha. The seed should be treated with systemic fungicide to control loose smut.

7. **Fertilisation**: The recommended doses of fertilisers are 80 to 120 kg nitrogen, 50 to 60 kg phosphorus and 40 kg potash per hectare, in the light of soil test values and native fertility. If zinc deficiency is noticed in the soil, zinc sulphate at 15 to 20 kg per ha may be given at the seeding time." Apply the whole of the phosphoric and potassic fertilisers and half of nitrogenous fertilisers while sowing, or just before sowing. Apply the remaining half of nitrogenous fertiliser at first irrigation. Band placement of fertiliser gives better results. The fertiliser should not fall on the seed but should be dropped 5 cm away from the seed. Uniform fertiliser application is important. If soil has been tested, the recommendation of the soil testing laboratory should be followed.

8. **Irrigation**: Depending on the soil, four to six irrigations may suffice. The first irrigation should be given at crown root initiation stage, about 20-25 days after sowing. Other irrigations should be given at late tillering, late jointing, and flowering, milk and dough stages. Two to three extra irrigations may be needed on light soils.

9. **Interculture**: Timely weeding and interculture are essential. Periodic hoeing and weeding keep the field free of weeds. For control of broad-leaved weeds spray 2-4 D at the rate of 0.5 kg active ingredient per hectare in 750 litres of water after 25 to 30 days of sowing. For control of *Phalarisminor* or wild oats make a pre-emergence application of pendamethalin (stomp) @ 1 kg a.i. per ha in 750 litres of water or spray Isproturon @ 1 kg a.i. per ha in 750 litres of water after 35 days of sowing.

10. **Plant Protection**: For control of termites apply 10 per cent BHC dust at 25 kg per ha in the soil at the time of last ploughing. For control of termites in standing crop use chlorpyriphos 20 EC @2-3 litres/ha with irrigation water. For stem borer apply linden 6G or carbofuran 3G at 25 kg per ha two weeks after germination or spray the crop with endosulphan 35 EC at 1.5 litres per ha after 3rd, 5th and 7th week of germination.

For control of loose smut use seed treated with a systemic fungicide, such as, vitavex. For rust, Altemaria and Helmin- thosporium spray the crop with Zinc manganese carbamet at 2 kg/ha, or Zineb 75 per cent wp @ 2.5 kg or Ziram 80 per cent wp at 2.0 kg per ha. or spray the crop with Ziram 27 per cent liquid @ 2-2.5 litre/ha at the interval of 10-15 days as per requirement.

Rouging

Two to three roguings may be necessary to bring the seed plot to seed certification standards. The first roguing may be done just ahead of the flowering stage, or during flowering. It is essential that this roguing be done in time, to remove any of-type plants which are obvious at this stage of growth. Failure to do so can allow natural crossing of rogues with normal plants, thus adding the variation in the following year. Obvious rogues at this stage include plants of different colour, plants susceptible to various diseases, tall plants in a dwarf variety, dense

heads or other head variations, smutted plants and early heading plants. The best way to remove loose smutted plants is, that as soon as the crop starts to come in the heading stage, a gang should be formed to walk through all the rows of seed field. Each one of them should be supplied with a gunny bag and paper bags. Furthermore, they should be trained to identify the smutted plants. The smutted plantsare easily recognised on the basis of black ears. Soon after spotting the smutted plant its ear head should be covered with the paper bag and then the whole plant uprooted, without allowing the spores to fall.

A second roguing should be done just after flowering is completed, and before the crop starts to turn colour. If only a few rogues are present, this might suffice as the last roguing. Rogues at this time include those mentioned in the case of the first roguing, plus tall varieties which are late in heading and grow up late, thus escaping roguing in the first instance. Also, the ear characteristics at this stage are apparent and the off types distinguishable on the basis of ear characteristics need to be removed. The first two roguings are very important, as lodging may occur at highly fertile spots which may make it difficult or impossible to carry out the final roguing.

The third roguing should be done after the ear heads turn colour and start to mature. In addition to rogues previously mentioned, one is now able to rogue on the basis of differences in colour of heads, colour of awns and variations in earhead type which are most easily discernable at this stage. In addition to off-types, the objectionable weed plants such as HiranKhuri (*Convolvulusarvensis*). *Phalarisminor* and weeds such as Chatrimatri (*Lathyrus* species and *Vicia* species), as well as other crop plants, namely barley, oats, gram must be removed at this stage, or prior to harvest.

Field Standards (ISTA)

Seed Class	Off-type	Pollen shading	Object able plant	Plant head affected by designated disease
Foundation Seed	0.050	-	0.010	0.10
Certified Seed	0.1	-	0.010	0.10

Harvesting and Threshing

Soon after maturity, the seed crop should be harvested to avoid shattering and losses due to uncertain weather. Delay of harvest in rainy and stormy weather may result in sprouting in the ear and thus rejection of the crop for seed.

Harvesting may be done by sickle, and later the threshing with stationary threshers or with trampling done by bullocks. Care must be exercised to ensure that labourers do not mix the harvested certified seed with other wheat on the farm. Threshing should be done promptly. Threshing equipment, if used, or the threshing floor must be thoroughly cleaned to prevent mixtures. The crop can also be combined directly in the field. The following instructions should be followed in combining the seed crop.

Do's

1. Combine your seed plot only when moisture content in the grain has come down to sixteen per cent or below.
2. Start combining from the later morning hours, when dew dries up.
3. Harvest plants growing on bunds and channels by hand before combining the plot.
4. The combine should be allocated variety-wise, and it should bear the name of the variety under combining in bold letters.
5. After complete harvesting of a variety, a combine can be assigned to another variety. But it should be ensured that not even a single grain of the previous variety is left in the combine.
6. Thepercentage of cut grains should be kept at the bareminimum by adjustment of the combine so as to avoid loss

Don'ts

1. Do not combine a plot having moisture content in the grain more than 16 per cent so as to avoid crushing and spoilage of grains.
2. The combine should not be run in the early morning hours when excessive dew will hinder the proper operations of the combine, resulting in damaged seed.
3. Do not changes combine to another variety until the combine harvest is cleaned thoroughly in order to avoid varietal mixture.
4. Do not combine without harvesting of later maturing plants in sprout growing on bunds and channels so as to minimise the percent- age of green kernels in the seed lot and to avoid the chances of spoilage of seed because of the high moisture percentage in green kernels.

Drying, Cleaning and Bagging

Wheat seed is usually very dry at harvest time in North India, i.e., at nine to ten per cent moisture. To maintain the good quality in the seed, it is recommended that the seed be cleaned, treated and bagged immediately after threshing and prior to the start of the monsoon. The cleaned, bagged seed should be stored in a dry, insect and rodent proof warehouse.

Seed Yield

Average seed yield varies from 30 to 40 qtls per hectare.

Processing

After a seed crop has been harvested, the seed, if necessary, has to be dried and cleaned. For wheat seed cleaning, mainly screens, indented cylinders and air screen cleaner are used.

- Screens separate based on the width and thickness; a width (or diameter) separation is obtained by round screens, while for thickness separation oblong screens are used.
- Indented cylinders carry out length separation; the indents (cells or pockets) in the cylinder will, depending on their size, lift the seeds, which fit in the indents.
- Air separates seeds according to their behaviour in an air stream (seed density). The most important characteristic is the weight; light particles (dust, chaff, glumes or empty

or partly filled seeds) will be lifted, whereas the heavier seed will fall down through the air stream.

Pre-cleaner

It has one air channel to remove light material, one top scalping screen to remove large particles and one bottom grading screen to remove small particles.

Dryer

If wheat seed is above 11 to 12 percent moisture, it is dried before it goes into bulk storage or processing.

Air-screen cleaner

This is the basic cleaner, usually with two air channels and, preferably, four screens. The first air channel removes dust and light materials as the seed falls from the feed hopper. The second air channel removes light seed and materials after the seed passes through the last screen. Screen configurations vary considerably, one or two top or scalping screens remove particles larger than the good seed, and one or two bottom or grading screens remove particles smaller than the good seed.

Because the average size of wheat seed varies according to the growing conditions, standard screen sizes cannot be recommended. In general size of screen aperture for all wheat variety is:

Top screen 6.40 mm(R);

Bottom screen 2.10 mm(S)

Length separator

A length separator is almost always used to clean wheat seed. By using the proper machine configuration, shorter or longer undesirable materials (such as broken grains, weed seeds, oat, barley, etc.) are removed. Broken grains and weed seeds, which are shorter than the good seed, are removed by using cylinders with smaller indents.

Larger impurities can be removed by using a cylinder with indents that lift all good seed, but contaminants (wild oats, oats or barley grains and unthreshed glumes) remain in the cylinder.

Gravity separator

The gravity separator classifies a seed mixture mainly according to density or specific gravity. It can be used to remove unthreshed glumes and soil particles, which have similar sizes to wheat but different weights.

Another application is the removal of weevil-infested grains from the seed lot and upgrading seed (in order to improve germination).
Further-more, wild oats and some barley may be removed from the wheat seed lots.

Treater

Wheat seed should, if necessary, be treated with the appropriate fungicide to protect the seed and seedling after planting. Insecticides are sometimes applied to protect seed in storage and in the soil.

Treatments may be applied to protect the seedlings or adult plants against pathogens carried on or in the seed.

Dryer

In humid and hot climates, seeds may be sealed in vapour- tight plastic bags to maintain viability over longer periods. In such cases, wheat seed moisture content must be below 9 percent, preferably not Cover 8.5 percent. Usually, a dehumidified, closed-circuit dryer is used after the seed treatment is applied.

Bagger-weigher

The final step is to weigh the proper amount of seed into the proper kind of bag. Wheat seed bags should be of a size that fits local farmer needs (seed rates and field size).

Seed Testing

Min. sample weight for testing seed weight

Minimum weight of seed lot (Kg)	Submitted sample (g)	Working Sample (g)	Working sample for counting of other species (g)
30,000	1000	120	1000

Germination Test (ISTA 2007)

Procedure:

Replications	Four replication of 100 seeds
Substrata (Moisture Reservoir/ Medium)	Top of Paper, Between paper, Sand
Temperature	20°C
RH	95 %
First Count	at 4th day
Final Count	at 8th day
Dormancy breaking treatment	Preheating (30-35° C)

Moisture% Test (ISTA 2007)

Objective

To determine the moisture content of seeds by methods suitable for routine use.

Definition

The moisture content of a seed sample is the loss in weight when it is dried. It is expressed as a percentage of the weight of the original sample. It is one of the most important factors in the maintenance of seed quality.

Method of moisture determination

1. Air oven method

In this method, seed moisture is removed by drying the seed sample at a specified temperature for a specified duration.

2. Moisture meters

Moisture meters estimate seed moisture quickly but the estimation is not as precise as by the air oven method.

Weight of the submitted sample

100 g for species that have to be ground. 50 g for all other species. The sample should be submitted in polythene bag of 700 gauge.

Procedure:

1. Three Replication of 4 gram seed.
2. Grinding: Course grinding
3. Either LCT (103°C for 17h; or HCT (130°C) for 2h
4. Use desiccators: 30-45 min
5. Calculate moisture content using following formula:

$$\text{Moisture content} \quad \frac{m2-m3}{m2-m1}\times 100$$

Where,

M = Seed moisture content
m1 =Weight of the empty container withitscover
m2= Weight of the container with its cover and seeds before drying
m_3 = Weight of the container with its cover and seeds after drying

Wheat Varietal Identification

Phenol color reaction: Extensively used for identification wheat varieties. It is easy, quick and reliable test. Pieper (1920) was first to use this test

Procedure:

1. Soak 50 seeds in water for 16 hrs
2. Place seeds in Petri dishes on 2 layers of filter paper soaked in 1% phenol solution. Petri dishes are immediately covered.
3. Observe after 2 hrs and finally at 4 hrs

The varieties could be grouped into Nil, no reaction, Light brown, Brown, Dark brown, Black

Prescribed Seed Standard for Seed Certification (ISTA)

Seed Class	Germination% (min.)	Moisture%	Pure Seed (min.)	Inert matter% (max.)	Other Crop Seed (max.)	Other Dist. Var. (max.)	Objectionable weed (max.)
Foundation Seed	85	12.0	98	2.0	10	-	10
Certified Seed	85	12.0	98	2.0	10	-	20

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Hybrids Seed Production of Maize: the practical Aspects

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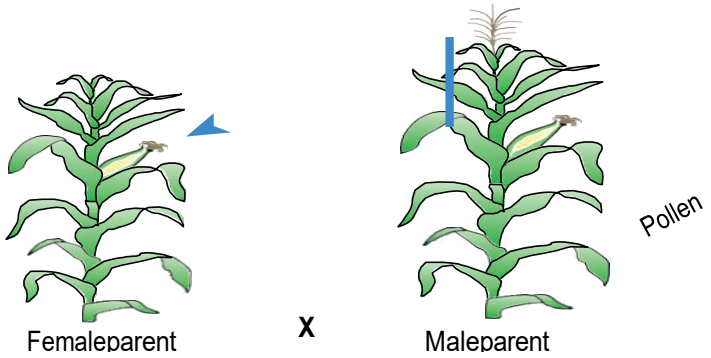
Hybrid maize seed production involves deliberately crossing a female parent population with a male parent in isolated fields. Thus, from the very start of hybrid seed production, the identity and arrangement of the two parent populations determine the outcome. Each hybrid variety is composed of a specific combination of a female (seed bearing) and male (pollen providing) parents. The field management of the two parents is also important and requires attention to timing of planting, elimination of off-types, removal of tassels from the females before pollen shedding, separate harvesting of the female seed and careful shelling and processing of the seed to maintain seed quality. The sequentially dependent nature of the process means that any errors in earlier stages have a significant impact on following stages and major errors or problem scan result in complete failure or rejection of the crop.

Simply put, a maize hybrid results from the fertilization of one maize plant by another genetically un-related plant. 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. This seed bears a unique genetic make-up from the female and male parents and will produce a plant with particular characteristics. Plant breeders produce the female and male parents of each hybrid to generate progeny with particular characteristics, such as plant maturity, disease resistance, grain color, food processing quality and soon. It is this unique hybrid seed that farmers will sow in their fields.

When a grower purchases a particular hybrid, he or she expects the seed to perform in the field as designated on the varietal description.

With maize, there are a number of possible kinds of hybrids, such as single-cross, three-way, double-cross and top-cross hybrids. 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 (detasseled) before pollen shed, so that the only source of pollen for the female flower (the cob or ear) on the female plants is the tasselson the male plants. Detasseling of the female is necessary to prevent any pollen from the female pollinating the female silks. If this occurs, known as "female-selfing," the result is a significant loss of seed quality that will clearly be seen in a crop grown from the seed. Female-selfing is to be avoided at all costs.

The ratio of the number of female rows to male rows in the field is usually on the order of 3:1 for single-crossesandthree-waysbutmayextendto8:1 for double-cross hybrids. The actual ratio that is planted depends on a number of factors, but principally on the pollen production of the male,



the height of the male tassel relative to the female silk and the size of the female plant. Furthermore, the timing of pollen shed of the male and silking of the female must coincide. If the male and female plants are known to flower at different times, adjustment in the sowing dates of each component will be required to ensure flowering synchrony of the two parents. The hybrid seed that is useful to farmers is harvested from the female plants. Plants and seeds from the male rows are usually discarded before harvest to avoid mixing of seed from the parents.

With this preliminary description of maize hybrid seed production, it is clear that numerous key factors determine the success and quality of hybrid seed production, including the following:

- Female and male parent identity, purity and identity preservation.
- Ratio of female to male rows in the seed field.
- Timing of planting of the female and male plants.
- Timely removal of the tassels from the female plants before they shed pollen and before silk emergence.
- Timing of female silk emergence relative to male pollen shed.
- Avoidance of contamination of female silks with unwanted pollen, particularly from females, off- type males and foreign pollen.
- Avoidance of seed mixtures between and within the male and female plants.

Hybrid composition:

The basic building blocks of maize hybrids are inbred lines. Inbred lines are the result of repeated self-pollination of particular maize populations to produce a plant that essentially has a fixed and uniform genetic composition. Consequently, all the plants of a particular inbred line are identical, but each inbred line will differ in its genetic composition from other inbred lines. Because maize is normally cross-pollinated, inbred lines are usually smaller, less vigorous and lower-yielding than open pollinated maize plants due to a phenomenon called "inbreeding depression." But, when two unrelated inbred lines are crossed to form a hybrid, the resultant seed produces plants with restored vigor and a significantly higher yield than either of the two parents. This is known as "hybrid vigor," and it is this vigor that is exploited in hybrids and makes hybrid varieties useful to farmers.

The most common types of hybrids in maize are single-cross, three-way and double-cross hybrids .A single-cross hybrid is made by crossing two inbred lines; a three-way hybrid is made by crossing a single-cross hybrid with an inbred line; while a double-cross hybrid is made by crossing two single-cross hybrids. Two other types of hybrids are top-crosses and varietal crosses. A top-cross hybrid is made from an open-pollinated variety crossed with an inbred line, while a varietal cross is a hybrid of two unrelated open-pollinated varieties.

On the assumption that the best genetics and agronomic management are applied, general statements may be made about the advantages of different hybrid types. Single-cross hybrids are generally higher-yielding than other hybrid types. They are very uniform in appearance, because every plant has the same genetic make-up, but the seed yield of a single-cross hybrid is lower than other hybrids, because the female is an inbred line.

Consequently, seed of single-cross hybrids is the most expensive, but this is usually acceptable because of the high yield potential of the seed. Three-way and double-cross hybrids use a single-cross hybrid as a female, and so the seed yield is high. Infact, with double-crosses, the seed yield can be the highest of all hybrid types because a high female: male ratio may be used, given the vigor and abundant pollen production of the single-cross male. Thus, double-cross hybrid seed is the least expensive, but the resulting hybrid crop is more variable and the grain yield is usually less than that of a three-way or single-cross hybrid. Three-way hybrids are the most common in eastern and southern Africa, while in China, India, South Africa, Thailand, The USA, Vietnam, and other developed seed markets, single-cross hybrids are most common. This

is because farmers in these settings aim at higher yields and can afford to pay the higher price, given that the seed cost is a lower percentage of total costs than in low-yield situations.

Varietal cross hybrids and top-cross hybrids are also used in some African countries or where seed markets require low-cost products. The advantage of using a varietal cross hybrid is that the male parent produces abundant pollen that enhances seed setting. In addition, there may be better synchrony between male tasseling and female silking, because of the greater variability in the two parents. By the same token, varietal cross or top-cross hybrids are the least uniform and least productive in farmers fields, among the different types of maize hybrids.

Seed classes

Hybrid seed production takes place over a number of sequentially-dependent stages. The first task is to prepare the breeder's seed of the initial inbred lines. This is done by breeders under controlled hand pollination to ensure genetic purity and identity. The breeder's seed is then bulked up over successive generations into sufficient quantities to make the final hybrid. The generations of seed bulking are termed "seed classes" and are carried out under national seed regulations. With each generation there may be a decline in genetic purity, but if strict procedures are followed, this decline will be minimized. National seed regulations specify the procedures for multiplying each seed class and differ slightly from country to country, but the same principles apply, namely:

- An identified source seed for each seed class.
- Isolation of the seed production field from potential contaminant sources, by distance (spatial) or time (temporal).
- Removal of off-type plants before flowering.
- Controlled pollination of hybrid crosses.
- Inspection of seed production field at critical stages to certify conformity to regulations.
- Identity preservation and seed labeling.

Pre-basic, basic and certified seed production: The rules and procedures for certified seed production are laid down in the national seed regulations of the country in which the seed is to be produced. The aim of certification is to produce seed with an acceptable level of genetic purity

and a specified seed quality in terms of minimum germination percentage (usually 90% for maize), maximum seed moisture (12.5%) and minimum seed purity (99% pure seed with less than 3% total defects). Genetic purity is assured by using the correct seed parents of the right seed class, growing the seed in isolation from contaminant crops removing off-types and, in the case of hybrids, controlling the pollination of the female.

Certification procedures are based on standards for growing conditions (e.g., field history, isolation, female-male identity preservation, removal of

off-types and detasseling of female plants in the case of hybrid production), field inspections,

Box2: Hybrid seed crop genetic contamination

The main sources of genetic contamination of a hybrid seed crop are:

- Seed ad mixture in the parents prior to sowing.
- Impure seed sources and in adequate removal of off-types.
- Foreign pollen contamination due to inadequate spatial or temporal isolation.
- Re-growth plants of the same crop from previous seasons.
- Poor detasseling of the female, resulting in female selfing.
- Poor synchronization of male and female plants, exposing the female plants to a greater risk of contamination from foreign pollen.

Sources: Box are collected from CIMMYT Manual

prevalence of weed seeds, proportion of defective seeds, germination percentage and seed moisture content. If a seed field or seed lot does not meet the prescribed standards for the intended seed class, it will be rejected for certification. Consequently, seed producers must be familiar with and adhere to the national seed regulations for the seed class that is being grown.

The standards for pre-basic and basic seed production are higher than those for certified seed production , particularly as regards isolation requirements and the maximum percentage of off-types. The standards are evaluated in every seed field by means of field inspection sand laboratory tests. The field inspections are required to verify the origin of source seed, identify the variety, determine the cropping history, check isolation distance (or time) and production practices and ensures that all certification procedures are adhered to. Usually, three-to-five field inspections are required through the season. Following shelling or threshing, samples of seed are taken for laboratory tests to evaluate the purity of the seed, presence of other seeds, the germination percentage and the moisture content. The sampling procedures assure that a sufficiently representative sample is drawn from the seed lot. For seed sampling, the entire seed lot should be accessible to the seed sampler to enable the collection of are presentative sample. This is the final stage in the certification process, and if the seed lot passes all the standards, it is granted certified status.

Field management of hybrid seed production: Since seed has higher value than grain, the standard of management to be applied ought also be higher. However, in principle, agronomic practices for seed crops are similar to those for normal crops, in that due attention must be given to field practices that improve yield (e.g., optimizing timing of planting, appropriate and calibrated fertilizer application, conservation agriculture and water management) and to minimizing factors that reduce yield (e.g., water stress, weeds, pests and diseases). In addition, safe procedures must be followed when using machinery or applying fertilizers and chemicals.

In types of hybrid seed production where one or both parents are inbred lines, extra care needs to be taken with those lines, which tend to be weak and more susceptible to environmental stresses (e.g., diseases, certain herbicides and nutrient stress) than hybrids. Seed of inbred line parents is usually smaller than normal maize seed. While seed size does not necessarily affect germination percentage, it may affect ability to emerge quickly and resultant seedling vigor. Consequently, inbred lines should not be sown too deep or into a cloddy seed bed. If sowing is done by machine, differential calibration of the planting units for the male and female may be necessary, based on required plant density, seed size and germination percentage of each of the two parental components.

The better the agronomic management applied to a seed field — especially in timing of operations and the efficiency and appropriateness of fertilizer, herbicide and pesticide application, weed control and water management — the greater will be the yield potential. However, because these production factors are determined by field context and environment, they will not be discussed in detail. Local expert advice relevant to each seed field should be sought. Here, only issues related to hybrid quality assurance will be discussed, but note the following general principles for good crop management:

- Well before planting time, collect soil samples from the seed field and obtain a soil nutrient test report and fertilizer recommendation. With three-way and double-cross hybrids, the females have higher yield potential than the females of single-cross hybrids, so nutrient removal by the females will be greater in seed production fields of three-way and double-cross hybrids. In the case of single-cross hybrid production, the female is an inbred line, which uses less fertilizer but still requires a fertile soil to produce well. This also applies to the males of single-cross and three-way hybrids.
- If the soil is acidic, apply lime with appropriate calcium and magnesium ratios according

to the soil clay content, soil pH and soil test results. Lime should be applied three to six months before sowing, to have time to take effect (lime applied at sowing will not be effective for the emerging crop).

- Apply phosphorous and potassium fertilizers just prior to or at the time of sowing. The effectiveness of these fertilizers is greatest when they are applied in a band alongside and below the seed. Ensure that there is no direct contact between fertilizer and the seed so as to avoid fertilizer burning of the germinating seed. About one-third of the total nitrogen fertilizer should be applied at or before sowing.
- Inbred lines may be more sensitive to micronutrient deficiencies than hybrids. Observe the growth
  of inbred lines, looking for nutrient deficiency symptoms, and correct these with foliar or soil- applied fertilizers if required. Where known micronutrient deficiencies occur in the soil, correct these with pre-plant fertilizers.
- Certain maize herbicides, especially those in the Sulfonylurea and Chloroacetamides groups, may be phytotoxic to inbred lines. Check with the seed company representatives regarding which herbecides may be applied to the seed parents being grown. When applying post-emergent herbicides, it is advisable to band apply these between the rows, avoiding foliar contact.
- Time sowing so that flowering occurs when reliable rains are expected, but also at a time that will avoid the crop maturing during wet weather, so as to avoid rain damage to maturing seed in the field.
- The sowing of hybrid seed is critical—it determines crop establishment and potential. Therefore, sow the two parents at the recommended times, aim for the correct plant density and conduct operations to achieve a uniform emergence. Ensure the micro- seed bed is optimal for germination and emergence, considering seed-soil contact, sowing depth, soil moisture conditions and avoiding compaction.
  Beware of soil pests and seedling diseases that may reduce stand establishment and apply recommended seed treatments or pesticides to the soil, if needed.
- Monitor and manage the crop throughout the season, controlling weeds (inbred lines are particularly sensitive to weed competition), pests and diseases, and providing irrigation if possible. In most seed regulations, weedy fields, especially at harvest, will disqualify a seed crop from certification.
- The remaining two-thirds of the nitrogen application may be applied in two side-dressings, one at the 4-5 leaf stage and the other at the 8-10 leaf stage. Use the application method best suited to the type of fertilizer, crop stage, machinery available and weather conditions. Avoid wastage of nitrogen by leaching, run-off or volatilization.
- At flowering time, check for stalk borer and boll worm on the silks of the females, as these pests may feed on the silks and reduce seed set or feed on the developing kernel sand reduce seed quality and yield. The four-week period spanning the flowering stage of seed maize is most sensitive to water deficits.
  If a dry spell occurs at this time, irrigation will significantly improve yields.
- In countries where maize is grown on acid soils, it is beneficial to do a foliar application of 100-150 g/ha of sodium molybdate at the mid-silk to milk-dough stage of the females. This increases the molybdenum concentration in the seed and helps overcome molybdenum deficiencies in the field.
- Foliar applications in the late vegetative and early grain-fill stages with recommended fungicides for expected diseases will improve yields and seed quality. Apply these chemicals according to label instructions.
- Harvest the seed as early as possible, considering drying facilities and processing

requirements. Reducing the time mature seed remains in the field improves seed quality by minimizing pest and disease infestation.

Hybrid seed production is a step-wise process, with each step influencing the following steps. Managing hybrid seed production involves two parallel processes: the technical aspects of the seed crop, such as female-male ratios, detasseling, etc., and the agronomic field management of the female and male plants.

Furthermore, there is a close relationship between the grower of the seed, the seed company for whom the seed is being grown and the regulatory agency that will certify the seed crop. It is evident therefore that maize seed production is more complex and dynamic than grain production.

Success depends on beginning with a thorough understanding of the whole process, planning crop areas, inputs, activities and labor requirements, maintaining good communications with labor, the Seed Company and regulators, and carrying out management activities in a timely and efficient manner. The ultimate goal of hybrid seed production is the high yield of seed that meets quality standards. Only when this is achieved can any thought or hope of profit be considered. Thus, successful hybrid seed production begins with planning the whole process from the beginning to the end. Be certain to match the proposed area of seed production with financial, labor, time, machinery and management resources.

Selecting the seed field

The best fields on a farm should be used for hybrid seed production, but other considerations include:

- Accessibility–the seed field needs to be inspected regularly and therefore must be easy to reach throughout the season.
- Cropping history–the previous crop should not be maize, to minimize the possibility of re-growth plants in the seed field.
- Isolation–the field must be sufficiently isolated from contaminant maize crops by the required distance or time.
- Size of field – due to the time pressure for detasseling in hybrid seed fields, a maximum field size of 10 to 40 ha should be planted at one time, depending on labor availability. Blocks of about
  10 ha are most manageable for detasseling and quality assurance. Smaller fields may increase the risk of foreign pollen contamination. Larger fields may not allow efficient detasseling.
- Field map – this is helpful to establish the size of the field, isolation distances and for future records.
- Registration of the seed crop – usually seed regulation authorities require seed fields to be registered within a short time of establishment. Ensure that this is done.

Box3: Handling the parent seed

Parent seed of a hybrid is precious, therefore handle it with care:

- Keep the male and female seed bags separate.
- Be careful not to lose the labels attached to the bags, and retain the se after sowing the seed for certification purposes and for any claims that may arise.
- Store seed in a cool, dry place.
- Protect the seed from rodents and storage pests.
- Keeptheseedsecurefromtheft.
- Handleseedgently.

- Sources: Box are collected from CIMMYT Manual

Crop establishment:

The establishment of a crop is one of the most important stages, since decisions taken at sowing will affect the entire life cycle of the crop. Usually, the seed company will provide planting recommendations for a hybrid (an example is given in Table 5).At this stage, the following points are noteworthy:

- Ensure the correct parents are assigned to the seed field and that the female and male seed is clearly identifiable.
- Establish the ratio of female-to-male rows in the field, based on recommendations from the seed company, and implement a planting system to sow the female and male rows correctly at the appropriate seeding rates.
- Calculate the seed rate for each parent based on the desired plant density, seed weight, germination percentage and expected field losses for the female and male. Recommendations for these should be provided by the seed agency.

Different popular planting ratios of seed and pollen parents in maize

Sources: Photographs are collected from CIMMYT Manual

3:1female: male ratio.

Sources: Photographs are collected from CIMMYT Manual

2:1 squeeze row configuration, where the male row is planted in-between two normally-spaced female rows.

Male row Female rows Male row detasseled

Sources: Photographs are collected from CIMMYT Manual

Sources: Photographs are collected from CIMMYT Manual

Sources: Photographs are collected from CIMMYT Manual

Photographs showing the distinct male and female plant rows at different crop stages, from early vegetative to flowering.

Roguing: The removal of off-types:

During the vegetative growth of the seed crop, regularly inspect the field for pests, weed sand diseases and control these as necessary. From the 6-to12-leaf stage and before tassels emerge, remove off-types from both male and female rows. Off-types are usually clearly identifiable as taller or smaller, earlier-or later-flowering, or plants with characteristics distinctly different from the norm.

Descriptions of the distinguishing characteristics of the parents should be available from the developing agency and will include aspects such as the angle of the leaf blade to the stem coloration of the leaf sheath and stem, and the shape of the tassel. Persons who conduct roguing must become familiar with these characteristics so that only off- type plants are removed. Off-type plants should be completely destroyed before start pollen shading.

Sources: Photographs are collected from CIMMYT Manual

Table6. Distinguishing characteristics of maize plants during the vegetative and flowering stages.

Leaf	Angle between blade and stem. Attitude of blade(i.e.,straight or curved). Width of blade. Anthocyanin coloration of sheath.
Stem	Anthocyanin coloration of internodes. Degree of zig-zag. Anthocyanin coloration of brace roots.
Plant	Height Ratio of height of insertion of ear to plant height.
Tassel	Length of main axis above lowest side branch. Length of main axis above upper side branch. Time of anthesis (pollen shedding). Anthocyanin coloration of base of glume. Anthocyanin coloration of glume sexcluding base. Anthocyanin coloration of anthers.Density of spikelets.Angle between main axis and lateral branches. Attitude of lateral branches.Number of primary lateral branches.
Ear	Time of silk emergence. Anthocyanin coloration of silks. Intensity of anthocyanin coloration of silks.

Sources: Box are collected from CIMMYT Manual

after cutting the off-type plant at the base, side shoots may grow and produce an undesirable cob and tassel. Thus, it is best to uproot off-type plants.

For efficient roguing, note the following recommendations:

- Limittheroguingteamto10-12peopleincluding the supervisor, because larger groups get easily distracted. If more people are needed to rogue the fields, divide into several groups and assign them to different parts of the field, giving specific responsibilities for specific sections.
- Select responsible people for the rouging team and provide training on the identification and removal of off-type plants.
- The team should start in a corner of the field and work through it slowly, walking parallel to and in the same direction down the rows.
- Each member of the rouging team should have an arrow zone to observe. For maize consider a maximum of two adjacent rows.
- Use large stakes to mark are as of the field that have been rogued.
- The position of the sun and wind movement can affect the team's ability to identify undesirable plants.
- After several hours of roguing, a person tires and becomes less efficient. Thus it is advisable to rogue relatively few hours per day. Roguing teams may work most efficiently during the early morning or late afternoon.
- The supervisor should concentrate on overseeing and inspecting roguing team activities, than actually roguing.

When to rogue

Roguing should be conducted before genetic or physical contamination occurs and during times favorable for visual identification.

- Rogue volunteer plants; these are easily identified by size and position out of the rows (post emergence).
- During vegetative development, rogue off-type plants that deviate from the given geno type with respect to root and stalk development, plant type, pigmentation, leaf and stem pubescence, etc. Effective roguing during this period will help reduce the work load during the critical flowering period.
- At the flowering stage, important agronomic and morphological characteristics can easily be identified. This is the critical stage to prevent genetic contamination of crop. Roguing on male plants must be complete before pollen shedding begins. Roguing on female plants should be complete soon after silk-emergence.

Detasseling:

In hybrid maize seed production, detasseling of the female plants must meet the required standard and be conducted in a timely fashion. Any delays in detasseling or inadequate detasseling that results in tassel-stubs or missed plants will seriously diminish the genetic purity of the hybrid seed and might result in rejection for certification. Note the following:

- The tassels on the female plants must be removed before they begin to shed pollen.
- Detasselingmustcommencewhenthetop3-4cm of the tassel is visible above the leaf whorl.
- Detasseling must continue every day until complete, come rain or shine.
- Some female parent plant types are more easily detasseled than others. For example, some female parents have tassels that are physically hard to pull out, others break easily and some begin shedding pollen before fully emerging from the upper leaves. Tall female plants, especially when the female is a single-cross hybrid, are difficult to detassel. In top-cross or varietal cross hybrids, where the female is an open pollinated variety, time of tassel exertion in the female population will vary. Lastly, with some parents, silks emerge much earlier or later than pollen shed. All these situations, may be compounded and make for difficult detasseling supervision and potential management problems. Close supervision of the field is crucial.
- Detasseling may take two to three weeks, depending on the field size, uniformity of the crop and labor availability.
- About six people can detassel one hectare per day, but this rate will be a function of the difficulty of detasseling.
- Individual workers may be allocated specific sections of the field to detassel, so as to give responsibility and accountability. However, monitoring each person's detasseling effectiveness will be necessary to ensure that one or more laborers do not spoil the entire field.
- Removal of more than one leaf with the tassel will reduce yields.
- Mechanical detasseling to cut or pull female tassels improves efficiency, but will require manual follow-up to remove any remaining tassels or stubs. Mechanical detasseling is not always possible on three-way hybrids because the females may be too tall for the machines to drive over
  the crop. Mechanical detasseling usually cuts or removes one to three of the upper most leaves, which will reduce yields.

Synchronization of male and female flowers Ideally, the male plants should begin shedding pollen when the first female silks begin appearing and they should shed pollen for as long as it takes for all the female silks to emerge. However, male and female plants do not always take the same time to reach flowering, due to different growth rates and environmental variations. Furthermore, the duration of pollen shedding may be shorter than the time for females to reach full silk emergence. Any mistiming of male and female flowering will reduce yields and expose the female seed parent to contamination from foreign pollen.

Pollen shedding and silk emergence may take place over7to14daysandmaynotcoincide,even if the male and female parents are planted on the same date. For example, the silks on the female may begin to emerge before the males begin to shed pollen. Indeed, the silks in the example were showing for five days before significant pollen shedding occurred, there by exposing the female to possible contamination from foreign pollen. The time to 50% silking of the female occurred 64 days after planting, and the time to 50% pollen shedding on the male occurred 67 days after planting. To achieve a perfect nick (male-female flowering synchrony) in this case, the male would need to be planted three to five days earlier than the female.

If a male parent is an inbred line with a weak growth habit, or if it has a short pollen shedding period or does not produce a profuse amount of pollen, it is advisable to sow male plants on two (or even three) consecutive dates a few days apart, so that the pollen shed period covers the whole period of silk emergence. The split-planting of the male is usually done in two adjacent rows. To reduce the land required, the two split- planted male rows may be seeded relatively close together, compared to the female rows. For example, if the normal row spacing is 90 cm, the two split male rows could be sown 45 or 60 cm apart, but 45 to 60 cm away from the adjacent female rows. Where the male does not produce an abundance of pollen, the female-to- male ratio should not be more than 3:1, where as if the male is a profuse pollen producer (as in the case of a double-cross hybrid), the female-to-male ratio may be increased to 6:1 or even 8:1. In some cases, even with single-and three-way cross hybrids, a ratio of 6:2 may be planted, but the male must be a prolific pollen producer.
In single–cross hybrid seed production, where the male and female inbred parents are of similar vigor and stature, a "squeeze-row" configuration maybe feasible. In this arrangement, the male row is planted at half the normal row spacing between alternate rows of females, which are planted at the normal row spacing. For example, if the female rows are planted in their normal row spacing, say 90cm, then in every second female row-space the male is planted at 45 cm from the female. Thus, the female: male ratio is 2:1, but effectively the female covers the entire field and the land is optimally used. However, it is important in this system to remove the male immediately after pollination, to reduce competition with the female.

Other methods of improving synchronization, especially where there is a small difference between the times of flowering of males and females, include the following:

- Soaking the seed in water for 12 to 24 hours prior to sowing may advance flowering by 1 to 2 days. Soaked seed absorbs water and begins to germinate. It is therefore vulnerable to damage if mishandled. Water soaking only works with hand sowing into wet soil. Sowing soaked seed into a dry soil will likely lead to poor germination and emergence.
- Clipping the two-to-four whorl leaves of the male plants when four to six leaves are fully emerged (determined by the presence of leaf collars) is effective in delaying pollen shed by 2 to 3 days.

Box4: Effect of poor synchronization on yield and grading of seed maize

1. **Pollen too early or silking late relative to pollen**
   - The base of the cob will be pollinated, with the tips empty.
   - Depending on the percent seed set, yield loss is usually low, since kernels at the base of the cob are usually larger and compensate better than the normally smaller kernels at the tip.
   - Expect a higher proportion of large round seed compared to other seed grades.
2. **Silking too early or late pollen shed relative to silks**
   - The tips of cobs will be filled, with blind butts.
   - Yield loss is usually high, since large butt kernels missing but small kernels on tip present.
   - The seed will comprise mostly small round and thick grades, with a small proportion of medium flat seed.
3. **In consistent or in sufficient pollen shed**
   - The filling of the cob is irregular, with empty cobs when pollen is not available.
   - Yield loss is high due to reduced kernel number.

Source: Box are collected from CIMMYT Manual

However, if the plants are clipped too severely they may produce small tassels and less pollen than if not clipped. If clipped too late, there will be little effect on time of pollen shedding, but tassel size may be reduced.

- Burning male plant leaves with herbicide or flame at the three-to-five leaf stage may delay tasseling and pollen shed by 2 to 3 days. This has proven to be effective, if burning is not excessive.
- Adding extra phosphate and nitrogen fertilizer in the planting furrow of the male or female may hasten plant growth, particularly in soils that are not very fertile. But the hastening of plant growth may only cause flowering to occur one to two days earlier than if no fertilizer were applied or if fertilizer were broadcast.
- Irrigation applied one to two weeks before flowering will ensure that the silks emerge at the expected time, especially if the weather is hot and dry at that time.
- In cases where male plants are in sufficient due to germination failures, pollen may be collected from remaining plants, bulked into "pepperpots" and applied to the silks of female plants. Alternatively, or in addition, walking through the field at pollen shed with motorized mist-blowers can blow the pollen across the female rows and improve pollination.
- Early detasseling can hasten the emergence of silks on females by one or two days.
- Cutting back the sheath on the ear can advance silk emergence by two to three days, but as the cob grows, it may extend out of the cuts heath leaves, exposing the tip to insects, birds and diseases.

Removal of Male Lines:

As soon as possible after pollination, remove the males from the field. Male plants are cut at the base and either removed from the field or left to rot in the row. Removing males soon after pollination ensures that there will be no mixture of male and female seed at harvest. Male removal also improves the yield of the female by allowing more light penetration into the female rows and reducing competition for moisture. Note that weeds will take advantage of the free ground and will need to be controlled.

Inspections of Field of the seed crop:

Seed crop inspection is a regular and normal requirement for seed certification. Seed regulators will visit the seed field 3-to-6 times during the season to ensure that the crop meets

the standards for certification. Seed inspectors need to have free access to the seed field and to all records. Cooperation and implementation of instructions concerning the seed crop will facilitate certification.

Following are key criteria assessed in such inspections:

- The seed crop is grown from an approved seed source (retaining the labels is necessary to prove this).
- The field meets the prescribed land requirements as to the previous crop.
- The prescribed isolation standards are observed.
- The seed crop has been planted with the prescribed ratios of female and male parents.
- The crop is properly rogued and detasseled to national standards.
- The crop is true to the varietal characterization.
- The crop is harvested properly to avoid mixtures.

Maize seed harvesting

Seed germination rate and vigor (i.e., viability), improves from fertilization of the embryo to physiological maturity, when it will reach a maximum (Figure 7). The absolute or maximum quality of the seed at physiological maturity will have been determined by the growing conditions during seed development, but whatever this quality is at physiological maturity, it will be the maximum.

If male plants are not removed from field after pollinations and remains in field, Harvest it first and keep the cobs separate as these are selfed progenies of male lines and may use as pure male parent in next year.

The Female cobs then harvested in bulk and put separately.

Summary:

1. Select recommended parental lines of the hybrids for particular areas.
2. Apply 25t /ha FYM before sowing of lines in field.
3. Plant the seeds on raised bed plot in appropriate female: male ratios.
4. Mark the male beds before planting of female lines.
5. Apply weedicides followed by manual weeding to keep seed plots free from weeds.
6. Regular inspection of field is must. Remove diseased and insect damaged plants.
7. Remove off-types before start flowering.
8. Harvest the cobs/plants at physiological maturity.
9. Keep both seed and male plants separately.
10. Remove the cobs not showing uniformity before shelling.
11. Use insecticides recommended for storage to avoid possible damage in store.

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Quality Seed Production Technology in Barley

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Quality seeds are defined as varietal purity with high germination percentage, free from disease and pests, and with a proper moisture content and weight. It ensures good germination, rapid emergence and vigorous growth.

CRITERIA OF QUALITY SEEDS: -

1. They are genetically pure (true to type).
2. The good quality seed has high return per unit area as genetic potential is fully exploited.
3. Less infestation of land with weed seed/other crop seed.
4. Less disease and insect problem.
5. Minimization of seed/seedling rate i.e., fast and uniform emergence of seedling.
6. They are vigorous, free from pest and diseases.
7. They can be adopted themselves for extreme climatic conditions and cropping systems of the location.
8. Quality seeds respond well to high fertilizer dose.
9. Uniform in plant population and maturity, yield prediction is easy.
10. Handling in post-harvest operation will be easy.
11. High produce value and their marketability.

BOTANICAL DESCRIPTION OF BARLEY-Since barley is a self-pollinating crop, farmers can produce quality seed on their own farms with the proper precautions. The stems are erect, thick, tufted, and reach heights of 60 to 120 cm. It has few alternately arranged leaves. Near the spike is the upper leaf. Smooth and striated describe the sheath. Large auricles that frequently clasp or overlap are present in barley. The ligules are thin, membrane-like structures.

Seed Characteristics: Spindle shaped, light tan to yellowish in hue, seeds. Compared to rye and wheat, barley is lighter.

SEED QUALITY PARAMETERS:-

1. Physical attributes

- ✓ A minimum of damaged seeds
- ✓ A minimal amount of weed seed or inert matter
- ✓ A minimum of diseased seeds
- ✓ Near uniform seed size

2. Physiological attributes

- ✓ **Germination percentage or viability-** This is an indicator of seeds ability to emerge from soil to produce a plant in field under normal condition.
- ✓ **Seed vigour-** It is the capacity of seeds to emerge from the soil and survive under potentially stressfull field condition and to grow rapidly under favourable conditions.

3. Genetic attributes

- ✓ Seeds of the same variety

- ✓ Adapted to the local conditions
- ✓ Pest and disease tolerance
- ✓ High yielding ability

4. Storability

- ✓ Moisture content
- ✓ Temperature of the environment
- ✓ Seed treatment

GENETIC PRINCIPLES OF SEED PRODUCTION

1. Developmental variations- Arises when seeds are grown in

- ➢ Difficult environment
- ➢ Different soil and fertility conditions
- ➢ Different climatic conditions
- ➢ Different photoperiods
- ➢ Different elevations

2. Mechanical mixtures- Takes place

- ➢ At sowing time if more than 1 variety is sown with same drill
- ➢ During harvesting and threshing operation
- ➢ Gunny bags, seed bins, elevators are contaminated with seeds of other varieties.

Solutions-

- ➢ Rouge the seed field.
- ➢ Care during seed production, harvesting threshing and further handling.

3. Mutations-

- ➢ Not a serious factor
- ➢ Difficult to detect minor mutation

Solutions-

- ➢ Remove mutant plants
- ➢ Increase of true to type stock to eliminate the problem

4. Natural crossing- The deterioration in the variety due to natural crossing occurs due to following reasons-

- ➢ Natural crossing with undesirable types
- ➢ Natural crossing with diseased types
- ➢ Natural crossing with off types

Genetic contamination in seed fields due to natural crossing depends on following factors:

- Breeding system of species
- Isolation distance
- Varietal mass
- Pollinating agent

Solutions-

- ➢ Isolation between plantations
- ➢ Small amounts of contamination over wide distances.

5. Genetic drift- When seeds are multiplied in large areas only small quantities of seeds is taken and preserved for the next years of sowing. Because of such improper sub sampling, all genotypes will not be represented in the next generation and leads to change in genetic composition. This is called genetic drift.

6. Techniques of plant breeder-

- ➢ Premature release of variety

- Variety testing program
- Breakdown in male sterility
- Environmental conditions
- Heritable variations

Solution - Careful handling and adaptation of techniques.

7. **Breakdown of male sterility**- Generally in hybrid seed production if there is any breakdown of male sterility it may lead to a mixture of F1 hybrids and selfers.
8. **Improper seed certification**- It is not a factor that deteriorates the crop varieties, but if there is any lacuna in any of the above factors and if this has not been checked it may lead to deterioration of crop varieties.

AGRONOMIC PRINCIPLES OF SEED PRODUCTIONS

1. **Selection of suitable agro-climatic region and seed plot-**Barley crop requires 12-15° C during growing period and 30° C during maturity. It cannot tolerate frost at any stage of growth and incidence of frost is highly detrimental at flowering stage. It posses high degree of tolerance to drought and sodic conditions. In order to have the best seed output and quality, barley seed cultivation requires terrain that is fertile, level, and well-draining. Barley cultivation is not good for acidic soils. The seed plot must be free of any cultivated weeds from the previous year. This will stop contamination from crops that grow on their own or other varieties.
2. **Isolation distance-** Since barley is a self-pollinating crop, it is necessary to maintain a 3-meter separation between neighbouring barley seed and grain production plots in order to prevent mechanical mixing or variety contamination. However, it is advised to maintain a 150-meter isolation distance for smut-infected plots.
3. **Preparation of field-** A flat, well drained field should be ploughed two to three times with a cultivator to discover tilth before being planked. The field needs to be levelled for optimal water distribution across the seed plots since barley is sensitive to water logging.
4. **Sowing time**- In order to produce high-quality seeds, it is recommended to sow them at the right period, ideally between November 10 and 25.
5. **Seed rate & sowing**- For the best plant population and the simplest rouging of off kinds, a seed rate of 40 kg per acre should be used in timely sowing conditions. Knowing seed germination before spreading seeds in the field is a crucial technique. 400 seeds can be chosen to test their germination-on-germination paper (the paper towel method) or newspaper for 7 days at room temperature while keeping the conditions wet. The quantity of seeds that germinated and healthy seedlings must be counted after seven days. The seed lot is deemed suitable for sowing if the barley seeds' germination percentage is greater than 85%.
6. **Methods of sowing**-
   - Row method of sowing
   - Mechanical drilling can be used
   - Desired amount
   - Uniform depth
   - Clean equipment's and proper distance between the plants.
7. **Seed treatment**- Seed treatment is mainly done to break dormancy due to hard seediness.To prevent smut disease, seeds should be treated with Bavistin or Vitavax @2.5 gm/kg.

8. **Spacing**- When producing seeds, line sowing is always favoured because it makes inspection and rouging easier. The ideal row spacing for the production of barley seed is 22.5 cm. Preferably, sowing should take place at a depth of 4-5 cm.
9. **Rouging**-Rouging is the selective removal of unwanted plants from a seed production plot, such as other kinds, diseased plants, off-types, other crop plants or weed plants, and volunteer plants, in order to preserve the genetic purity, physical purity, and disease-free characteristics of the seed plot. Rouging is during booting or pre-flowering stage, followed by 2nd rouging at flowering and final rouging at maturity stages of the barley crop since most off types and other varieties of plants may be easily detected at these developmental periods. It is advised that barley seed plots be cleared of all other crop plants, including wheat, oat, triticale, and gram. In isolated areas, diseased plants and off-types can be carefully removed or disposed or killed.
10. **Irrigation-**

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

11. **Nutrient management-**

Stage	**Nitrogen**	**Phosphorous**	**Potash**
Timely sown and irrigated condition	12 kg	24kg	08 kg
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	36kg	12kg	08 kg
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.			

12. **Weed management**- Producing quality seeds and preventing further contamination in the cycle of seed multiplication need the absence of weed seeds in the seed production process. The following herbicides may be used for successful weed control depending on the situation and type of weed flora:

    Pre-emergence: Spraying Pendimethalin (1250 ml per acre) on weeds with narrow and broad leaves between one and three days after sowing can be used as a pre-emergence method of management.

    Grasses type: Various weeds viz., Phalaris 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); Convolvulus arvensis (Hirankuri); Melilotus indica (Senji/Metha) can be controlled by 2,4-D (400 ml per acre) at 30-35 days after sowing.

13. **Disease and Pest management-** 1. Vitavax @ 2g/kg seed and Vitavax& Thiram in a 1:1 ratio should be used for seed treatment on covered smut of barley.
    2. Rust: You can spray Propiconazol 0.1% (1 ml/litre of water) on the affected area as soon as the ailment manifests itself.
    3. Spraying with propiconazol 0.1% or (1 ml/litre of water) is advised for leaf blight.
    4. Aphid: Imidacloprid (17.8 SL) @ 40 ml per acre is sprayed on plants to effectively control aphids. The second spray can be used 15 days apart in cases of severe incidence.
14. **Harvesting and Threshing**: In India, harvesting is typically done by hand, however recently combine harvesters have been used to make harvesting and threshing easier. Therefore, it is crucial to thoroughly clean all combine machines in order to prevent any admixtures or mechanical combinations of various kinds. It is advised that seeds be properly dried before storing to prevent storage losses caused by high moisture. To lower the moisture content to a safe level, or less than 12%, seed crops are exposed to sun drying for three to four days.
15. **Drying of seed crops**-
    - More moisture at the time of harvest.
    - Precautions for the seed drying.
    - Identify of the lots must be maintained.
    - Care should be taken to ensure that mechanical mixture does not take place.
    - Drying of seeds to safe moisture limits should be done rather quickly.
16. **Storage of raw seeds**-
    - Short period storage should be in stacks or bags kept in ordinary buildings or godown after sun drying.
    - Filling in neat and clean bags , if od then properly treated before use
    - Proper labelling.
    - The stacks of bags should be made of wooden pallets
    - Storage place should be – properly clean, dry, cool, sprayed with malathion and fumigated.
17. **Biofortification**- Biofortification is the process of improving the nutritional quality of food crops by the process of adding micronutrients essential trace elements and vitamins) to food.

    Crop biofortification: It is the idea of breeding crops to increase their nutritional value. e.g: Zn rice, Zn wheat, Fe pearl millet, QP Maize, Golden rice etc.

18. **Biopriming** (Synonymous term to biological seed treatment)- A new technique of integrating biological(inoculation of seed with beneficial organism to protect seed) and physiological aspect of disease control. It is an effective and ecological alternative to chemical control unique from chemical seed treatments by their utilization of living microorganisms.

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Maintenance of Nucleus and Breeder Seed in Cereal Crops

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Preface

Indian seed production system is a robust route to mitigate the seed requirement of the country. The seed class involves Nucleus, Breeder, 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 who are involved in development of variety. The developer maintains the seed purity of released varieties by curbing the chance of 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. Further, seed traits such as seed dormancy, viability, priming, foliar spray etc. are being given importance to improve cultivars for seed traits. 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 wherever it is needed 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 non-availability 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 description about it has been given as follows.

A branch of plant breeding which deals with principles and method of breeder seed production and 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 principles and methods of breeder seed or nucleus seed production. It deal with ways and means of maintaining genetic and physical purity of released and notified variety. It is also known as varietal maintenance technology.

It undertake breeder seed production of parental line of released variety. Genetic purity, physical purity and germination are main point taken into account. Seed health also taken. Breeder seed is use 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 2 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 pre-released or newly released varieties is described below:

Sampling of the variety to obtain nucleus seed: New numbers, lines or selection 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.

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 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. Rouging:** 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 itself. 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.

2- 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 rouging 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 self-pollination, 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.Roughing 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 experimental material 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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Factors Affecting Seed Quality during Production in Cereals

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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.
(A) 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.

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

(A) 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

(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 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.

(2) 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).

(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 due to its natural frequency.
(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 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

(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. To overcome these, regress yields trials are suggested.

(6) 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.

(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 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.

(B) Agronomic principles-

1.Selection of a Agro-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) Seed 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**
Varieties 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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Water Management Practices during Seed Production with Special Reference to Cereal 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 atoll 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 grain number 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 are 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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Management of Weeds during Seed Production with Special Reference to Cereal Crops

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Introduction: The use of high-quality seeds is one of the most vital elements in increasing agricultural production in any farming system. As a catalyst in agricultural production, quality seed is a critical component in ensuring the success of development strategy for improved agricultural production and productivity, food security and livelihoods The importance of quality seed can be traced in ancient scripture, *Manu Smriti* stating "*SubeejamSukhetre Jayate Sampadyathe*" meaning thereby Good seed in good soil yields abundantly. Further, The Rigveda. 2000BC accorded importance to seed and mother earth. The role of seed in improving crop production is documented in 5th century *Kautilya Artha Shasthra, surapalasvrikshayurveda* which mentioned about seed treatments to ensure good germination and seed dressing with milk, vidanga, cowdung, honey to protect the seed during germination. The need for organized seed production was understood in the beginning of 20th century led by recommendation of Royal Commission on Agriculture in India. Besides other, it recommended availability of improved crop varieties seeds to the farmers.

A number of attributes related to quality seeds have been identified and practices are in place for quality seed production. Amongst these, weed management in crops cultivated for seed production has been greatly emphasized. In commercial crops, weeds are considered as competitor for inputs required by crops, in seed crops, greater emphasis is laid on weed free produce of crops. The weed seed contaminants in crop produce cause quality deterioration and weed seeds in grain crops perpetuate when the seed is replanted. Global climate change, increased use of tractor and power tiller, intensive cultivation etc. have been aggravating weed problems. Weeds like *Echinochloaspp.*(barnyard grass) and weedy rice (*Oryza sativa* var, rifopogan) in rice; *Phalaris minor,Avenaludoviciana* and*Convolvulus arvensis* (Hirankhuri) in wheat; and a number of weeds in other crops have been a great concern to the farmers. Due to morphological similarity and growth habits, the visual detection is difficult in early stages and limits manual and/ or mechanical weed control tactics. Whereas, small seed size often create problems in separation during processing.

Therefore, a multitactical approach relying on ecological principles is required for weed management in cereal crops.

The seed: Seed are well known carrier of weed seeds. Weed problem basically starts when the crop seed is contaminated with weed seeds. The problem is more serious in countries like ours where seed chain is farmers-farmers. If not cleaned properly, the harvested weed seeds move from one farmer to other farmer or sown by same farmer in next year. Further, free flow of food grains and other commodities across boarders also enhances the possibility of movement of weed seeds along with food grains from one country to other. Utmost care should be taken to

avoid mixture of weed seed and crop seed because weeds also act as alternate hosts for various diseases and pest attacks.

Good quality seed lot has high vigour, free from weed seeds, pests and disease so, there will be less infestation of land with weed seed. The vital factors are weight of seeds (1000, seed weight) and seed rate. For example, in wheat, a thousand seed weight of 38 gram is desirable and for rice it will vary between coarse and fine rice varieties. Low weight seed results in delayed emergence, weak seedling, poor early vigour and thus, provide early advantage to emerging/emerged weeds. By maintaining optimum seed rate, it will help in fast and uniform emergence of seedling and supress weed growth in field conditions.

The Establishment: Proper crop establishment ensures optimum germination, early vigour and opportunity for easy weed removal and also precise nutrient application. Method of planting is very crucial for crop grown for seed production. It must facilitate rouging (the removal of undesirable plants), fertilizer application and removal of diseased plants. In this context, Furrow Irrigated Raised Bed (FIRB) planting of wheat has been found to reduce seed rate from 75 Kg from 100 Kg/ha, save 20-30% water, provide space for movement to hand weeding/ rouging and fertilizer placement near crop plant. It also discourages the germination of weeds.

The Fertilizer: Like crops, weeds do absorb nutrients from soil and added fertilizers. In early stages, much of the energy for germination of seeds comes from digestion of starch present in seeds. Therefore, less quantity of nitrogenous fertilizers should be applied in early stages. Further, placement of nitrogenous fertilizers near crop rows enhances growth and competitive ability of crops against weeds. Broad casting in standing crop favours weeds more than crops.

Mulching: Covering the inter row spaces with straw/ residues help in conserving soil and discourage weed seed germination. It has special significance in production of seeds for organically cultivated crops where chemical weeding is restricted.

Rouging: "Selection" and "rouging" are common practices in seed production that maintain or improve crop genetic integrity and physical quality. Technically speaking, "rouging" refers to routine removal of plants that exhibit off-type characteristics or undesirable traits. "Maintenance" and "selection" refer to genetic improvement of the crop. The amount of selection required depends upon the quality of the seed stock planted. Rouging can be conducted for any physical attribute such as off-type color, shape or stature. It can also include plant quality traits such as presence of disease, insect damage, or low vigor. Selecting for these traits can improve the overall appearance and performance of varieties. Timing of rouging can be critical, as key traits might be visible only at specific times, for example at bolting or heading. Rouging must be completed before flowering to prevent cross-pollination of the seed crop with undesired plants. Discuss and negotiate the following with your seed buyer when writing your contract:

Herbicides: With the discovery selective herbicides, which provide cheap, effective and easy methods of weed control, today much of the weed control is realized from herbicide use. However, development of resistance in weeds at alarming rates has raised serious concern about the chemical-based weed management. Several strategies are suggested to avoid the problem, an easy way is to scout the field and remove uncontrolled plants of the weed. Herbicide rotation is another way to prevent resistant development.

Recommended herbicides for wheat

Weed flora	**Herbicides**	**Rate (g/ha)**	**Application times (DAS)**
Grasses	Clodinafop*	60	30-35(2-4leaf stage of weeds)
	Fenaxapro-ethyl*	100-120	
	Pinaxadon	35-40	Preemergence 1-3 DAS
	Sulfosulfuron	25	
	Isoproturon	1000	
	Pendimethalin	1000-1500	
Broad leaved	2,4-D	500	30-35 (2-4leaf stage of weeds)
	Metsulfuron	4	
	Carfentrazone	20	
Both grassy and broad leaved	Sulfosulfuron +metsulfuron Isoproturon+ 2,4-D	25+2 1000+500	30-35 (2-4leaf stage of weeds)

*Should not be tank mixed wih either 2,4-D or Metsulfuron

Recommended herbicides for rice

	Herbicide	Rate (g/ha)	Time of Application
Transplanted rice	Butachlor	1.0-1.5	
	Pretilachlor	1.0-1.5	
Wet seeded rice	Pretilachlor+fenclorim	0.9+*0.67/L**	
	Oxadiazone	1.0	1-3 DAS/DAT

Dry seeded rice	Pendimethalin	1.0	
	Oxadiargyl	**0.09**	
	Bispyribac	**0.025**	
	Fenoxaprop	**0.4**	**3-4 leaf stage of weeds**
	Metsulfuron+chlorimuron	**0.020**	
	Penoxsulum +cyhalofopbutyl	**0.135**	
TP/DSR/Nursery	**Pyrazosulfuron**	**0.08**	**1-3 DAT/DAS**

*Soak seed in solution

Harvesting and Threshing: To avoid contamination of weed seed, harvesting is most important. Care should be taken to separate any undesirable plants. Similar precautions are needed while threshing the seed crop. This will ensure weed free seed for future propagation.

Conclusions: Weed management is most important for quality seed production. Cultural practices play an important role in controlling weeds in cereals grown for seeds. Herbicides should be used in rotation and with label instructions regarding rate, time and spray volume.

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Nutrient Management in Quality Seed Production of Cereal Crops

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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 rise 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, a better 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 radicals 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 of Zn in grain occurs during the milk stage of the grain development. Results show a high potential of Zn fertilizer strategy for rapid improvement of grain Zn concentrations, especially in the case of late foliar Zn application. In practical agriculture, it is known that foliar uptake of Zn is stimulated when Zn fertilizer is mixed with urea (Mortvedt and Gilkes, 1993).

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Management of Major Insect Pests of Cereals

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Insect-pests of Paddy

Insect-pests of nursery:

There are following pests which affect nursery, these are thrips, green leaf hopper, case worm, stem borer, and paddy swarming caterpillar,

Main field pests:

yellow stem borer**,** gall midge, swarming caterpillar, rice skipper, leaf folder/ leaf roller**,** rice horned caterpillar, yellow hairy caterpillar, grasshopper, rice hispa/ spiny beetle, whorl maggot, green leaf hopper, brown plant hopper, white backed plant hopper, mealy bug, rice earhead bug and thrips.

1. Thrips, *Stenchaetothrips biformis* (Thripidae: Thysanoptera)

Distribution:

Bangladesh, India, Indonesia, Japan, Malaysia, Sri Lanka, Thailand and Vietnam.

Alternate host: *Echinocloasp*.

Life cycle:

Eggs are laid in the slits of leaf blade tissue. Newly hatched nymphs are transparent but turn yellowish white after the first molt. Neonate larvae feed on the soft tissues of unopened young leaves. Pupation takes place inside the rolled leaves. Adult is 1mm long, dark brown to black in colour with fringed wings. Male is smaller, slenderer than female.

Damage symptoms:

It causes damage both in nursery and main field. Both the adults and nymphs lacerate the tender leaves and suck up the plant sap. As a result, fine yellowish lines or silvery streaks are seen on the leaves. Later, the leaves curl longitudinally and begin to dry from the tip downwards in severe cases, the entire nursery may dry up and fail to produce seedling.

Management:

1. Submerge infected crops intermittently for 1-2 days.
2. Controlling weeds, which prevent thrips from building up on alternate hosts.
3. Use resistant/tolerant varieties.
4. **ETL**: > 25% affected leaves, or 10 damaged leaves per hill
5. Spray any one of the following in nursery and main field: Spinosad (or) Phosphamidon 40 SL 50 ml
6. Encourage biological control agents: predatory thrips, coccinellid beetles, anthocorid bugs, and staphylinid beetles.

2. RICE STEM BORER / YELLOW STEM BORER
Scirpophaga incertulas (Pyralidae: Lepidoptera)

Distribution:

The pest is widely distributed in all asian countries, monophagous and is a major pest on rice in India.

Life cycle:

Eggs are laid near the tip on the upper surface of tender leaf in small masses, covered with a felt like buff colored mass of hair and scales. Single female lays 2 or 3 clusters of eggs, each having 15-80 eggs. Eggs hatch in about 5-8 days. There are 6 larval instars and full-grown larva measures 20 mm long and is white or yellowish. Larval duration is 33-41 days. Pupation takes place inside the stem near base in a white silken cocoon. Moth emerges in 6-10 days or in about a month depending on climate. The female moth has bright yellowish-brown forewings with a clear single black spot and the anal end having tuft of yellowish hair. The male is pale yellow and the spots on the forewings are not conspicuous.

Symptoms of damage:

- "Dead-heart" at vegetative stage which turns brownish, curls and dries off.
- "White ears" at heading stage with empty, partially filled grains.
- Activity of moths in the vicinity.
- Frass at the feeding site.

MANAGEMENT:

1. Harvesting of crop close to soil surface, ploughing or flooding the field after harvest to kill hibernating larvae in the stubbles.
2. Selection of varieties resistant to yellow stem borer: Swarnamukhi (NLR 145), Pothana (WGL 22245), Varsha (RDR 355).
3. Clipping the tips of the seedlings prior to transplantation aids in the elimination of egg masses.
4. Seedling root-dip with chlorpyriphos (0.02%) @ 200 ml in 200 litres of water in a plot of 3 m x 3 m for 12-14 hours.
5. Setting light traps or pheromone traps for monitoring the pest.
6. **Egg parasitoids:** *Tetrastichus schoenobii, Telenomus beneficiens*, *Trichogramma chilonis, T. japonicum*,
7. **Larval parasitoids:** *Goniozus indicus, Apanteles ruficrus, A. schoenobii, Bracon chinensis*
8. **Pupal parasitoids:** *Elasmus albopictus, Tetrastichus ayyari, Xanthopimplae maculata*
9. **Predator:** *Chlaenius*sp.
10. Foliar sprays with chlorpyriphos 2.5 ml/l or phosphamidon 2.0 ml/l or acephate 1.5 g/l or cartap hydrochloride 2.0 g/l or chlorantraniliprole 0.4 ml/l.
11. At panicle initiation stage: cartap hydrochloride 4 g @ 8 kg/acre.

3. Rice gall midge, *Orseolia oryzae* (Cecidomyiidae: Diptera)

Distribution: The pest is endemic and is distributed in most parts of India. It is a major pest in Telangana.

Alternate Host: *Cynodon dactylon, Eleusine indica, Ischaeum ciliare, Panicum* sp., *Paspalum scrobiculatum*

Life cycle:

Eggs are laid singly or in groups of 2-6 just below or above ligule *i.e.*, on leaf blade or leaf sheath. Single female lays 100-300 eggs. Eggs hatch in 3-4 days. Larval duration is 15-20 days. The full-grown larva is pale red in colour. Pupation is at the base of the gall. Pupal period is 2-8 days. Fly is mosquito like. Female has bright orange red abdomen, swifter with a reddish telescopic body. Male is darker and smaller. Adult longevity is 1-3 days.

Symptoms:

Hollow whitish to pale green cylindrical tube in tillers known as gall / silver shoot/onion shoot bearing at its tip a green, reduced leaf blade complete with ligules and auricles. Gall is a modified leaf sheath.

MANAGEMENT:

1. Avoid late transplanting in endemic areas. Early planted kharif crop escapes pest.
2. Selection of variety resistant to a biotype of the region. Varieties resistant to different biotypes of gallmidge-
   Biotype 1: Kakatiya, Potana, Kavya, Dhanyalakshmi (BPT 1235), Phalguna, Vikram, Surekha, IR 36, Lalat.
   Biotype 2: Phalguna, Vikram, Vikramatya, Lalat.
   Biotype 3: Surekha
   Biotype 4: IR 36
   Biotype 5: Phalguna, Kavya, Dhanyalakshmi, Kakatiya, Divya.
3. Seedling root dip with chlorpyriphos 0.02%
4. The larvae are naturally parasitized by *Platygaster oryzae, Polygnotus*sp., and *Propicroscytus mirificus*.
5. Application of granules in nursery 5 days before pulling the nursery – phorate 10 G 60 g/cent or carbofuran 3G @ 200 g/cent
6. Application of granules in the main field at 10-15 DAT: Phorate 5 kg/ac or carbofuran 10 kg/ac in endemic areas

4. Brown Plant Hopper, *Nilaparvata lugens* (Delphacidae: Hemiptera)

Distribution: This is distributed in most of the rice tracts of India.

Alternate host: Apart from rice, it infests *Cyperus rotundus* and *Panicum repens*.

Life cycle:

A female lays, about 232 eggs. Eggs are thrust within parenchyma. The egg is white elongated and shaped like a curved club. It hatches in 7-9 days. Brownish nymph undergoes five instars during a nymphal period of 10-18 days. The female is 5 mm long and male 4.5 mm. Female exists in two forms, the fully winged macropterous and the truncated–winged brachypterous.

Damage symptoms:

- Premature yellowing of leaves and drying of plants in isolated circular patches.
- Drying of plants spreads in a circular fashion.

- Sooty mould development.
- Exuviae at the base of plants.
- Affected stems turn soft and are unfit for use as straw.

MANAGEMENT:

1. Avoiding monoculture of susceptible varieties.
2. Growing resistant varieties like Chaitanya (MTU 2067), Godavari (MTU 1032), Krishnaveni (MTU 2077), Indra (MTU 1061),Vajram (MTU 5249), Vijetha (MTU 1001), Pratibha (MTU 5293), Cottondora Sannalu(MTU 1010), Nandi (MTU 5182), Surya (BPT 4358), Deepti (MTU 4870), Chandan (RNR 74802), Tolakari (MTU 1031), Pushyami (MTU 1075).
3. Seedling root dip with chlorpyriphos 0.02%
4. Formation of alleys or pathways of 20 cm width for every 2 metres of planting to facilitate aeration, light, basal spraying, monitoring and other farm operations.
5. Draining the field during the middle of the season to suppress the pest population
6. Conservation of natural enemies*viz.,*
   Spider: *Lycosa pseudoannulata*
   Mirid bug: *Cyrtorhinus lividipennis*
   Aquatic bug: *Gerristristan*
   Coccinellids: *Coccinella arcuata*
   Egg parasitoids: *Anagrus*sp, *Oligosita*sp.,
   Nymphal and adult parasitoid: *Haplogonatopus orientalis*
7. Foliar sprays (directing the spray towards base of plants) with any of the following insecticides *viz.,* ethofenprox 2 ml/l; acephate 1.5 g/l; BPMC 2 ml/l; imidacloprid + ethiprole 80 WG 0.25 g/l.

5. Rice Hispa, *Dicladispa armigera* (Chrysomelidae: Coleoptera)

Distribution: This is known to occur in all rice tracts in India, especially in Andhra Pradesh, West Bengal and Bihar.

Life cycle:

Eggs are laid singly, generally towards the tip @ 55 eggs/ female. The egg hatches in 4-5 days. Small, yellowish, flattened grubs feed on leaf tissue inside the leaf. After feeding for 7-12 days, it pupates in leaf mine or grub tunnel and the beetle emerges in 3-5 days. Adult longevity is about 78 days.

MANAGEMENT:

1. Clipping of leaf tips of seedlings while transplanting eliminates eggs laid towards the tip
2. Removal of left-over nursery
3. Grubs are parasitized by *Bracon*sp.
4. Foliar sprays with Profenophos 2 ml/l or chlorpyriphos 2.5 ml/l.

6. Rice leaf folder, *Cnaphalocrosis medinalais* (Crambidae: Lepidoptera)

Distribution: This is widely distributed in India occurring in all rice growing tracts.

Alternate host: *Echinocloa*spp. *Panicum* spp. and other grasses.

Life cycle:

Flat oval, yellowish eggs are laid singly on the under surface of tender leaves which hatch in 4-7 days. The larva folds 3-4 Pale yellowish green larva measuring 16-20 mm long becomes full grown in 15-27 days. Pupation is inside the leaf fold and the moth emerges in 6-8 days. Total life cycle takes 26-42 days. Moth is small with a wing span of 15 mm, brownish orange coloured with light brown wings having two distinct dark wavy lines on forewings and one line on hind wings. Both wings have dark brown band on their outer margin. Adult longevity is 3 -4 days.

Damage symptoms:

- Larva folds the leaf of young plant and feeding from within.
- Whitish membranous folded leaves with typical white streaks.
- Faecal pellets observed when leaf opened.

MANAGEMENT:

1. Early clipping of infested, folded leaf tips.
2. The Ichneumonid, *Xanthopimplae maculata*is parasitic on the pest larvae.
3. Passing a rope 2-3 times over the crop at tillering stage mechanically to dislodge caterpillars.
4. Foliar sprays with chlorpyriphos 2.5 ml/l or acephate 1.5 g/l or cartap hydrochloride 2 g/l or granules of cartap hydrochloride 4 G 8 kg/acre.

7. Rice Gundhi bug, *Leptocorisa acuta* (Alydidae: Hemiptera)

Distribution: This is present in all rice growing tracts.

Alternate host: The bug over- winters in millets and wild grasses.

Life cycle:

Eggs are laid in single or double rows close to midrib on the upper surface of leaves @ 10-20 per cluster. Each female lays about 100 eggs. Dark reddish-brown egg is boat shaped. Egg hatches in about 7 days. Nymphs are pale yellowish green. Nymph passes through 5 instars in about 15-21 days. The total life cycle takes about a month. The adult is olive-brown, diurnal, elongated bug with long legs.

Symptoms:

- Affected grains become shriveled and chaffy.
- Brown spot is observed at the feeding site where sooty mould develops.
- Lower grain quality and broken grains when infested at soft dough stage.

MANAGEMENT:

1. Clean cultivation.
2. Collection and destruction of bugs by hand nets.

3. Foliar sprays in the evening hours at milky stage starting from borders of the crop with Dichlorovos 1 ml/l +chlorpyriphos 2 ml/l or malathion 2 ml/l.
4. Dusting with carbaryl 10 D @ 10 kg /acre.

Insect-pests of Sorghum

1. Sorghum shoot fly, *Atherigona varia soccata*
(Muscidae: Diptera)

Distribution: The pest is found distributed in India and West Africa infesting sorghum, maize, ragi, bajra etc.

Life cycle:

Eggs are laid singly on the ventral surface of the leaves. Egg is whitish cigar shaped or flattened boat shaped. The egg hatches in 2-3 days. Full grown maggot is pale yellowish. Larval duration is 6-10 days. Pupation takes place inside the stem at the base with a pupal duration of 7-10 days. Fly is a small 3 mm long; dark grey housefly like with its abdominal segments marked with two rows of six dark spots in female and four dark spots in male.

Damage symptoms:

- Dead heart which can easily be pulled out giving offensive smell at cut end.
- Production of side/secondary tillers which are in turn attacked.

MANAGEMENT:

1. Use of a higher seed rate of 12 kg/ha instead of normal rate of 10 kg/ha and removal of affected and extra plants at the time of thinning four weeks after sowing since shoot fly affects only young plants of 4-5 weeks age.
2. Timely sowing of kharif sorghum before July 15th, however for highly susceptible variety CSH-1, the above measures prove ineffective.
3. Some varieties found resistant to shoot fly: IS 1054, IS 1071, IS 2394, IS 5484, SPV 86, SPV 462
4. Set up the fish meal trap @ 12/ha till the crop is 30 days old.
   ETL: 1 egg/plant in 10% of plants in the first two weeks of sowing or 10% dead hearts
5. Dimethoate 30 EC 500 ml/ha
6. Neem Seed Kernel extract 5%
7. Application of carbofuran 3 G granules @ 2 g/one metre row length in furrows at sowing time.

2. Stem borer, *Chilo partellus*
(Crambidae: Lepidoptera)

Distribution:
This pest is very important and common in East Africa and Indian subcontinent.

Life cycle:

A single female lays nearly 300 eggs on undersurface of leaf, often near the midrib. Eggs are laid in batches. Eggs hatch in 4 - 5 days. The larva is cylindrical, yellowish brown with a

brown head. Larval duration is 19-27days. Pupation inside the stem. Pupa within the stem is obtect type, reddish brown with 6 spines at caudal end. Pupal stage lasts 7-10 days. Moth is medium sized, straw coloured with black specks along caudal margin of forewings.

Damage symptoms:

- Shot holes due to biting across leaf spindle.
- Dead heart with no offensive smell at cut end when pulled out.
- Chaffy earheads in later stages.

MANAGEMENT:

ETL: 10% damage

1. Uprooting and burning affected stubbles after harvest to destroy hibernating larvae.
2. Adoption of early planting, higher seed rate, pulling and destroying affected plants in the early stages.
3. Selection of sorghum varieties resistant to stem borer CSH 7,8; SPV 17, 19, 29,58; ICSV 197, 745, 88013.
4. Preservation of natural enemies*viz.,*
    a. Egg parasitoid: *Trichogrammachilonis*
    b. Larval parasitoids: *Cotesiaflavipes, Bracon chinensis*
    c. Pupal parasitoids: *Xanthopimpla punctata, Tetrastichusayyari*
5. Placement of Phorate 10 G @ 8 kg/ha or carbofuran 3 G granules @ 4 kg/ac at 35-40 DAS in leaf whorls since first instar caterpillars congregate in leaf whorls.

Insect-pests of Wheat

1. Ghujia weevil

Distribution:

It is a common pest of young wheat and other crops in Uttar Pradesh, Bihar and Punjab.

Life cycle:

Eggs are laid singly under clods of soil @ 80 eggs/ female. Eggs hatch in 15- 50 days depending on climate. Larvae develop in soil in about 3 months. After 2 months of pupation, adults are formed during April – May but adults remain in soil till June and come out with rains in June and when sorghum is available in field. It is grey or greyish brown weevil measuring 5 mm long.

Symptoms:

Only adults feed on the host plants' leaves and tender shoots. They cut the germinating seedlings at the ground level. The crop is frequently resown. The damage is more severe between October and November, when the rabi crops germinate.

MANAGEMENT

- Deep ploughing during April-May to destroy pupae
- Dusting the soil with carbaryl @ 10-12 kg/ac and raking it into the soil at the time of sowing is effective.

2. Termites, *Microtermes obesi, Odontotermes obesus* (Termitidae: Isoptera)

These are the most important pests of wheat in India and are present wherever wheat is cultivated. *M.obesi*causes up to 25% destruction of the germinating grains.

Life cycle:

Queen, after fertilization enlarges in size to a length of 11 cm. Eggs are laid @ 30,000/day and the longevity of the queen is 5-15 years, even up to 50 years. Males undergo little morphological changes but become more flattened. Egg period lasts for 30-90 days and nymphal period 6-12 months. Workers are whitish yellow, soft bodied, flat and wingless. They only are injurious to crops. They feed on roots, stem of growing plants, even dead tissues of plants feeding on cellulose.

Symptoms of damage:

Termites cause crop damage soon after sowing and occasionally when it is nearly mature. They feed on the roots, stems, and even dead plant tissues. The damaged plants totally dry out and can be removed easily from soil. White ears are produced at later stage of feeding. Unirrigated areas and fields where un-decomposed farm yard manure is spread before sowing show significant infestations.

MANAGEMENT:

1. Locating termitarium, digging out queen and destroying is the only permanent remedy
2. Deep ploughing of fields during summer. Three summer ploughings at 10 days interval reduces juvenile population.
3. Fumigation of ant hill with carbon disulphide or chloroform mixture
4. Apply well rotten farm yard manure.
5. Destruction of crop residues which form sources of infestation.
6. Apply neem cake@ 80 Kg/acre.
7. Seed treatment with chlorpyriphos @ 6 ml/kg of seed or Thiamethoxam 30% FS @ 1.32 Kg per 40 Kg seeds.
8. Soil application of chlorpyriphos 50 EC @ 10 ml/l as a soil drench at sowing time in termite prone soils.

Insect-pests of maize

1. Maize shoot fly, *Atherigona orientalis*

Distribution:

Uttar Pradesh, Andhra Pradesh, Tamil Nadu, Maharashtra, Karnataka. In South India it is a serious pest but it also appears on spring and summer maize crop in North India.

Host range: Maize, sorghum, ragi and bajra

Life cycle:

Eggs are elongated like a small rice grain, milky white in colour. The incubation period is 1-3 days. Larval period is 7-10 days with 3-4 instars. Full grown maggot is yellow in colour. Pupation takes place inside the stem. The pupa is dark brown, barrel-shaped. The pupal period lasts for about a week. Adult is small grey-coloured fly. The adult lives for 3-4 days. The life cycle is completed in about 3 weeks.

Damage symptoms:

Maggots bore into the shoot while feeding, progressively destroying the developing point, and causing the core shoot to wither, resulting in the formation of a dead heart within two weeks of germination.

Management:

1. Treatment of seeds with Thiamethoxam 30 FS @ 8.0 ml/kg seed or Imidacloprid 600 FS @ 6 ml/kg seed.
2. Taking out and destroying dead hearts.
3. Plough soon after harvest, remove and destroy the stubbles.
4. Predators include ear wigs, coccinellids, spiders, robber flies, and pentatomid bugs.
5. Set up fish meal trap @ 12/ha till the crop is 30 days old.
6. Soil application of phorate 10% G 10 kg/ha at the time of sowing.

2. Maize stem borer*Chlio partellus* (Pyralidae: Lepidoptera)

Distribution:

Major pest of maize in India is called as Stalk borer *Chilopartellus* that occurs during monsoon season and is a major pest throughout the country. It is also most destructive pest of maize and Sorghum in India, Srilanka, Pakistan, Afghanistan, Uganda, Central and East Africa.

Alternate hosts:

This Insect has also been recorded on Bajra, Sugarcane, Sudan grass and some other grasses.

Life cycle:

Adult is a medium sized straw-colored moth fore wings: are light brownish with a row of black dots on the apical margin hind wings: are pale white colour. Female lays eggs 10-25 days after germination on lower side of the leaves. Incubation period is 2-5 days. Larva passes 5-6 instars, the larva yellowish brown with reddish brown head and prothoracic shield and measures 25mm long with series of black dots. Larval period is 21-28days. It pupates inside the stem in a small chamber pupal period is 4-7 days.

SYMPTOMS:

- Larvae bores in to the shoot and feed on the internal tissues and causes typical 'dead heart' symptoms.
- Upper part of maize plant dies due to the boring of the caterpillar in the stem.
- Young larva crawls and feeds on tender folded leaves causing typical "shot hole" symptom.

Management: ETL 10% Dead hearts

1. Maize varieties / hybrids Ganga 5, DHM 101, 103, 105 have been found resistant to C. *partellus*
2. Planting of lab lab or cowpea as an intercrop to reduce stem borer damage (Maize: Lablab 4:1).
3. After harvesting, collect the stubbles and burn them to eliminate diapausing borers.
4. Release egg parasitoid, *Trichogrammachilonis* @2,50,000/ha coinciding egg laying period. Three releases at weekly interval is desirable. Third release is to be accompanied with larval parasitoid *Cotesiaflavipes* @ 5000/ha.

5. Mix any of the following granular insecticides with sand to make up a total quantity of 50 kg and apply in the leaf whorls on the 20th day of sowing-Phorate 10% CG10 kg/ha or Carbaryl 4% G 20 kg/ha.
6. If granular insecticides are not used, spray any one of the following: Carbaryl 50 WP 1 kg/ha on the 20th day of sowing (500 ltr of spray fluid/ha) or Dimethoate 30% EC 660 ml/ha.

3. Fall Army worm, *Spodoptera frugiperda* (Noctuidae: Lepidoptera)

Distribution:

Widely distributed in all maize growing areas of the world. It has been spread to most of the states in India such as Tamil Nadu, Andhra Pradesh, Telangana, Maharashtra, Madhya Pradesh, Uttar Pradesh, Odisha, Bihar, West Bengal, Gujarat, Chhattisgarh, Kerala and Mizoram. It was first reported in India in 2018.

Host range: Maize, sorghum, forage grasses, rice, sugarcane, cotton, peanuts etc.

Life cycle:

The female moths lay egg masses on upper or under side of the leaf and covered with tan coloured scales. Each egg mass contains 50-150 eggs. Incubation period varies from 4-5 days. The larvae are smooth-skinned and vary in colour from light tan or green to dull grey body with three creamy yellow dorsal and lateral lines. The larva contains reddish brown head with predominant white, inverted Y-shaped suture between the eyes. The larva contains 6 instars in which the larval period varies from 15-18 days. On 8th and 9th abdominal segment, four large spots are arranged in a square shape on segment 8 and in trapezoid pattern on segment 9. Pupa is reddish brown in color. After 7-9 days, adults emerge from pupae. The total lifecycle completes in about 30-35 days which vary according to climatic conditions.

Damage symptoms:

The young larvae of FAW feed in and around the whorl leaves by scraping and skeletonizing the upper epidermis leaving a silvery transparent membrane resulting into papery spots. The damage also results in pinhole symptoms on the leaves. Older larvae remain and feed inside the whorl. The damages by late instars (4th instar onwards) result in extensive defoliation of leaves and presence of large amounts of faecal pellets in whorls. Damage during vegetative stage leads to leaf damage but if damage happens during reproductive stage, it may damage tassels or may bore inside the corn ear and eat away the kernels.

Management:

1. Deep plough the fields to expose pupae to sun light and predatory birds.
2. Add neem cake @ 200kg/acre to the fields.
3. Maintain field bunds clean and plant flowering plants such as marigold, sesame, niger, sunflower, coriander, fennel etc. to attract natural enemies.
4. Natural Enemies-
   Egg Parasitoid: *Trichogrammapretiosum*, *Telenomusremus*
   Egg-larval Parasitoid: *Chelonus*sp
   Larval parasiotoid: *Coccygidium*sp, *Campoletischloridae*
   Predators: Predatory Pentatomid bugs, ear wigs

Entomopathogen: *Nomuraearileyi*

- Minimum one week interval should be there between parasitoid release and application of neem or chemical insecticides.

5. Seed treatment: Cyantraniliprole 19.8% + Thiamethoxam 19.8% FS @ 6 ml/kg of seed offers protection for 15-20 days of crop growth.
6. Plant 3-4 rows of napier grass/hybrid napier as trap crop around maize fields.
7. Intercrop maize with legumes, viz., pigeonpea, cowpea, black gram, kidney bean etc. in 2:1 to 4:1 ratio.
8. Erect bird perches @10/acre to encourage natural FAW predation by birds.
9. Install pheromone traps @ 4/acre soon after sowing and monitor moth catches.
10. Adopt clean cultivation to eliminate possible alternate hosts.
11. Destruction of egg masses and larvae by crushing.
12. To manage 2nd and 3rd instars larvae at 10-20% damage, spray Spinetoram 11.7% SC @ 0.5 ml/litre of water OR Thiamethoxam 12.6% + lambda cyhalothrin 9.5% @0.25 ml/l of water OR Chlorantraniliprole18.5% SC @ 0.4 ml/litre of water.

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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.

PADDY/RICE (Oryza sativa) DISEASES

Blast:

The disease is caused by a fungus known as Magnaporthe grisea. 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 1918 from Tanjore (Tamil Nadu). Depending on the base of 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:

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.

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).**

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 panicle stands 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 *Magnaporthe grisea.* 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*, *Digitaria marginata, Brachiaria mutica, Leersia hexandra, Dinebra retroflexa, Echinochloa crusgalli, Setaria intermedia,* and *Stenotaphrum secondatum* 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 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, thus favouring the disease. Blast was the first leaf blast model developed by Japan for forecasting of the disease. Other models include Pyriview, Pyricularia, P Blast and 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 include DRR 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 elimination of the primary inoculum and delay the starting of the disease. Removal of infected plant debris and collateral hosts give much advantage in long-term.

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

e. Seed treatment in the areas where seedborne inoculum is a problem may be undertaken for 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 last ploughing can be done to minimize the severity of the disease.

Brown Spot or Helminthosporium leaf spot or Helminthosporiose or Sesame leaf spot:

This disease is 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 *Drechslera oryzae* (Sexual stage: *Cochliobolus miyabeanus).* It produces phytotoxins called ophiobolin A, (or named Cochliobolin A after it), ophiobolin B(or cochliobolin B) and ophiobolin I. Ophiobolin A is 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 *Digitaria sanguinalis, Echinochloa colonum, Pennisetum typhoides, Leersia hexandra,Cynodon dactylon*and *Setaria italica*. Environmental conditions with temperature of 25-30^{0}C and relative humidity above 80 per cent are highly favourable for the development of the disease. Excess of nitrogen is known to aggravates 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. 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*., Sabour Sampanna Dhan (IET 25960), Swarna Smriddhi Dhan (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 fluorescence* 1.5% WP with min. volume of water and coat the seed uniformly, shades dry the seeds just before showing. 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

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, *Sarocladium oryzae* (Syn: *Acrocylindrium oryzae*). The pathogen is favoured by high doses of nitrogen, closer planting, high humidity and temperature between 25 and 30ºC. Injuries made by leaf folder, brown plant hopper and mites increase 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 or Flubendamide 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, application of Hexaconazole 0.5% GR @10kg/ha has been found effective in reducing the disease incidence.

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 impacted 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, puddle-ing, 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 fertiliser doses.

Management of the disease:

a. Use recommended doses fertilizers with an eye on the nitrogenous fertilizers.
b. Deep summer ploughing and safe disposal of stubbles and infected straw reduced primary inoculum for the disease.
c. 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.
d. Draining off the irrigation water to flush sclerotia may be done. The soil may be allowed to dry afterwards.

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

Sheath blight:

Sheath blight is among the most economically important rice diseases worldwide. The disease causes significant losses in grain yield and quality. As much as 50% losses in yield have been reported from various areas under conducive environments. The disease is soil borne in nature and difficult to eliminate from the soil.

Symptoms of the disease:

The crop is impacted by the fungus from the tillering to heading stages. On leaf sheaths close to the water's surface, the first signs are seen. Initially, oval or elliptical to irregular spots of greenish grey colour are formed on the leaf sheath. As the spots enlarge, their centres become greyish-white with an asymmetrical blackish-brown or purple-brown margins. Lesions on the upper portions of plants spread rapidly coalescing with each other eventually to cover the entire stools from the water level to the flag leaf. Numerous large lesions on a single leaf sheath generally cause death of the whole leaf. In severe cases of infection, all the leaves of the plant may become blighted in this way. The infection later extends to the inner sheaths and causes death of the whole plant. Older plants are usually highly susceptible to the disease. Leaf sheaths of five to six-week in age are highly susceptible. Heavily infected plants produce poorly filled grains, particularly in the lower portion of the panicle.

Cause of the disease:

Rhizoctonia solani AG1-IA is the fungal pathogen responsible for the disease. The sexual stage of the pathogen is *Thanetophorus cucumeris.* The fungus produces large number of orbicular sclerotia, which are initially white but later change their colours to brown or purplish brown. The pathogen can over winter in the form of sclerotia or mycelium itself in dry soils for about 20 months and in moist soils, it can survive for 5-8 months. The pathogen is known to infect more than188 crop species across 32 families. Sclerotia are spread through irrigation water. Higher relative humidity (96-97 per cent) coupled with high temperature (30-32 ^{0}C) with closer planting and heavy doses of nitrogenous fertilizers are known to favour the development.

Management of the disease:

a. Avoid excess doses of nitrogenous fertilizers.
b. Adopt optimum spacing to avoid canopy build up.
c. Eliminate weed hosts.
d. Apply organic amendments to promote production of organic acids that can kill primary inoculum in the soil.
e. Avoid movement of irrigation water from infected fields to healthy ones.
f. Deep summer ploughing and safe disposal of stubbles/infected crop debris.
g. Grow disease tolerant/moderately tolerant varieties like JKRH 2154 (IET 24914) and Swarna Smriddhi Dhan (IET 24306).
h. Mix 2.5 kg of *Trichoderma viride* 1.0% WP in 500 litres of water. Spray three times at 15 days interval uniformly over one hectare land 30 days after planting.
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.

False smut

The disease is widespread in distribution across the continents and is known to cause heavy losses every year.

Symptoms of the disease:

The pathogen converts individual grains into yellow to greenish spore balls which are velvety in appearance. The balls are small at first and increase to 1 cm or longer at later stages. At early stages these spore balls are covered by a thin film which bursts with further growth. Due to the development of the fructification of the pathogen, the ovaries are transformed into large velvety green masses. Usually only a few spikelets in a panicle are affected.

Cause of the disease:

The cause of the disease is a pathogenic fungus, *Ustilaginoidea virens* (perfect stage-*Claviceps oryzae - sativae*). Chlamydospores of the pathogen are formed on the spore balls. In temperate regions, the fungus overwinters through sclerotia and/or chlamydospores. Ascospores which are produced on the overwintered sclerotiaseeminglyserve as primary inoculum. Chlamydospores are important in secondary infection which is a major part of the disease cycle. Infection usually occurs at the booting stage of rice plants. Rainfall and cloudy weather during the flowering and maturity periods are favourable for disease development.

Management:

a. Use of resistant/tolerant varieties is by far the best measure to manage the disease. Varieties including DRR Dhan 54 (IET 25653) (RP 5943-421-16-1-1-B), Swarna Smriddhi Dhan (IET 24306), DRR Dhan 56 (IET 26803) and Indam 100-012 (IET 26999) are resistant whereas RH 150025 (ADV 8082) is moderately resistant.
b. Use of chemical fungicides at panicle emergence stage has been found effective. Copper Hydroxide 53.8% DF (dry flowable @1500g/ha), Copper Hydroxide 77% WP @2000g/ha, Fluopyram 17.7% w/w + Tebuconazole 17.7% w/w SC @550ml/ha, Picoxystrobin 7.05% + Propiconazole 11.7% SC @1000ml/ha, Tricyclazole 20.4% w/w + Azoxystrobin 6.8% w/w SC @1000ml/ha, Tricyclazole 18.0% w/w + Tebuconazole 14.4% w/w SC @1000ml/ha are good examples of the chemical compounds for management of the disease.

Bacterial leaf blight

The disease was first observed in India, in 1959. A severe outburst of the disease happened in Bihar and Uttar Pradesh in 1963. In the tropics the disease is usually referred to as bacterial blight as it often kills entire young seedlings. Yield losses in severely diseased fields range from 20-30% and occasionally 50%. In India, millions of hectares are infected every year. Yield losses have been as high as 60% in some states and Godavari district of Andhra Pradesh which are endemic to this disease. **Taichung Native 1** is highly susceptible.

Symptoms of the disease:

The pathogenic bacterium induces two types of symptoms, i.e. wilting of plants and leaf blight. Wilt syndrome known as **Kresek** is seen in seedlings within 3-4 weeks after

transplanting of the crop. Kresek leads to either in the killing of whole plant or wilting of only a few leaves. The pathogen enters the plant through the hydathodes and cut wounds in the leaf tips. After its entry, it becomes systemic and causes death of entire seedling. The disease is usually noticed at the time of heading but in severe cases occur earlier also. In grown up plants water-soaked, translucent lesions appear usually near the leaf margin. The lesions enlarge both in length and width with a **wavy margin** and turn straw-yellow within a few days, covering the entire leaf. As the disease progresses, the lesions cover the entire leaf blade which may turn white or straw-coloured. Milky or opaque dew drops containing bacterial masses are formed on young lesions in the early morning. They dry up on the surface leaving a white encrustation. The affected grains have discoloured spots surrounded by water-soaked areas. If the cut end of leaf is dipped in water, bacterial ooze makes the water turbid.

Cause of the disease:

The disease is caused by a phytopathogenic bacteriaum *Xanthomonas oryzae* pv. *Oryzae.* The bacterium is strict aerobe, gram negative, non-spore forming, rod shaped with **monotrichous** polar flagellum of at one end. After their entry in the plant hosts, the bacterial cells move along the vascular tissues causing wilting. Irrigation water also carries the organism from field to field. The primary source of infection is through bacterium overwintering in seed (husk and endosperm). Bacteria may survive in soil, plant stubbles and debris. The pathogen also survives on collateral hosts like *Leersia oryzoides, Leersia hexandra, Zizania latifolia, Cyprus deformis, Cyprus rotundus, Cyanodon dactylon*, *Phalaris arundinacea,* etc. The bacterial ooze serves as secondary inoculum and causes secondary infection. Clipping of tip of the seedling at the time of transplanting, heavy rain, heavy dew, flooding, deep irrigation water, severe wind, temperature of 25-30^{0}C and application of excessive nitrogen, especially late top dressing.

Management of the disease:

a. 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, Chinsura Boro, DRR Dhan 56 (IET 26803-released in 2021) and Moderately resistant like 27P27 (IET 25745)(PHI-16101),28S44 (IET 26549) (PHI-17108), Sabour Sampanna Dhan (IET 25960), Swarna Smriddhi Dhan (IET 24306), Field tolerant like CG Jawaphool Trombay (RTR-31) and tolerant like JKRH 2154 (IET 24914)helpsreduce the losses from the disease.
b. Infected plant debris are to be destroyed safely.
c. Judicious use of nitrogenous fertilizers
d. Avoid clipping of tip of seedling at the time of transplanting.
e. Avoid flooded conditions or drying of the field (not at the time of flowering)
f. Avoid flow of irrigation water from infected to healthy field
g. Remove and destroy weed hosts.
h. Seed treatment with *Pseudomonas fluorescens* 1.5% WP (BIL-331 Accession No. MTCC5866) @5g/kg of seed. Make a thin paste of required quantity of *Pseudomonas fluorescens* 1.5% WP with min. volume of water and coat the seed uniformly, shade dry the seeds just before showing. Seedling root dip treatment followed by spray may also be done by Pseudomonas fluorescens 2.0% AS (Strain No. IPL/PS-01, Accession No. MTCC 5727) @10ml/litre water. Mix 10 ml of *Pseudomonas fluorescens* 2.0% AS in one litre of water and dip the paddy seedling root for 30 minutes before transplanting followed by 4 foliar applications after 40-45 days of transplantation.

i. Seed Treatment, seedling treatment and spray with Streptomycin Sulphate 90% + Tetracylin Hydrocloride 10% SP eradicates seed borne inoculum. Prepare streptocycline 40 ppm solution and soak seeds for 12hours at room temperature before sowing. Seedling treatment: Dip the seeding in streptocycline 40 to100 ppm solution. The antibiotic will be absorbed through the injured roots and penetrate the vascular bundles insides the seedlings. Spray: Spray streptocycline 100 to 150 ppm solution 25 at early root stage. Second spray, if necessary, before grain set.

Bacterial leaf streak:

Bacterial leaf streak was first found in Philippines in 1918. The disease is common in tropical Asia, but is not present in Japan or other parts of the world. In India, it is reported by Srivastava from U.P, MP, AP, Maharashtra, Karnataka, Orissa, Haryana and West Bengal. **IR 8, Jaya** and **Padma** are highly susceptible to BLS.

Symptoms of the disease:

Symptoms initially appear as small, water-soaked, linear lesions between leaf veins. These streaks are initially dark green and later become light brown to yellowish gray. The lesions are translucent when held against the light. Entire leaves may become brown and die when the disease is very severe.

Under humid conditions, yellow droplets of bacterial ooze, which contain masses of bacterial cells, may be observed on the surface of leaves. Fine translucent streaks appear between the veins of the leaf are the first symptoms. The lesions enlarge lengthwise and advance over larger veins laterally and turn brown. On very susceptible varieties a yellow halo appears around the lesions. On the surface of the lesions, bacteria ooze out and form small yellow band-like exudates under humid conditions. In severe cases the leaves may dry up.

Cause of the disease:

The disease is caused by a phytopathogenic Gram negative bacterium called, *Xanthomonas campestris p.v. oryzicola.* The organism is short rod, about 1.2µ x 0.3 to 0.5µ, and gram negative. The strains of the bacteria differ in pathogenicity, the virulent strains causing longer streaks. The pathogen can survive in infected seed but not in crop debris. The bacteria enter the leaves through stomata and wounds. It mainly infects the parenchymatic cells but does not enter the vascular systems. BLS is not a systemic disease. When the leaves are wet, exudate from infected leaf spread to other portions of the leaf and to other plants. Rain storms and typhoons favour the spread of the disease. High relative humidity (83-93%) or dew during morning hours for 2 to 3 hours is known to favour the disease.

Management of the disease:

a) Grow resistant varieties. IR 20, Krishna and Jagannath are tolerant to BLS.
b) Affected stubbles are to be destroyed by burning or through ploughing
c) Judicious use of nitrogenous fertilizers
d) Avoid clipping of tip of seedling at the time of transplanting.
e) Avoid flooded conditions or drying of the field (not at the time of flowering)
f) Avoid flow of irrigation water from infected to healthy field
g) Soak the seed in Streptocycline (250 ppm) followed by hot water treatment at 52 ^{0}C for 30 minutes eradicates seedling infection.
h) Spray Streptocycline (250 ppm) along with copper oxychloride (0.3%)

Rice Tungro disease:

In India, the disease is seen in states of West Bengal, Kerala and other parts of India. Tungro is one of the most widely distributed and most destructive diseases in tropical Asia.

Symptoms of the disease:

Infection occurs both in the nursery and in the main field. Plants are markedly stunted. Stunting is more severe on susceptible varieties and slight on more resistant varieties. Leaves show yellow to orange discolorationand interveinal chlorosis. Yellow discoloration is commonly seen in "Japonica" varieties, while "Indica" varieties show orange discoloration. Yellowing starts from the tip of the leaf and may extend to the lower part of the leaf blade. Young leaves are often mottled with pale green to whitish interveinal stripes and the old leaves may have rusty streaks of various sizes. The plants may be killed if infected early. Tillering is reduced with poor root system. The infected plants have few spikelets and panicles are small with discoloured grains.

Tungro infected plants can be chemically identified by **Iodine Test.** Ten cm long leaf tip is cut in the early morning before 6 A.M. and dipped in a solution containing 2g Iodine and 6 g Potassium Iodide in 100 ml of water for 30 minutes. Tungro infected leaves show dark blue streaks.

Cause of the disease:

It is a composite disease caused by two morphologically unrelated viruses: rice tungro bacilliform virus (RTBV) and rice tungro spherical virus (RTSV). Other than infected rice plants in the farmer's field, other primary sources for tungro, include: stubble of previous crops, new growth from infected stubbles that had not been properly plowed under and harrowed effectively, volunteer rice, infected plants in nearby rice fields.

Two types of virus particles are associated with the disease. Bacilliform particles cause majority of the symptoms of the disease. Spherical particles help in the transmission of bacilliform virus by the green leaf-hoppers. If the bacilliform virus particles are alone present in the rice plant they will not be transmitted by the leafhopper vector.

The virus causes severe damage only in area where the host plants and the insect vector multiply the year round. In the areas where the rice is not grown continuously, collateral hosts, especially wild rice are probable sources of inoculum. Stubbles of infected plants from the previous season also serve as a source of inoculum. Grassy weeds such as *Eleusine indica, Echinochloa colonum, Echinochloa crusgalli* may be infected occasionally. The leafhoppersviz, *Nephotettix virescens, N. nigropictus, N. parvus, N.malayanus* and *Recilia dorsalis* transmit the virus in a non-persistent manner.

Management of the disease:

a) Summer deep ploughing and burning of stubbles.
b) Destroy weed hosts of the virus and vectors.
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 Smriddhi Dhan (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.

Wheat (*Triticum* sp.)

Black or stem rust:

The most important and damaging disease across the world wherever wheat is grown. The rust epidemics of 1946-47 in M.P, Maharashtra, Rajasthan and U.P destroyed over two million tonnes of wheat. In 1956-57 rust was severe in West Bengal, Bihar and Eastern parts of U.P causing heavy losses to the crop and rendered the grain in some areas unfit to harvest. In India though the disease is prevalent in all the parts of the country, it normally appears in epidemic form only in central, southern and eastern parts of the country where high temperatures prevail during crop season. Apart from wheat, barley crop is also susceptible to this rust.

Symptoms of the disease:

The initial symptom of infection is flecking of leaves, leaf sheaths, culms and floral structures. These flecks soon develop as oblong, reddish-brown uredopustules (also called uredia), frequently coalescing into one another, finally opening to expose a mass of brown uredospores. When large number of uredia burst and release uredospores, the entire leaf blade and other affected parts seem to have a brownish appearance and can be noticed even from a distance. Later in the season, teleutosori (also called telia) are produced in the same uredosori. They are noticeable, linear or oblong, dark brown to black in colour, and often coalesce with one another, to cause linear patches of black lesions, giving the disease its name black rust. On maturity the telia burst open, exposing masses of dark brown teleutospores/teliospores. In the transitional stage, there is a mosaic of brown and black masses of spores on the affected tissues, which dry up prematurely. Additionally, in the case of severe infections the diseased plants are become dwarf and produce small spikes and shrivelled grains, or no grain at all.

Cause of the disease:

*Puccinia graminis tritici*is the fungal pathogen causing the disease. Black or stem rust is heteroecious full cycle rust showing all the five spore stages. Being heteroecious, it requires more than one host species of different families to complete its life cycle. The uredial and telial stages occur on wheat, barley and some grasses and the pycnial and aecial stages on the species of *Berberis* (Barbery) and *Mahonia*, the alternate hosts. The fungus is highly specialized and has number of physiological races (over 250). Races 11, 15c, 34-Aand 122 are most predominant appearing in virulent form in wheat growing tracts of India. Primary infection is mainly through barberry, i.e., *Berberis vulgaris*. These barbery plants play a role in USA, Europe and Australia, where as in India they are not known to play any role in the perpetuation of the fungus. The source of inoculum for black rust comes from south, i.e., Nilgiri and Pulneyhills. In plains of North India during summer months the uredospores cannot survive because of the high temperatures. The possibilities of the fungus surviving on ratoon tillers or self-sown wheat plants, late and off-season wheat crops and certain grasses growing in cool areas particularly in the foot hills of Himalayas in the North, the Nilgiris and Pulney hills in the South appear to be great.

The grasses, viz., *Briza minor, Bromus patula, Brachipodium sylvaticum* and *Avena fatua*, harbor the fungus in the off-season. It is believed that the fungus over summers on the wheat plants and grasses in the hilly areas and spreads to the plains in the main wheat crop season. In the central Nepal, the wheat crop sown in August and harvested in December, January becomes infected by *P. graminis tritici* from October. This may be a source of inoculum for the main crop sown in the plains, which becomes infected from February each year.

Management of the disease:

a) Eradication of self-sown wheat plants and weed hosts
b) Adjust the time of sowing to mismatch the load of inoculum with earlier stages of the crop.
c) Grow resistant varieties like GW 1339 (BANAS) (VD 2014-24), Chhattisgarh Genhu-4 (CG 1015), K-1317, MACS 3949 (d), Pusa Tejas (HI 8759), GW 499etc.
d) Avoid late sowing
e) Balanced application of nitrogenous fertilizers
f) Seed dressing with Plantavax@0.1% followed by two sprays with the same chemical.
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.

Leaf, brown or orange rust:

It is the most common rust in the northern and eastern parts of India. In Punjab, Bihar and Uttar Pradesh it causes more damage than stem/black rust. In South India, it is found in the crops grown both in the hills and in the plains.

Symptoms of the disease:

The initial symptoms of the disease include the appearance of minute, round, orange sori, irregularly distributed on the lamina, rarely on the leaf sheath and stem. The sori change in colour to brown approaching maturity. As the disease advances, the telial stage may be found in the same sori. The teliopustules are small, oval to linear in shape, black in colour and are covered by the host epidermis. The telia are also found on the leaf sheath. Severe rusting of leaves causes reduction in yield.

Cause of the disease:

The fungus, *Puccinia recondita*, is also heteroecious in nature. The uredial and telial stages appear on wheat and some other grasses and aecial and pycnial stages on species of ***Thalictrum***. In India, the role of *Thalictrum javanicum* and *T. flavum* as alternate hosts has not been precisely determined. In early January, the rust gets well-established in the foothills of Himalayas and also in the plains of Tamil Nadu and Karnataka in the South. The first build-up of inoculum takes place in the plains of Karnataka and moves northwards to Maharashtra and Madhya Pradesh. The inoculum from the foothills of Bihar and UP moves to the northern plains. Therefore, the brown rust appears slightly later in the Western hills of North India. The rust population of the north and the south moves in opposite directions, finally merging into each other, and causes serious disease in 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, Pusa Tejas (HI 8759), CoW 3, DBW 110, PBW 660, WB 2, PBW 1Zn, (HPBW 01) and HD 3171 are also resistant to yellow rust.

b) 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.
c) RH-124, an Indofil product is very specific to brown rust (or) spray dithiocarbamates like zineb@0.25% or Mancozeb@0.25%
d) Seed dressing with Plantavax@0.1% followed by two sprays with the same chemical

Yellow or stripe rust:

The disease is confined to the cooler part of the country particularly the foothills of Himalayas, Punjab, Himachal Pradesh, Haryana, Uttar Pradesh and parts of Rajasthan and Bihar. It is totally absent from South India except in Nilgiris and Pulney hills. It appears every year, but the damage is seen only in occasional years.

Symptoms of the disease:

The uredia appear as bright yellow pustules mainly on the leaves. In severe infections they may be seen on leaf sheaths also. The sori are elongated and are arranged in linear rows between the veins of the leaf and hence it is referred as stripe rust. These pustules are mostly sub-epidermal and are remained covered by the epidermal layer. They break only at the time of crop maturity. The teleutosori appear late in the season and are also arranged in linear rows. They are compact, elongated, and black in colour. They remain below the host epidermis. They do not break through epidermis for a long time remaining as black crust.

Cause of the disease:

Puccinia striiformis is the fungal pathogen causing the disease. Uredospores of the pathogen are yellow, spherical to oval with a spiny wall. The teliospores are dark brown, two celled, thick walled and flattened at the top. Its persistence in India is not known. It may overwinter on volunteer wheat plants at an altitude of about 1500 to 1800 meters in the Himalayas. The uredospores germinate after a period of dormancy and form a source of inoculum for early sown wheat crop. In Uttar Pradesh early sown crop is severely infected by the fungus than the late sown crop. Some weeds like *Agropyron semicostatum, Bromus catharaticus, Bromus japonicus* and *Hordeum murinum*also serve as primary source 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) 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 and Him 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.
b) 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.

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

Loose smut:

Loose smut is one of the major diseases on wheat. There was loose smut epidemic during 1970-75 in Punjab, Haryana and Western U.P. In Sonalika, the incidence was 5 to 6%. Incidence is more in North than in southern parts of India. Country wide loss is about 2- 3% in yield.

Symptoms of the disease:

The symptoms of the disease are obvious only at the time of emergence of the panicle from boot leaf. All the spikelets in a panicle are converted into a mass of black powdery spores. Infected panicles emerge two days earlier than the healthy ones and the spores are covered with the thin silvery membrane. This thin membrane gets ruptured exposing the mass of black spores. The spores are easily blown by wind leaving the bare rachis.

Cause of the disease:

Ustilago nuda tritici is the fungal pathogen responsible for the disease. Windblown teliospores that land on the flowers of wheat plants can germinate and infect the developing embryo of the kernel. The mycelium of the loose smut fungus remains dormant in the embryonic tissues of the kernel until the kernel begins to germinate. The mycelium then develops along with the growing point of the plant, and at flowering time replaces the floral parts of the spike with masses of black spores. Infection and disease development are favored by cool, humid conditions, which prolong the flowering period of the host plant. It is internally seed borne disease and is systemic in nature. The fungus is carried over in the seed as dormant mycelium. When the planted seed germinates the dormant mycelium becomes active and grows along with the plant and when the panicle is produced the mycelium reaches the ovaries and transforms the ovaries into a mass of black smut spores. Secondary spread occurs through wind borne smut spores. The sporidia infect the healthy flowers. The mycelium enters the ovary and remains in the seed as dormant mycelium.

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 ^{0}F or 52^{0}C 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 (42-44^{0}C)

d) ***Anaerobic seed treatment*** (USA): Soak the seeds for 2-4 hours in water between 60- 70^{0}F 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.

Karnal bunt:

The disease was first described in India from Karnal (Haryana) by Mitra (1931). The disease was comparatively less severe till 1970's, after which it assumed greater significance in early years of seventies'decade with the usage of high-yielding, nutrient responsive, semi-dwarf cultivars. The disease was observed in epidemic form in various parts of India during the years of 1976, 1979, 1981-83 and 1986.

Symptoms of the disease:

The infection is usually confined to a few grains in the spike with irregular arrangement. In some cases the infection may spread to only a part of the grains. In severe cases, the grain is reduced to black shiny sac of teliospores. As the grains mature the outer glumes spread and the inner glumes expand, exposing the bunted grains. The bunt balls are first enclosed by the pericarp but when it bursts the masses of bunt spores are exposed. The bunt affected plants emits a foul smell which is mainly due to the presence of Trimethylamine. Karnal bunt is not easily detected prior to harvest, since it is usual for only a few kernels per spike to be affected by the disease. Following harvest, diseased kernels can be easily detected by visual inspection: a mass of black teliospores replaces a portion of the endosperm, and the pericarp may be intact or ruptured. Diseased kernels give off a fetid or fishy odor when crushed.

Cause of the disease:

The disease is caused by a fungus, *Neovossia indica* (formerly *Tilletia indica*). In severe cases grain is reduced to black shiny sack of teliospores. The embryo and endosperm are not colonized. The pericarp ruptures during threshing and teliospores deposit in soil and adhere to the surface of the seed. Moderate temperatures (19-23^{0}C), high humidity (>70%) and cloudiness or rainfall during anthesis favour disease development in susceptible host varieties.

Management of the disease:

a) Grow resistant/tolerant varieties, viz., Pusa Wheat 8805 (HI 8805), HD 3249, HI 1628, NIDW 1149, HI 1634 (Pusa Ahilya), HD 3298, DBW 110 and HD 3171.
b) Use resistant sources like wild species of *Aegilops* and *Triticum*, HD 2329, HD 29 and HD 20 for breeding programme.
c) Follow strict quarantine measures to avoid its introduction in the newer areas.
d) Use disease-free seed from apparently healthy crop for sowing
e) Judicious application of nitrogenous fertilizers
f) Adjustment in the date of sowing
g) Intercropping with Gram or Lentil
h) Seed treatment with Thiram 75% WS @3g/kg seed
i) Spray with Bitertanol 25% WP @2240g/ha, Propiconazole 25% EC @500ml/ha

Leaf blight:

The disease was reported by Prasad and Prabhuin 1962 from India. It is prevalent in parts of Maharashtra, Bihar, West Bengal and UP. Seedlings are not prone to infection.

Symptoms of the disease:

Small, chlorotic, oval- or elliptical shaped lesions appear and, as they enlarge, these lesions become irregular in shape. The chlorotic borders of the lesions may become diffuse and turn light to dark brown in color (See picture). Lesions are difficult to distinguish from those caused by spot blotch. Infection usually starts on the lower leaves, but symptoms can be found on all plant parts. Reddish-brown oval spots appear on young seedlings with bright yellow margin. In severe cases, several spots coalesce to cause drying of leaves. The young leaves are not usually infected. Heavily infected fields display a burnt appearance even from a distance. In some varieties reduction in grain yield is as high as 90% if the infection takes place at or before the boot leaf stage.

Cause of the disease:

Alternaria triticina is the fungal pathogen causing the disease. The pathogen over summers in plant debris and soil. Primary spread is by externally and internally seed-borne conidia. Secondary infection is mainly through wind-borne conidia. Bread wheat and durum wheat, as well as several related grasses, are the primary hosts. The disease is common in the eastern and central areas of the Asian Subcontinent. Temperature of 25 ^{0}C and high relative humidity favour the disease.

Management of the disease:

a) Grow resistant/tolerant varieties like HD 3171, K0402 (MAHI), WH 1105, HD 3298, HI 1634 (Pusa Ahilya), 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.

Powdery Mildew:

Powdery mildew can cause major yield losses if infection occurs early in the crop cycle and conditions remain favorable for development so that high infection levels are reached before heading.

Symptoms of the disease:

On all hosts, the first visible symptoms of this disease are white to pale gray, fuzzy or powdery colonies of mycelia, and conidia on the upper surfaces of leaves and leaf sheaths (especially on lower leaves), and sometimes on the spikes. Older fungal tissue is yellowish gray (picture on right). This superficial fungal material can be rubbed off easily with the fingers. Host tissue beneath the fungal material becomes chlorotic or necrotic and, with severe infections, the leaves may die. Eventually, black spherical fruiting structures (cleistothecia) may develop in the mycelia and can be seen without magnification.

Cause of the disease:

The fungal pathogen *Blumeria graminis* sp. *tritici* [teleomorph]*Oidium monilioides* (Nees) Link [anamorph] is the cause of the disease. The development of powdery mildew is favored by cool (15-22^{o}C), cloudy, and humid (75-100% relative humidity) conditions. The pathogenic fungus has a high degree of host specificity. Isolates infecting wheat do so exclusively; the same appears to be true for isolates infecting barley, oats, and rye. Further specialization exists in the

form of races. Powdery mildew occurs worldwide in cool, humid, and semiarid areas where cereals are grown.

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 respite from 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.

Tundu disease or yellow slime disease

The disease was first reported by **Hutchinson** (1917) from Punjab in India. It is caused by a complex of two different organisms, one a nematode and the other a bacterium.

Symptoms of the disease:

The disease is characterized by the twisting of the stem, distortion of the ear head and rotting of the spikelets with a profuse oozing of yellow liquid from the affected tissues. The ooze contains masses of bacterial cells.

The nematode alone causes winkling, twisting and various other distortion of the leaves, stem and produce small round galls on the leaves. The infected plants are shorter and thicker than healthy plants. In the distorted earheads dark galls are found in place of kernels. When the bacterium is associated with the nematode, the disease symptoms are intensified at the flowering stage and yellow ear rot sets in due to combined action of the nematode and bacterium. The earhead becomes chaffy and the kernels are replaced by dark nematode galls which also contain the bacterium. The infected plants produce more tillers than the healthy ones. Another interesting feature is the early emergence of ears in the nematode infected plants which is about 30 to 40 days earlier than the healthy ones.

Cause(s) of the disease:

The disease is caused by a complex of two taxonomically different organisms-*Anguina tritici* (Nematode) + *Corynebacterium tritici or Clavibacter tritici* (bacterium). The bacterial partner *Corynebacterium* is rod shaped, Gram positive and is motile by single polar flagellum. The disease starts from the seeds contaminated with the nematode galls. When such contaminated seeds are sown in the field, they absorb moisture from the soil and the larvae (juveniles) escape from the galls and climb upon the young wheat plants. At the time of flowering, the nematodes enter the floral parts and form galls in the ovaries. When once the nematode is inside the tissues of the ovary, the bacterium becomes active and causes rotting. The yellow ooze coming out of the rotting earhead provides the inoculum for the secondary spread of the disease which is favoured by wind and rain. The nematode probably functions as a vector transporting the bacterium to otherwise inaccessible meristematic regions of the host. The nematodes secrete some substances in the presence of the host bacterium which can remain viable for atleast 5 years in the galls of *A. tritici*. The nematode galls are reported to remain in the soil for 20 years or more and the bacterium can also survive for the same period inside the nematode gall.

Management of the disease:

a) Sow gall free seeds. Separate the galls from the seed by floating in brine at 160 g of sodium chloride in liter of water.
b) Wheat, barley or oat should not be sown in the infested soil.
c) Spray the crop with streptocycline, 1g in 10 liters of water.

Barley Diseases:

Covered smut:

The disease is externally seedborne and is of quite much significance in the crop cultivation. It is prevalent ia almost all the barley cultivation regions.

Symptoms of the disease:

Masses of dark brown smut spores replace the entire head of plants. Floral bracts and awns at least partially develop and spores are contained in a membrane until plant maturity when they are dislodged by threshing and infect the seed. They are recognizable by their blackened ears that emerge from the leaf sheaths. All the ears in a diseased plant and all the grains in a diseased ear are infected. All the infected grains in a diseased ear are transformed into masses of teliospores which are held in place by persistent, tough, greyish-white membrane**.**

Cause of the disease:

Ustilago hordei is the fungal pathogen primarily responsible for production of the disease. The fungus is externally seedborne and can reach healthy seeds during threshing. The covered masses of teliopores are not released from their enclosing membranes until threshing time, unless the membrane is broken accidentally. When the infected ears are broken open during threshing, innumerable teliospores are released. Many of these lodge on healthy kernels and remain dormant until the seed is sown (Externally seedborne). A warm, moist, acid soil favours seedling infection. The greatest number of seedlings is infected at a soil temperature range of 10°C to 21°C.

Management of the disease:

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.

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.

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.

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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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.

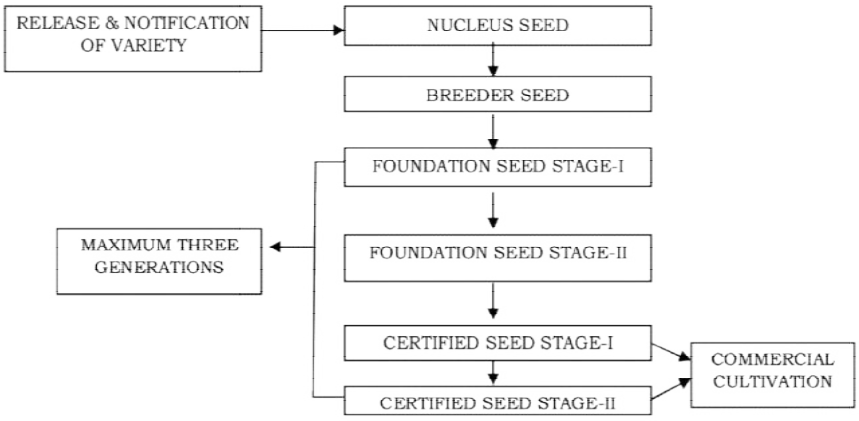
Modern seed supply systems are primarily dependent on improved varieties, which are developed and released by crop breeding institutions. The seeds of these varieties should be multiplied in large quantities for distribution to the farmers in a manner to maintain the genetic purity. At the time of release of a variety, small quantity of seed, normally known as Nucleus Seed, is available with the plant breeder. To facilitate easy systematic increase, seed multiplication is undertaken following Generation System, which is nothing but the production of a particular class of seed from a specific class of seed up to the certified seed stage. The choice of a proper seed multiplication model is the key to the success of a seed programme that depends on:

- The rate of genetic deterioration
- Seed multiplication ratio and
- Total seed demand

Based on these factors different seed multiplication models may be derived for each crop and the seed multiplication agency should decide how quickly the farmers can be supplied with the seed of newly released varieties, after the nucleus seed stock has been handed over to the concerned agency, so that it can spread quickly, replacing the old varieties. In view of the basic factors, the chain of seed multiplication models could be:

Three-generation model: Breeder seed - Foundation seed - Certified seed (adopted for cross-pollinated/open cross pollinated crops)

Four-generation model: Breeder seed - Foundation seed (I) - Foundation seed (II) –Certified seed (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 Sorghum,	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, crops 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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Post-Harvest Management for Seed Quality Assurance in Cereals

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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 minimize 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 emphasizes 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 centered on the needs of developing countries but also applies to more industrialized 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 molds 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 utilized 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 practices 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 over dried. 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 utilized 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 standardized 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 summarized (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 flavor, 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 flavor, color, texture, and nutritional value loss (Atanda, 2011). Due to enzyme-activated processes, biochemical losses can include softening, discoloration, and unpleasant flavor. 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, flavor, 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 minimized. 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, discoloration, 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 utilized 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 categorized 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 organizations) 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, mechanized 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 are 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 unfavorable 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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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 plants	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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Genetic Purity Assessment through Grow-Out-Test

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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 originate 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 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 specifications, 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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Recent Advances in Genetic Purity Testing of Diverse Crop Plants using Molecular and Imaging Techniques

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Introduction

The success of any agricultural technology depends on the timely production and adequate supply of genetically pure seeds to the farmers. The genetic purity has direct effect on ultimate yields. If there is any deterioration in the genetic makes up of the variety during seed multiplication and distribution cycle, there would definitely be proportionate decrease in its performance e.g. yield, disease resistance etc. to the tune of 15-20%. Genetic purity of seeds refers to the trueness to type. The purity test provides the actual percentage of varietal purity from the nominated grain variety. This provides better assurance of crop purity. The test is particularly useful prior to seeding to identify the purity of seed grain. By conducting the test prior to seeding, it can potentially identify the purity of the crop before it is grown. Quality seed is one which meets the Minimum Seed Certification Standards *viz*., physical purity, germination per cent, moisture content, seed health and genetic purity. The genuineness of the variety is one of the most important characteristics of good quality seed. Genetic purity test is done to verify any deviation from genuineness of the variety during its multiplication. For certification, genetic purity test is compulsory for all foundation and certified seeds. The genetic purity during multiplication stages is prone to contaminate due to the presence of out crossing with foreign pollens besides physical admixtures. Thus use of seeds with low genetic purity results in segregation of the traits, lower yields and genetic deterioration of varieties. Therefore, maintenance of varietal purity is a prerequisite to ensure high genetic purity of seeds.

Varietal purity testing

Every new plant variety to be registered has to pass through species-specific tests defined by the guidelines of the International Union for the Protection of New Varieties of Plants (UPOV 1990, 1991). By definition, a new variety has to show to be distinct (D) from other existing varieties 'in common knowledge' by at least one character, and to demonstrate uniformity (U) and stability (S) in characteristics used to distinguish them. The characters used for the distinctness, uniformity and stability (DUS) test are traditionally and primarily morphological, being scored in field and seed laboratory tests. Morphological characters, both quantitative and qualitative, have long been used to identify species, genera, to evaluate systematic relationships, and to discriminate between varieties. In practice, distinctness is assessed by comparing the variety (or variety mean) of the candidate with the means of varieties of a reference collection. The number of morphological traits is limited, most of them are multi-genic, quantitative or continuous characters, and their expression is influenced by environmental conditions. As a complementary approach, biochemical analysis of isozyme markers proves its diagnostic potential, but a limited degree of polymorphism and potential sensitivity to environmental and developmental variation prevented its broad application. In

line with the popularity and proven utility of molecular markers, there is a clear tendency to introduce and use them as characters for distinctness.

Conventional Vs biotechnological tools

Grow-out test (GOT) is a popular and very often used methodology practiced by the researchers in detecting off types (genetic purity) since long ago. However, it is land and labour intensive, time consuming, tedious procedure involving high cost. At present, molecular markers like SSR are the reliable alternative method used for detecting both genetic purity and hybrid purity of hybrids and varieties. Use of molecular markers evident to facilitate these processes very quickly with ease and confidence and a cheaper rate, since it can provide means of detecting and resolving complications. Ideal molecular markers are stable, abundant and detectable in plant tissues regardless of growth, differentiation and defence status.

A large number of various molecular methods have been developed to provide such descriptors (RAPD, RFLP, SSR, IRAP, AFLP, etc.). The goal for variety identification is to obtain a specific pattern for each variety. Especially in crops with limited genetic diversity, the molecular marker of choice must be very informative. Microsatellite (SSR) approach has proven its utility for variety identification in numerous crops. The great advantages of SSR analysis are: accuracy, high polymorphism owing to multi-allelism, possibility of genetic mapping, and codominance. Therefore, the UPOV working group on biochemical and molecular techniques has identified SSR markers as the most widely used marker system for plant variety characterization (UPOV 2002) and recommended them as an additional marker system along with morphological characters.

With the introduction of Indian legislation on "Protection of Plant Varieties and Farmers Rights" the new crop varieties should be **distinct** from other varieties, **uniform** in their characteristics and generally **stable** over the years (DUS testing). Farmers and seed growers need an assurance that they are being supplied with correct seed material having known identity of a specific variety and assured quality. Thus, there is a need to search for rapid and reliable methods of varietal identification and genetic purity testing of seed. The characters for which a variety is distinct from other could be **morphological, chemical** and **biochemical** or **physiological** in nature which aids in varietal identification. According to International Union for Protection of New Plant Varieties (UPOV), any new characteristic used in varietal characterization should be clearly defined, accepted and should have standard method of observation and not affected by environment, accessible to breeders, associated with reasonable costs and efforts. There are three broad classes of markers available to estimate the genetic purity and they are,

- Morphological marker (those based on visually assessable traits)
- Biochemical markers (those based on gene product)
- Molecular markers (those relying on a DNA assay).

Types of markers

i) Morphological markers

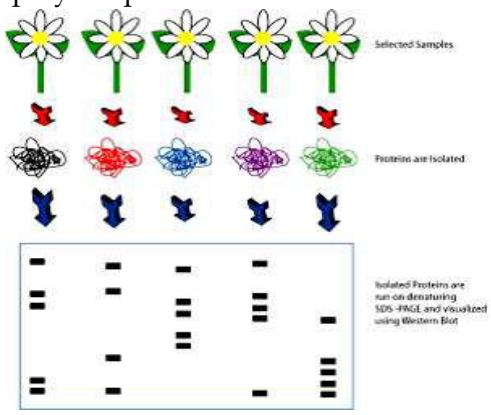
Seeds, seedlings and plants of various cultivars exhibit a wide range of morphological distinctness which is helpful in varietal identification and genetic purity testing. Continuous usage of morphological data to describe cultivars indicated that these data retain popularity as

descriptors. There are several undesirable factors that are associated with morphological markers.

1. High dependency on environmental factors. Often the conditions that a plant is grown in can influence the expression of these markers and lead to false determination.
2. These traits often have undesirable features such as dwarfism or albinism.
3. Performing genetic purity test (GOT) with these markers is time consuming, labour intensive and the large populations of plants required need large plots of land.

ii) Biochemical markers

Isozymes are used as biochemical markers in plant breeding. Isozymes are common enymes expressed in the cells of plants. The enymes are extracted, and run on denaturing electrophoresis gels. The denaturing component in the gels (usually SDS) unravels the secondary and tertiary structure of the enzymes and they are then separated on the basis of net charge and mass. Polymorphic differences occur on the amino acid level allowing singular peptide polymorphism to be Detected and utilized as a polymorphic biochemical marker.



Biochemical markers are superior to morphological markers in that they are generally **independent of environmental growth conditions**. The only problem with isozymes is that most cultivars (commercial breeds of plants) are genetically very similar and isozymes do not produce a great amount of polymorphism and polymorphism in the protein primary structure may still cause an alteration in protein function or expression.

Fig.1: Sequential Summary of events occurring in isozymes analysis of plant samples. Although useful in some plant varieties, isozymes provide little variation in highly bred cultivars

iii) Molecular markers

Molecular markers are based on naturally occurring polymorphisms in DNA sequences (i.e.: base pair deletions, substitutions, additions or patterns). Molecular markers are superior to other forms of markers because

1. They are relatively simple to detect,
2. Abundant throughout the genome even in highly bred cultivars,
3. Completely independent of environmental conditions and
4. Can be detected at virtually any stage of plant development.

The ideal characters of suitable molecular marker:

1. Must be polymorphic

2. Co-dominant inheritance
3. Randomly and frequently distributed throughout the genome
4. Easy and cheap to detect
5. Reproducible

Varietal purity testing through conventional and biotechnological tools

The traditional way to assess the seed genetic purity of cotton is grow-out test (GOT), where the crop is grown and evaluated at different stages of crop growth with the aid of available morphological descriptors. The process is time consuming, requires larger area for replicated trails and highly skilled personnel for making often subjective decision (Luccheseetal., 1999) and also the marketing of seeds is delayed due to late receipt of results. While the differential response of seeds or seedling to various chemical test, biochemical test and molecular marker can be used as a tool to identify the hybrids which are time consuming, simple and reproducible

Conventional tools: GOT/morphological characters

To meet the demand of genetically pure seed, the Certification Agencies are following a Grow out techniques (GOT) where morphological characters are scored at various stages of plant growth, which has been used extensively in purity control mechanism of hybrid seed and for the purpose of identification of varieties. A set of morphological descriptors are currently in use for variety identification and description. Some of these characters, particularly those showing quantitative inheritance, interact with the environment in which the variety is grown and thus make the process of variety identification subjective. The main disadvantages of this method are time consuming, laborious and demanding more space. Besides, certain characters are influenced by the environmental factors and also require the collection of extensive data at different locations. The environmental effects mask the phenotype, so the phenotype provides an imperfect measure of a plant genetic potential. These limitations of conventional GOT demands a new technique which shall be environmental independent, quick and reliable ones. The alternative way to overcome this limitation and to speed up the testing procedures is to use chemical, biochemical and DNA markers in addition to morphological markers.

Chemical tests

The chemical tests are on spot tests and useful in identification by change in seed colour as well as solution due to added chemicals. Simple chemical tests *viz.*, phenol test, peroxidase test, NaOH, KOH test, seedling response to various chemicals have been proved quite useful in detecting varietal mixtures and grouping of large number of genotypes into distinct classes.

Biotechnological tools: biochemical and molecular markers

Biochemical markers

Electrophoresis of total proteins was found to be extremely useful technique for distinguishing genotypes as noticed by several workers (Anderson and Mc Daniel, 1979; Bonfitto*et al.*, 1999 and Basu*et al.*, 2002). The analysis of protein composition for plant variety identification is now well established (Cooke, 1984; Wrighley*et al.*, 1982). The success of electrophoretic procedure depends on the wide ranging polymorphism of seed and seedling proteins. During the last decade, use of electrophoresis of proteins and isozymes in seed purity

testing has been recommended by International Seed Testing Association (Anon., 1996a) and possibility of usage of molecular markers is underway. The use of proteins as genetic markers has been accepted as reliable tool, since proteins are the direct products of a gene and any change in the phenotype due to the effect of environment is not accounted in this method. The separation of seed proteins is based on the net charge and the molecular size of a protein in a charged electric field. The criteria for identification of a variety are based on presence or absence of a band, position and its intensity. Electrophoresis of seed storage proteins show promising results in genetic purity determination of cultivars and hybrids.

Molecular markers

Molecular markers is a powerful PCR based technique which is very fast reliable and require minimal amount of tissue for investigation (Rana *et al.*, 2006). This is a new approach to test the genetic purity of the seeds done at nucleotide level. This test screen through whole genome and produces enough polymorphism in closely related parental lines also. The DNA markers have several advantages over morphological traits, which are the resultant of genotype and environmental interactions, while, DNA markers are resultant of only genotype of the cultivar and are independent of environmental interactions. With the choice of techniques, proper sampling procedures and judicious interpretation, these laboratory methods can provide reliable and accurate results for varietal identification and assessing genetic purity in a considerably short period of time (Silvanacristae*et al*., 2005).

Types of Molecular Markers

Molecular markers can be classified into different groups based on:

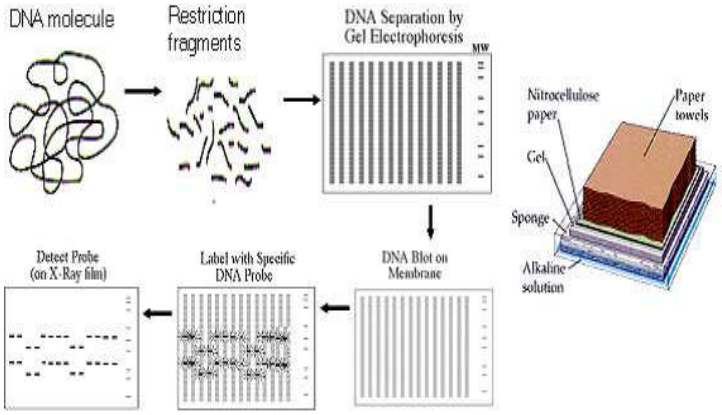
a) Mode of transmission (bi-parental nuclear/ maternal nuclear/ maternal organelle/ paternal organelle inheritance).
b) Mode of gene action (dominant or co-dominant markers).
c) Method of analysis (hybridization-based or PCR based markers).

In recent years, different marker systems such as Restriction Fragment Length Polymorphisms (RFLPs), Random Amplified Polymorphic DNAs (RAPDs), Sequence Tagged Sites (STS), Amplified Fragment Length Polymorphisms (AFLPs), Simple Sequence Repeats (SSRs) or microsatellites, Single Nucleotide Polymorphisms (SNPs), allele specific associated primers, allele specific oligo (ASO), allele specific polymerase chain reaction (AS-PCR), anchored microsatellite primed PCR (AMP-PCR), anchored simple sequence repeats (ASSR), arbitrarily primed polymerase chain reaction (AP-PCR), cleaved amplified polymorphic sequence (CAPS), degenerate oligonucleotide primed PCR (DOP-PCR), diversity arrays technology (DArT), DNA amplification fingerprinting (DAF), expressed sequence tags (EST), inter-simple sequence repeat (ISSR), inverse PCR (IPCR), inverse sequence-tagged repeats (ISTR), microsatellite primed PCR (MP-PCR), multiplexed allele-specific diagnostic assay (MASDA), random amplified microsatellite polymorphisms (RAMP), random amplified microsatellites (RAM), selective amplification of microsatellite polymorphic loci (SAMPL), sequence characterized amplified regions (SCAR;), sequence specific amplification polymorphisms (S-SAP), sequence tagged microsatelite site (STMS), sequence tagged site (STS), short tandem repeats (STR), simple sequence length polymorphism (SSLP), simple sequence repeats (SSR), single nucleotide polymorphism (SNP), single primer amplification reactions (SPAR), single stranded conformational polymorphism (SSCP), site-selected insertion PCR (SSI),

strand displacement amplification (SDA), and variable number tandem repeat (VNTR) and others have been developed and applied.

Hybridization-based molecular markers

Restriction Fragment Length Polymorphisms (RFLP)



RFLP is the first generation molecular markers most widely used hybridization-based molecular marker. The technique is based on restriction enzymes that reveal a pattern difference between DNA fragment sizes in individual organisms. Although two individuals of the same species have almost identical genomes, they will always differ at a few nucleotides due to one or more of the following causes: point mutation, insertion/deletion, translocation, inversion and duplication. Some of the differences in DNA sequences at the restriction sites can result in the gain, loss, or relocation of a restriction site. Hence, digestion of DNA with restriction enzymes results in fragments whose number and size can vary among individuals, populations, and species. The steps involved are a) Digestion of the DNA with one or more restriction enzyme(s). b) Separation of the restriction fragments in agarose gel. c) Transfer of separated fragments from agarose gel to a filter by Southern blotting. d) Detection of individual fragments by nucleic acid hybridization with a labeled probe(s) e) Autoradiography. The major strength of RFLP markers are high reproducibility, co-dominant inheritance, good transferability between laboratories, no prior sequence information required and relatively easy to score due to large size difference between fragments. However, several limitations for RFLP analysis are it requires the presence of high quantity and quality of DNA, it depends on the development of specific probe libraries for the species, the technique is not amenable for automation, the level of polymorphism is low, it is time consuming, laborious, expensive and it usually requires radioactively labeled probes.

PCR-based markers

PCR machine based markers are second generation markers that much more advanced to rectify almost all the flaw's of first generation marker The major advantages of PCR techniques compared to hybridization-based methods include: A small amount of DNA is required, elimination of radioisotopes in most techniques, the ability to amplify DNA sequences from preserved tissues, accessibility of methodology for small labs in terms of equipment, facilities, and cost, no prior sequence knowledge is required for many applications, such as AP-PCR, RAPD, DAF, AFLP and ISSR, High polymorphism that enables to generate many genetic

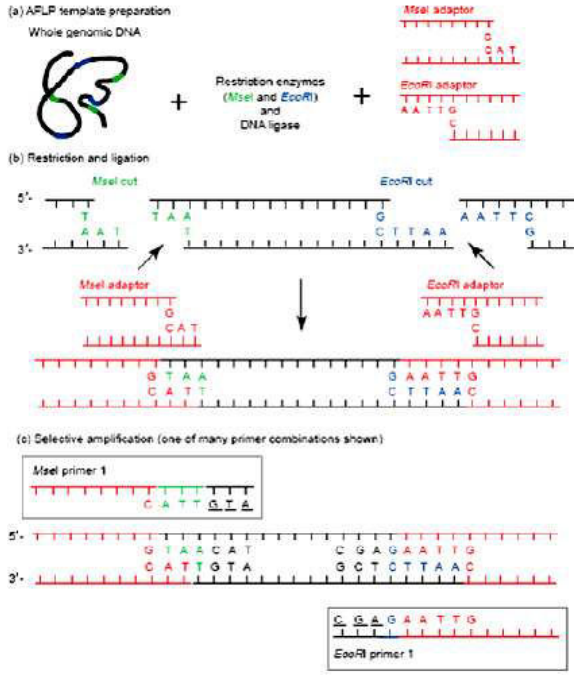
markers within a short time, and the ability to screen many genes simultaneously either for direct collection of data or as a feasibility study prior to nucleotide sequencing efforts. The various PCR-based techniques are of two types depending on the primers used for amplification

- Arbitrary or semi-arbitrary primed PCR techniques that developed without prior sequence information (e.g., AP-PCR, DAF, RAPD, AFLP, ISSR).
- Site-targeted PCR techniques that developed from known DNA sequences (e.g., EST, CAPS, SSR, SCAR, STS).

Arbitrarily Amplified DNA Markers RAPD (random amplified polymorphic DNA), AP-PCR (arbitrarily primed PCR) and DAF (DNA amplification fingerprinting) have been collectively termed multiple arbitrary amplicon profiling (MAAP). These three techniques were the first to amplify DNA fragments from any species without prior sequences information. The difference among MAAP techniques include modifications in amplification profiles by changing primer sequence and length, annealing temperature, the number of PCR cycles, the thermostable DNA polymerase used, enzymatic digestion of template DNA or amplification products, and alternative methods of fragment separation and staining. The RAPD protocol usually uses a 10 bp arbitrary primer at constant low annealing temperature (generally 3 –37ºC). RAPD primers can be purchased from different sources, such as the University of British Colombia (http://www.michaelsmith.ubc.ca/services/ NAPS/Primer_Sets) and the Operon Biotechnologies (http://www.operon.com). RAPD has two major limitations includes low reproducibility and dominant inheritance

Microsatellites

The genomes of higher organisms contain tree types of multiple copies of simple repetitive DNA sequences (satellite DNAs, minisatellites, and microsatellites) arranged in arrays of vastly differing size, also known as simple sequence repeats (SSRs), short tandem repeats (STRs) or simple sequence length polymorphisms (SSLPs), are the smallest class of simple repetitive DNA sequences. SSR allelic differences are the results of variable numbers of repeat units within the microsatellite structure. The repeated sequence is often simple, consisting of two, three or four nucleotides (di-, tri-, and tetranucleotide repeats, respectively). One common example of a microsatellite is a dinucleotide repeat (CA)n, where n refers to the total number of repeats that ranges between 10 and 100. These markers often present high levels of inter- and intra-specific polymorphism. PCR reactions for SSRs is run in the presence of forward and reverse primers that anneal at the 5` and 3` ends of the template DNA, respectively. PCR fragments are usually separated on polyacrylamide gels in combination with AgNO3 staining, autoradiography or fluorescent detection systems. Agarose gels (usually 3%) with EtBr can also be used when differences in allele size among samples is larger than 10 bp. SSRs are now the marker of choice in most areas of molecular genetics as they are highly polymorphic even between closely related lines, require low amount of DNA, can be easily automated for high throughput screening, can be exchanged between laboratories, co-dominance and are highly transferable between populations. High developmental cost is the major drawback of this marker. However, EST based SSR markers are still hope for the best.



Amplified Fragment Length Polymorphism (AFLP)

AFLP technique combines the power of RFLP with the flexibility of PCR-based technology by ligating primer recognition sequences (adaptors) to the restricted DNA. AFLP markers can be generated for DNA of any organism without initial investment in primer/probe development and sequence analysis. Both good quality and partially degraded DNA can be used for digestion but the DNA should be free of restriction enzyme and PCR inhibitors. The first step in AFLP analysis involves restriction digestion of genomic DNA (about 500 ng) with a combination of rare cutter (EcoRI or PstI) and frequent cutter (MseI or TaqI) restriction enzymes. Double-stranded oligonucleotide adaptors are then designed in such a way that the initial restriction site is not restored after ligation.

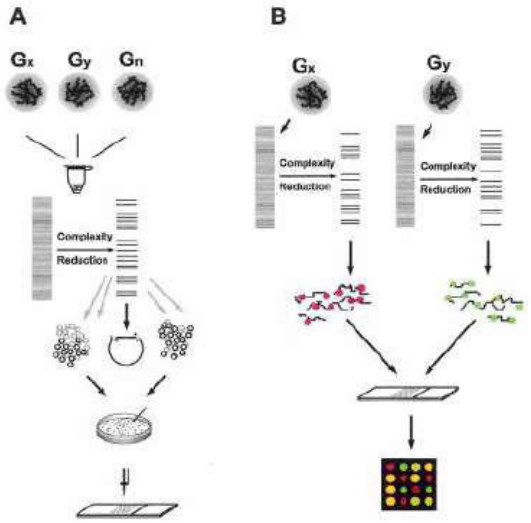
Such adaptors are ligated to both ends of the fragments to provide known sequences for PCR amplification. PCR amplification will only occur where the primers are able to anneal to fragments which have the adaptor sequence plus the complementary base pairs to the additional nucleotides called selective nucleotides. An aliquot is then subjected to two subsequent PCR amplifications under highly stringent conditions with primers complementary to the adaptors, and possessing 3` selective nucleotides of 1 – 3 bases. The first PCR (pre-amplification) is performed with primer combinations containing a single bp extension while final (selective) amplification is performed using primer pairs with up to 3-bp extension. AFLP analysis is not as easy to perform as RAPDs, but is more efficient than using RFLPs. The advantages of AFLP include it is highly reliable and reproducible, it does not require any DNA sequence information from the organism under study and it is information-rich due to its ability to analyze a number of polymorphic loci simultaneously (effective multiplex ratio) with a single primer. In contrast to RAPD, the limitations of AFLP include it requires more number of steps to produce the result, it requires template DNA free of inhibitor compounds that interferes with the restriction enzyme, the technique requires the use of polyacrylamide gel in combination with AgNO3 staining, radioactivity, or fluorescent methods of detection, which will be more expensive and laborious than agarose gels, it involves additional cost to purchase both

restriction and ligation enzymes as well as adapters and as like RAPD, most AFLP loci are dominant, which does not differentiate dominant homozygotes from heterozygotes.

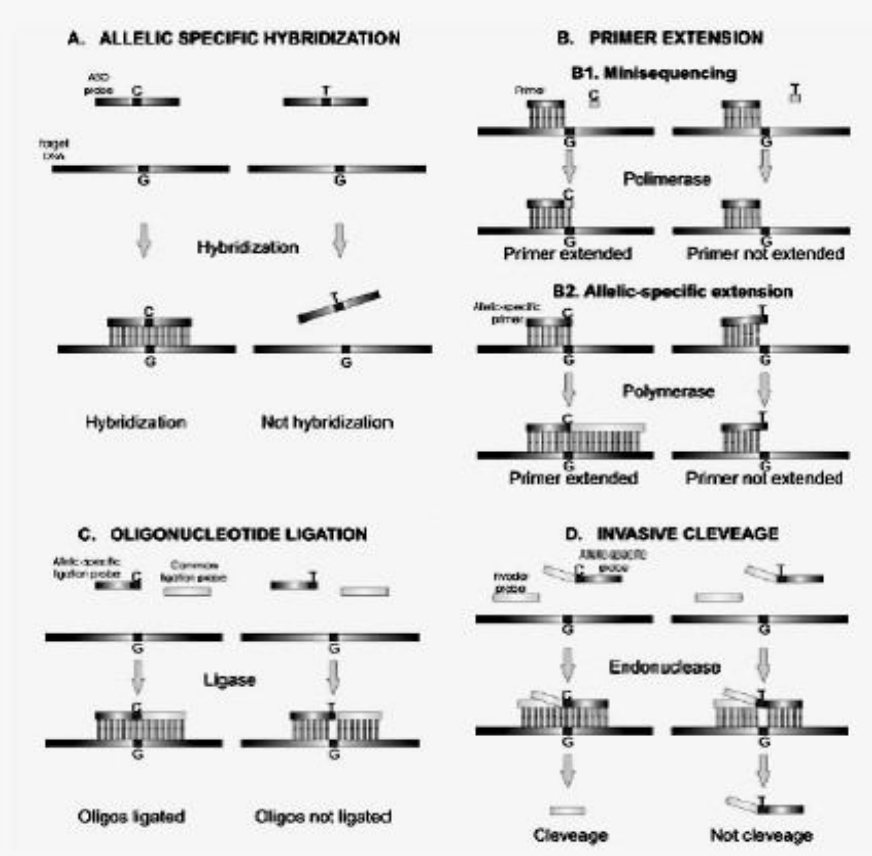
Single Nucleotide Polymorphism (SNP)

Among the third generation markers, single nucleotide polymorphisms (SNPs) and DArT (diversity arrays technology) are the technology recently available for the detection studies. A SNP marker is just a single base change in a DNA sequence, with a usual alternative of two possible nucleotides at a given position. Over the past years, a large number of different SNP genotyping methods and chemistries have been developed based on various methods of allelic discrimination and detection platforms. All methods for SNP genotyping combine two elements: first, the generation of an allele-specific product, and second the analysis thereof. There are two SNP detection methods available, 1) Direct hybridization techniques, 2) Those techniques that involve the generation and separation of an allele-specific product (restriction enzyme cutting, single strand DNA conformation and hetero-duplexes, primer extension, oligonucleotide ligation assay, pyrosequencing, exonuclease detection or Taq-Man, invasive cleavage of oligonucleotide probes or invader assay). Sobrino et al. (2005) assigned the majority of SNP genotyping assays to one of four groups based on molecular mechanism: allele specific hybridization, primer extension, oligonucleotide ligation and invasive cleavage. A large number of different SNP typing protocols are available for researchers, and there is no single protocol that meets all research needs. Different aspects should be taken into account to determine the best suitable technology in terms of sensitivity, reproducibility, accuracy, capability of multiplexing for high throughput analysis, cost effectiveness in terms of initial investment for equipment and cost per data-point, flexibility of the technology for uses other than SNP discovery, and time-consumption for analysis. It is difficult to predict if one technique will emerge in the future as a standard, especially since the needs will vary quite a lot between the academic laboratory performing medium-scale studies and commercial companies or genome centers aiming at very high throughput. The selection of technique is also dictated by the type of project envisaged, since it is quite different to perform genotypes with a limited number of SNPs on very large population samples, or a large number of SNPs on a limited number of individuals.

Diversity Arrays Technology (DArT)



DArT is a microarray hybridization-based technique that enables the simultaneous typing of several hundred polymorphic loci spread over the genome. For each individual DNA sample, genomic representations are prepared by restriction enzyme (e.g., PstI and TaqI) digestion of genomic DNA followed by ligation of restriction fragments to adapters. The genome complexity is then reduced by PCR using primers with complementary sequences to the adapter and selective overhangs. The fragments from representations are cloned, and cloned inserts are amplified using vector-specific primers, purified and arrayed onto a solid support (microarray) resulting in a "discovery array." Labeled genomic representations prepared from the individual genomes included in the pool are hybridized to the discovery array. Polymorphic clones (DArT markers) show variable hybridization signal intensities for different individuals. These clones are subsequently assembled into a "genotyping array" for routine genotyping.



DArT technique has a number of advantages they are, it does not need prior sequence information for the species to be studied- this makes the method applicable to all species regardless of how much DNA sequence information is available for that species, it is a high throughput, quick, and highly reproducible method, it is cost effective, with an estimated cost per data point tenfold lower than SSR markers, the genetic scope of analysis is defined by the user and easily expandable and it is not covered by exclusive patent rights, but on the contrary open-source. This technique do have own limitations like, it involved several steps, including preparation of genomic representation for the target species, cloning, and data management and analysis, it requires dedicated software's such as DArTsoft and DArTdb, the establishment of DArT system, therefore, is highly likely to demand an extensive investment both in laboratory facility and skilled manpower, DArT markers are primarily dominant (present or absent) or differences in intensity, which limits its value in some applications.

Comparison among the different molecular markers

	Isozyme	RFLP	RAPD	AFLP	SSR	SNP
Abundance	Low	Medium	Very high	Very high	High	Very high
Types of polymorphism	Amino acid change in polypeptide	Single base change, insertion, deletion, inversion	Single base change, insertion, deletion, inversion	Single base change, insertion, deletion, inversion	Repeat length variation	Single base change
DNA quality	-	High	Medium	High	Medium	Medium
DNA sequence information	-	Not required	Not required	Not required	Required	Required
Level of polymorphism	Low	Medium	High	High	High	High
Inheritance	Co-dominance	Co-dominance	Dominance	Dominance	Co-dominance	Co-dominance
Reproducibility	Medium	High	Low	Medium	High	High
Technical complexity	Medium	High	Low	Medium	Low	Medium
Developmental cost	Medium	High	Low	Low	High in start	High
Species Transferribility	High	Medium	High	High	Medium	Low
Automation	Low	Low	Medium	Medium	High	High

A number of factors need to be considered in choosing one or more of the various molecular marker types and compared herewith,

a) Marker system availability.
b) Simplicity of the technique and time availability.
c) Anticipated level of polymorphism in the population.
d) Quantity and quality of DNA available.
e) Transferability between laboratories, populations, pedigrees and species.
f) The size and structure of the population to be studied
g) Availability of adequate skills and equipment
h) Cost per data-point and availability of sufficient funding.
i) Marker inheritance (dominant versus codominant) and the type of genetic information sought in the population

Genetic purity of F_1 hybrid seeds using molecular markers

Molecular genetic techniques have been applied to plant cultivar identification in the past decade by developing molecular markers that detect differences in DNA sequences between cultivars. Highly specific marker profiles commonly known as DNA fingerprinting can be developed for each cultivar and used for its identification. Identifying breeding lines and determining hybrid purity are major requirements in plant breeding and quality seed production. To test the conformity of hybrid seed, one must be able to distinguish the true hybrid resulting from cross between the male and female parents and one coming from self-pollination of the female parent. Finger printing of parental lines, hybrid and off-types could be used as a data base to identify off-types in questionable seed lots.

Generally, F1 hybrid seeds in most of the crops are produced using established male-sterile systems. However, hybrid seeds are often contaminated with seeds from selfing of female parents or outcrossing with other cultivars because of weakening of self-incompatibility or restoration of pollen fertility in male-sterile lines (Crockett et al., 2000). Low genetic purity would cause seed suppliers a great loss from the planters' claim and could make it easy for a competitor to steal the inbred parent of a hybrid. Therefore, it is critical for seed suppliers to control seed genetic purity before marketing.

Higher genetic purity is an essential prerequisite for the commercialization of any hybrid. Besides, success of any hybrid seed technology depends on the availability of quality

seed supplied in time at reasonable cost. The genetic purity during multiplication stages is prone to contaminate due to the presence of out crossing with foreign pollens besides physical admixtures. Thus use of seeds with low genetic purity results in segregation of the traits, lower yields and genetic deterioration of varieties. Therefore, maintenance of parental line purity is a prerequisite to ensure high genetic purity of hybrid seeds. Conventional GOT requires one full season thus excluding the immediate cultivation of the hybrid seed produced. In addition, expenditure incurred on storage, ultimately increases the hybrid seed cost.

Furthermore, morphological differences between true and false hybrids are not always apparent and cannot be recognized easily, especially when parents are genetically similar, causing potential inaccuracy. Isozyme analysis has also been used in purity testing. However, this method may be limited by environmental conditions and tissue type and may require selection of a suitable isozyme. Because F1 hybrids contain DNA from both parents, identification of male and female parent-specific markers will allow differentiation of true hybrids from selfed parental lines and outcrossed lines. Molecular markers, such as RAPD, ISSR, SSR, SRAP, AFLP (amplified fragment length polymorphism), and RFLP (restriction fragment length polymorphism) have been used in hybrid seed purity testing in many species. Unlike radioactive chemicals involved RFLP and patent-protected AFLP, several other molecular markers, including RAPD, ISSR, SRAP, and SSR, could be effectively used for hybrid seed genetic purity testing and variety identification in many species.

Although male or female parent-specific markers can be used to screen hybrid seeds, codominant markers are always preferred for assessment of hybrid seed purity. It is suggested that a single codominant marker is sufficient to distinguish false hybrids from real hybrids. However, residual heterozygosity, detected only at the molecular level, occurs inevitably in many inbred lines; therefore, it is questionable to determine hybrid purity only using a single marker. The various researchers opined that RAPD, ISSR, SRAP, and SSR markers are fast and effective, and results are generally consistent with morphological analyses in field plots. Despite the added cost, use of multiple marker systems could result in more accurate and reliable assessment of hybrid seed purity. Combination of effective markers would be a good option for establishment of a seed quality control system to be applied for seed purity testing in commercial seed production. Molecular markers utilized for hybrid identification/genetic purity testing or assessment of genetic diversity in various crops *viz.*, maize, wheat, rice, cotton, cabbage, muskmelon, sugarcane hybrids. In this contest, conducting a national training on varietal purity testing through conventional and biotechnological tools is an imperative vogue for training personals involved in seed production and certification.

Imaging technologies for genetic purity testing

Discrimination among seed varieties and checking the seed purity plays a key great role in plant breeding programs, seed production, genebank management and in the general trading of seeds. Testing seed purity involves checking the presence of plant debris, foreign materials, weed seeds, contaminating species and broken and damaged seeds. Separating varieties and determining their critical properties in terms of distinctness, uniformity and stability standards are extremely significant for variety registration, intellectual property rights of plant breeders, as well as for developing new varieties in the markets. Measurements of some essential morphological features are very vital in varietal identification and cultivars discrimination to highlight the phenotypic variations, but in some occasions these features may be not enough to act as discriminators among such cultivars. For instance, molecular markers and other biochemical methods are usually used for the identification and characterization of germplasm.

The traditional method currently used in international genebanks is usually done by visual inspection of a huge number of seed varieties to evaluate their phenotype features and to determine whether such varieties are completely new or have already been registered in the genebank. As these procedures are very time consuming and require highly skilled seed analysts, the development of a non-invasive, rapid and reliable technique for identifying and distinguishing the purity of verities is of boundless advantages.

Recent studies have demonstrated the ability of multispectral imaging in tandem with multivariate analyses for evaluating seed purity and varietal discrimination. The potential of using this technology in identifying and characterizing seed variety on the basis of differences in spectral signature and the ordinary morphological features was investigated. By using illumination-based multispectral imaging system in the visible and near infrared region (375–970 nm) for varietal identification and discrimination tomato seeds, Shrestha et al. examined eleven varieties either all together or in a pairwise manner with their offspring using their spectral fingerprints by the aid of multivariate analysis of normalized canonical discriminant analysis (nCDA), principal component analysis (PCA) and partial least square discriminant analysis (PLS-DA). The nCDA model was used to minimize the distance within classes and to maximize the distance between classes. The developed models displayed overall classification accuracy of 100%, 85% and 82%, respectively. In reality, the nCDA method was employed as a supervised transformation building method to divide the image into regions of interest of different spectral signatures. When two different varieties have different spectral features, they will be appeared as two different region of interest in nCDA transformed image which will be easy to interpret and simple to segment for subsequent data analysis. When Olesen et al.tried support vector machine discriminant analysis (SVM-DA) in discriminating tomato seeds of different cultivars, they achieved 100% discrimination accuracy. The same Shrestha et al. research group used the same methodology in discriminating among tomato seeds of different maturity stages by following the same normalized canonical discriminant analysis (nCDA) algorithm. The data analysis showed a higher classification accuracy of tomato seed maturity measured by their germination potential. The result also suggests that seed maturity determination should be based on seeds instead of judging by fruit maturity or colour.

With the same technique, Hansen et al. collected both reflectance and fluorescence emission spectra by installing low-bass filters at 500, 600 and 700 nm in front of the CCD camera to discriminate twenty diverse varieties of rice. In total, each pixel contains 46 spectral values representing all possible chemical characteristics of the examined seeds. After segmenting multispectral imaging to locate rice seeds in a clear background, a set of 177 morphological and spectral features extracted from each single seed was modelled using canonical discriminant analysis (CDA) projections and k-nearest neighbour (k-NN) classifier to discriminate and enhance differences among rice seed varieties The results revealed that the proposed method was able to identify potential off-types within the seed lots of each accession with an accuracy of 93%., which may indeed be useful in managing genebank accessions by including only new accession and avoiding maintaining seeds that does not represent novel genetic diversity. For differentiation of wheat varieties and triticale varieties, Vrešak et al. used a VideometerLab multispectral imaging system with 19 bands (375–950 nm) for acquiring multispectral images of seed samples and then extracted both morphological features (e.g., colour, texture and major dimensions) as well as features from nCDA transformation images. Based on all extracted features, a k-nearest neighbour (k-NN) based model was built to discriminate different wheat varieties. The overall results on varieties separation using the proposed method revealed that Agostino variety was classified with accuracy of 97.4%and the overall classification accuracy for

the rest of varieties was below 67%. They reported that, discrimination accuracy could be greatly improved up to 95.8% in case of grouping varieties together according to visual similarity.

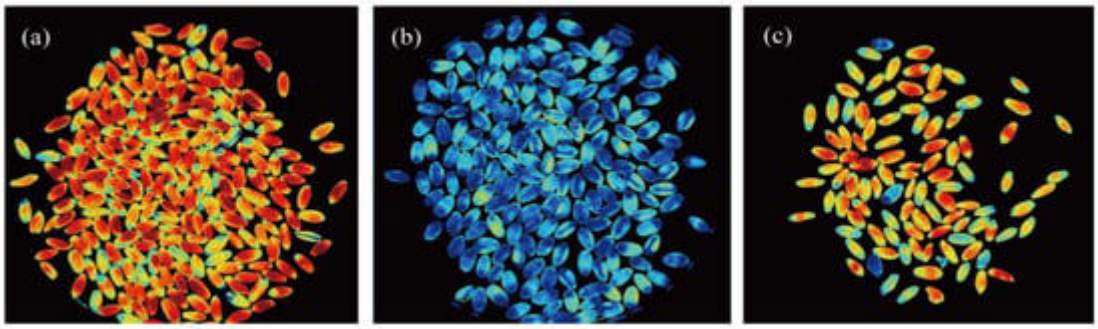
The feasibility of using LED illumination-based multispectral imaging (405–970 nm) associated with chemo metric data analysis was examined by Liu et al. for non-destructive discrimination of transgenic and non-transgenic rice seeds. Different chemo metric data analysis methods such as principal component analysis (PCA), partial least squares discriminant analysis (PLS-DA), least squares-support vector machines (LS-SVM), and PCA-back propagation neural network (PCA-BPNN) was tested to see their performance in classifying rice seeds according to their genetic origins. The results revealed that LS-SVM model method exhibited the highest classification accuracy (100%) in distinguishing insect-resistant Bacillus thuringiensis transgenic rice seeds from non-transgenic ones. In another study, the same authors followed the same routines in discrimination between conventional and glyphosate-resistant transgenic soybean seeds and their hybrid descendants by using the same multispectral system. Similarly, the results from this study attested the capability of the multispectral imaging supported by BPNN model in differentiation among conventional and glyphosate-resistant soybean seeds and their hybrid descendants with an excellent classification of 98%. In both studies, combining spectral data of the seeds with their corresponding morphological features extracted from their multispectral images (L*, a*, b* colour values, area, length, width and roundness) produced better predictive accuracies and helped in improving the discrimination for all examined multivariate analysis algorithms.

Because the sorting process of seeds based on certain genetic features is a very time-consuming process that can take thousands of hours of labour to complete for a single average-sized breeding programmer, De La Fuente et al. evaluated the ability of the VideometerLab3 multispectral imaging system to discriminate haploid from diploid maize seeds, testing the system on several maize genotypes that display varying difficulty in manual sorting. In addition to the 19 illuminated wavelength bands used for recording reflectance images, four band-pass filters at 400, 500, 600 and 700 nm were used for measuring fluorescence from the kernel surface producing a total of additional 60 excitation/emission combinations of fluorescence. The canonical discriminant analysis (CDA) method was used for segmenting the kernels form the background and to extract the main reflectance and fluorescence data either from the whole kernel or from embryo portions. The system has shown a great ability in discrimination between hybrids and haploids with accuracies ranging from 40% to 100% for different six genotypes.

While hyperspectral imaging systems with relevant multivariate analyses are able to identify kernel damage, multispectral systems are much simpler and less expensive. In this regard, Shahin et al. analyzed the hyperspectral data to select the most relevant wavelengths suitable for detecting green barely kernels. They then developed a multispectral imaging system with a single monochromatic camera and a high-speed filter wheel supported with three different band-pass filter centered at wavelengths of 580, 671 and 730 nm as nominated by the hyperspectral data analysis. The study indicated that the band ratio of 671/730 nm was very effective in scoring the greenness of barely kernels. Through experimentation, a threshold ratio of 671/730 = 75% helped in marking the transition to green kernels that related to the detection level by visual inspection; meaning that kernels having a band ratio less than 75% were considered green. Indeed, this is the first study that designed and developed a fully-functional multispectral imaging system using wavelengths resulting from the analysis of hyperspectral images of seed samples. In another study, Sumrid detchkajorn et al. used a multispectral

imaging system supported by simple image processing techniques for the identification of eight different breeds of rice. Under an ultraviolet excitation light at 265 nm (UVC), only two fluorescent wavelength bands at 540 nm and 575 nm selected by a liquid crystal tunable optical filter were used during image acquisition and simple image thresholding, blob filtering and blob analysis techniques were used for milled rice breed discrimination. The incident UVC light (at 265 nm) shining on milled rice grains was emitted with the corresponding fluorescent radiation and then received through the imaging lens. The tunable optical filter is electrically controlled in such a way that only the desired wavelength spectrum bands can get through to the 2-D digital camera with 45.1 ms switching time between them. The pixel fluorescence intensity at both images were then extracted for all rice breads and used as the basis of breed discrimination. The proposed method showed great potential in distinguishing rice breeds based on their amylose content. Furthermore, due to their action as germicidal light, UVC light used during rice breed identification can also kill unwanted germs attached to milled rice grains.

For manufacturing pasta, the current EU law permits up to 3% (w/w) adventitious contamination of durum wheat (T. durum) with other common wheat (T. aestivum), and any malpractice during manufacturing by adding a higher percentage is considered a kind of adulteration that should be instantly prohibited. In a study conducted for seed authentication, Wilkes et al. evaluated the applicability of multispectral imaging for the quantitation of durum wheat grain samples in relation to pasta authenticity by distinguishing between durum wheat T. durum and adulterant common wheat T. aestivum cultivars based on the spectral signature of each grain species. The performance of the system was evaluated on the basis of its ability to correctly assign the percentage of adulteration level (0, 0.5%, 2%, 3%, 5%, 10% and 100%) of the wheat test samples. Each grain was represented by thousands of pixels that can be scored based on their closeness to the spectral signature of T. aestivum or T. durum. The normalised-Canonical Discriminant Analysis model (nCDA) algorithm was then applied to calculate the likelihood of each grain being T. aestivum or T. durum based on composite spectral signature of the pixels within each grain. The resulting classification images, shown in demonstrate close agreement with the assigned percentage of adulteration values. The results of this study indicated the ability of the spectral imaging in testing seed/grain adulteration.



Images generated using nCDA algorithm for: (**a**) 100% T. durum wheat grains; (**b**) 100% T. aestivum wheat grains; (**c**) 10% adulteration of T. durum wheat grains with T. aestivum wheat grains.

Conclusion

The main challenges are now selecting one or more of these markers for varietal or hybrid genetic purity assessment. The desirable properties of molecular markers one should consider are high polymorphism, co-dominant inheritance, frequent occurrence and even distribution throughout the genome, selectively neutral behaviour, easy access, easy and fast

assay, low cost and high throughput, high reproducibility, and transferability between laboratories, populations and/or species. No molecular markers are available yet that fulfil all these requirements. However, according to the kind of study to be undertaken, one can choose among the variety of molecular marker systems, each of which combines at least some of these desirable properties. DArT is a recent technique and it remains to be thoroughly tested in various species. SCAR and STS markers would be developed by sequencing fragments associated with economically important traits and they are not available if one starts from scratch. SNPs seem very exciting markers but they require extensive investment in equipment and manpower. Hence, SNPs are highly unlikely to be taken up by the national agricultural systems and universities in developing countries. The use of EST and EST-based markers, such as EST-SSR, CAPS and ESTRFLP, are applicable only for species which have been extensively sequenced before. Therefore, SSR and ISSR are the only markers that could be used for a wide range of applications in plants including varietal purity testing. Recently, the potential of spectral imaging technique in providing rich and valuable information about seed quality traits and phenotyping parameters is powered from the robust integration among spatial imaging, spectroscopy and chemometrics tools that makes this technique an ideal tool in studying various morphological, physicochemical and physiological properties of seeds. This extraordinary capability has enticed researchers to exert cooperative efforts in developing fast, accurate and low-cost spectral systems to be installed in seed and grain industry. With the advantage of acquiring three-dimensional data across a wide range of the electromagnetic spectrum, state-of-the-art multispectral imaging along with relevant multivariate chemometric analysis has been successfully implemented, not only for food quality and safety control purposes but also in dealing with critical research challenges in seed science and technology. This paper provided an overview of the previous research activities employed for quality evaluation and safety analysis of different seed cultivars using morphological, biochemical, molecular and multispectral imaging techniques.

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Determination of Physical Purity of Seeds

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Despite all the care taken during the harvesting, cleaning grading etc, some unwanted seeds and other materials are always present in a seed lot. Thus, a seed lot comprises of desired seeds, unwanted weed or other crop seeds and other material which is not seed at all. Only desired seed is of value to the grower, therefore the grower needs to know the proportion of the lot actually consists of desired seed.

Purity test is the first test to made for ascertaining the physical composition of a seed lot. Seed sample can contain impurities i.e. Weed seeds, other crop seeds, broken / detached seed structures, soil particles, plant parts or other materials. The basic objective of physical purity analysis is to determine the composition of seed lot and to identify various kinds of seeds and inert materials present in the seed lot.

Principles :

In accomplishing purity analysis the each and every seed as well as particle in the seed sample is examined and separated into the following components:

Pure seed:

It is the portion of the working sample represented by the crop species for which the lot is subjected for testing. No attempt is made to separate the varieties of the same species. Immature, shriveled, frosted or other damaged seeds are considered as a pure seed provided they can be definitely identified as of that species. Intact seed units as defined for each genus or species and pieces of seed units larger than one half of their original size are also categorized as pure seed (ISTA,2004).Pure seeds may include the followings;

i. Intact seeds.
ii. Pieces of seeds, achenes, mericarp and caryopsis resulting from breakage that is more than half of the original size (Half Seed Rule). However, seeds of legumes, crucifers and conifers are considered as inert matter if their seed coat is removed.
iii. Achenes and similar fruits like caryopsis, schizocarp and mericarp with or without pedicel, perianth and whether they contain true seed unless it is apparent and when difficult to identify.
iv. Florets and caryopsis of gramineae.
v. Clusters of beta or pieces of such clusters with or without seeds that are retained by 200X 300 mm sieve.
vi. Free caryopsis
vii. Florets and one flowered spikelets with an obvious caryopsis containing endosperm, provided that the caryopsis of the particular genera and species has attained minimum size.

Weed and Other crop seed:

These seeds belong to weeds and crop seeds other than pure seed. Mostly other seeds can be readily identified but, as with pure seed, there may be species which are so similar in appearance that the precise identification is impossible. It is then sufficient to identify the genus

only. Some weed seeds whose plants are particularly troublesome and objectionable are classified as noxious weed seeds. Examination of noxious weed seed is an attempt to provide special information about noxious weed seed content in the seed lots.

Inert Matter:

Inert material refers to the portion of sample that is not seed, it consists of crop plant parts, chaff, pieces of broken (half or less than half)damaged or immature crop or weed seeds that do not qualified as entire seed and fungal fruiting bodies, nematode galls, small stones, soil particles etc.

Seeds or pieces of seed of species belonging to families Leguminaceae and Cruciferae from which the seed coat is entirely removed, seeds which have been transformed in to eelworm galls or fungal fruiting bodies i.e. smut balls, ergot and sclerotia, caryopsis of Gramineae replaced by insect larva, seeds which are botanically fruits in which it is easily seen that no true seed is present, the appendage not classed as being part of pure seed are classified in inert matter (ISTA,2008)

Procedure of for Testing of Physical Purity of Seed Sample:

In order to carry out the physical purity test the following small tools are required:

1. L shaped purity working table
2. Physical purity work board with illuminating light.
3. Wide field hand-lens or magnifying glass of 10 X magnification
4. Stereoscopic Microscope
5. Spatula
6. A firm pair of forceps
7. Analytical Balance with precision 0.1 mg
8. Precision Balance with capacity of 1000 g and accuracy of 10 mg
9. Sieves and Sample pan
10. Seed blowers and Seed dividers
11. Small screw cap containers to hold separated Seed and other matter

This test is done on working sample taken from submitted sample except for the species of *Poaceae* for which the uniform blowing method is to be used. Generally a purity working sample is a weight to contain 2500-3000 seeds approximately subject to a minimum of 0.5 g and maximum of 1000 g or otherwise not less than the weight prescribed in ISTA Testing Rules 2004.

The analysis is done on one working sample or on two sub-samples of at least half of of the weight, each drawn independently from the submitted sample. Prior to analysis the submitted sample is thoroughly mixed three times with the help of mechanical seed dividers. Then, the correct size of working sample is obtained from the submitted sample by repeated halving or by abreacting and subsequently combining small portions. In any case, the working sample must not be altered by adding or removing seed by hand.

In case the submitted sample contains very large quantity of extraneous matter, then the preliminary separation of small inert matter like chaff, dirt and other light matter would be removed by using seed blower and screen.

Analysis should be done on the clean surface of a purity working board mounted on a "L" Shaped purity work table. Each and every seed and inert matter of the working sample is

examined. The sample is separated into four components i.e pure seed, weed seed, other crop seeds and inert matter.

Sometimes the purity separations are also made by taking the advantage of Seed shape. The round seeds can be separated from the flat seeds and chaff by allowing the seeds to fall down on a slightly inclined surface.

The total weight of all the component fractions from the working sample must be compared with the original weight and checked against loss or gain. If there is discrepancy of more than 5% of initial weight, a retest must be made. If the sum does not equal 100% (either 99.9 or 100.1) then add or subtract 0.1% from the largest value (normally the pure seed fraction).

The number of decimal places necessary for weighing, in order to calculate percentages are as follows:

Working sample weight 1000g or more: weigh to 0 decimal places
Working sample weight 100g to 99.9 g : weigh to 1 decimal places
Working sample weight 10g to 9.99 g : weigh to 2 decimal places
Working sample weight 1g to 0.999 g : weigh to 3 decimal places
Working sample weight less than 1g : weigh to 4 decimal places

The results are reported as percentages by weight to one decimal place. So the percentage to at least two decimal places, are calculated. If the second decimal place is 5 or more, it is rounded off upwards. If the actual percentage is less than 0.05 percent, the result is reported as **trace** (Bould & Smith, 1981).

Purity analysis or Physical purity of a seed lot determines the crop plant population per unit area and contamination at field level population e.g. a trace of wild oat found in 125 g cereal purity test could resulting sowing seed containing up to about 150 wild oat seed per acre. Similarly one wild oat seed found in the examination of 500 g sample of cereal seed would be equivalent to about 70 wild oat seeds per acre. This indicates seriousness of the contaminant (Bould & Smith, 1981). Further, presence of contaminants becomes more important where seed lot may have chances to become a source of serious weeds or serious disease organisms i.e. Sclerotia, ergot or other crop species which ultimately reduces the value of the crop. In order to reduce seed concomitant contamination the maximum number of contaminants which may be tolerated in a sample of given size are prescribed.

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Germination Testing: Principles and Procedures

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The purpose of laboratory testing of seed germination is to assess seed quality or viability and to predict performance of the seed and seedling in the field. A Notified laboratory under SEEDS ACT or qualified laboratory of ISTA for testing seeds must test seed processed for sale. The ultimate aim of testing the germination in seed testing laboratory is to obtain information about the planting value of the seed sample and by inference the quality of the seed lot. In addition, the laboratory germination results are also required for comparing the performance potential or superiority of the different seed lots. In general, the farmers, seeds men and public agencies use the germination results for the following purposes:

1. Sowing purposes, with a view to decide the seed rate to achieve desired field establishment.
2. Labeling purposes.
3. Seed certification purposes.
4. Seed Act and Law Enforcement purposes.

In seed testing germination has been defined as "*the emergence and development from the seed embryo of the seeds, essential structures which, for the kind of seed tested indicate its ability to develop into a normal plant under favourable, conditions in soil*".

The seedlings devoid of an essential structure; showing weak or unbalanced development; decay or damage affecting the normal development of seedling are not considered in calculating the germination percentage. Factors that can affect the performance of seed in germination tests include; diseased seed, old seed, mechanically damaged seed, seed stored under high moisture, and excessive heating of seed during storage or drying. In most cases a seed treatment will improve germination of seed only if the poor quality is due to seed-borne disease. Several different kinds of testing are available depending on the type of seed to be tested, the conditions of the test, and the potential uses of the seed. The most common tests are the cold germination test, accelerated aging test, the tetrazolium test and warm germination test. Each test is designed to evaluate various qualities of the seed.

Germination testing

The most common test is a warm germination test because it is required by seed laws to appear on the label. The percentage of germinating seed in a warm germination test must be printed on the label of the seed if it is to be sold as seed. The warm germination test reflects the field emergence potential of a seed lot under ideal planting conditions. Usually 400 seed from each seed lot are placed under moist conditions on blotters, rolled towels, or sand and maintained at about 75 to 85 degrees F for about seven days in most of the cases. At the end of this period the seedlings are categorized as normal, abnormal, or diseased, and dead or hard seeds. The percentage germination is calculated from the number of normal seedlings from the total number of seeds evaluated. The method of testing germination is discussed below.

The first and foremost step is to draw a true representative sample from the seed lot. To obtain a random sample for testing it is always best to take samples from different parts of the bag or container. If the seed to be tested is from a seed lot that contains more than one bag, samples must be taken from several bags. A good rule of thumb for determining how many

bags to sample is to take samples from a number of bags that represents the square root of the lot size. For example if the lot contains nine bags, then sample at least three bags. If the lot contains 100 bags, then sample at least 10 bags. The sample thus drawn is further divided and the required numbers of seeds are the taken to perform the actual test.

Essential equipments and supplies for germination test

The following equipments and supplies are essential to carry forward the germination tests in the seed testing laboratories.

Seed germinator:

The seed germinators are the essential requirement for germination testing for maintaining the specific conditions of temperature, relative humidity and light. The seed germinators are generally of two types, namely: Cabinet germinator and walk in germinator. The cabinet seed germinators are essential under the situations, where various kinds of seeds that require different sets of conditions, are being handled in the laboratory. The number of the pieces of the germinators required by the laboratory will depend on the number of seed samples and the species being analysed by the laboratory. The seed testing laboratories that handle large number of seed samples and require maintaining only fewer (2-3) sets of temperature conditions, the walk-in-germinators are preferred. Such germinators are more useful for conducting the germination tests in sand media, which require large germination space.

Counting devices:

The counting devices include the counting boards, automatic seed counter and vacuum seed counter. These devices are required to aid germination testing by minimizing the time spent on planning the seeds as well as to provide proper spacing of the seed on germination substrata. Counting boards are suitable for medium and bold sized seeds, while vacuum counter can be, used for small sized seeds. In the absence of counting devices, the work may be accomplished manually.

Other equipments:

The other equipments required for germination testing include the refrigerators, scarifier, hot water bath, incubator, forceps, spatula, germination, boxes, plastic plates, roll-towel stands and plastic or surgical trays, etc. A large oven with temp. Range 100 -200 C is also required for sterilizing the sand.

Miscellaneous supplies, glassware and chemicals:

Germination paper (Creppe Kraft paper or towel paper, sunlit filter paper and blotters) and sand are the basic supplies required for germination tests. In addition, the laboratory may also require some glassware, such as Petri dishes, beakers, funnel, measuring cylinders, muslin cloth, rubber bands and tubes etc. and certain chemicals like Potassium nitrate, Thiourea, Gibrellic acid, and Tetrazolium chloride for specific purposes. Voltage stabilizers are required for the supply of the constant electric current. The voltage stabilizers are essential for costly germinators, air-conditioners and refrigerators. Under the situations of erratic power supplies and breakdowns, electricity generators are also required.

Care of equipments:

The seed analyst must ensure that:

1. All the equipments are in proper working condition
2. The germinators are maintaining correct temperature

3. The relative humidity inside the germinator is maintained 90--98%
4. The phytosanitary conditions of the germinators and germination trolleys are adequate
5. The germinators are disinfected periodically by flushing with hot water; solution of Potassium permanganate or chlorine water
6. The temperature and the R.H. of the walk-in-germinators are recorded daily and displayed on a chart
7. The floor, ceiling and walls of the walk-in-germinator are devoid of cracks, crevices;
8. Evenly plastered and duly painted to avoid contamination by fungus, bacteria or insects.

Handling of substrata:

The accuracy and reproducibility of the germination result are very much dependent on the quality of the substrata (paper and sand) used for germination testing. The germination substrata must meet the following basic requirements:

1. It should be non-toxic to the germinating seedlings.
2. It should be free from moulds and other microorganisms.
3. It should provide adequate, aeration and, moisture to the germinating seeds.
4. It should be easy to handle and use.
5. It should make good contrast for judging the seedlings
6. It should be less expensive.

Paper substrata:

The paper substrata are used in the form of top of paper (TP) or between paper (BP) tests. In most of the laboratories, paper-toweling method (Roll towel test) is most commonly used for medium sized and bold seeds. The paper substrata are not reusable.

Sand substrata*:*

The sand substrata have advantage of being relatively less expensive and reusable. The results in sand media are more accurate and reproducible in comparison with 'roll towel' tests especially in case of seed lots that are aged or heavily treated with chemicals. The sand should be reasonably uniform and free from very small and large particles. It should not contain toxic substances and its pH should be within the range of 6.0- 7.5. The sand should be washed, sterilized and graded with a sieve set having holes of 0.8 mm diameter (upper sieve) and 0.05 mm diameter (bottom sieve). The sand retained on the bottom sieve should only be used.

Testing of substrata

Phytotoxicity:

The substrata should be tested for its phytotoxicity, capillary rise, moisture holding capacity and bursting strength, etc., before accepting the supplies in the laboratory. Periodic checks of the quality of the substrata should also be made in the laboratory. By germinating the seeds of *Brassica*, Onion, Chillies or Berseem and studying the phytotoxic
Symptoms on the germinating seedlings can check the phytotoxicity of the paper or sand substrata.

1. The paper should be cut into circles and rectangles or squares of the desired size according to the size and shape of the containers.
2. Place 2-4 circles/rectangles of the paper to be tested in the petridishes or plastic containers.

3. Moisten the paper with tap water using only enough water to saturate the paper. Excess water should not be used.
4. Arrange 25 seeds of Brassica, Onion, Chillies or Berseem properly spread over the moist paper.
5. Cover the dishes with lids.
6. Conduct a control test as outlined above (step l-4) using paper of accepted quality such as 'Waterman' or 'Sunlit' brand filter paper.
7. Transfer the test to the prescribed temperature conditions of the species used at test crop.
8. Evaluate the test 1-2 days before the date of the first count of the crop specified
9. Check the phytotoxic symptoms on the seedlings.
10. Compare the seedlings with those grown on the non-toxic paper (control test).

The phytotoxic symptoms include shortened roots; discolored root tips; root raised from the paper; inhibition of root hairs development and root hairs bunched. The symptoms are more pronounced at an early stage of root growth. The phytotoxic symptoms are also evident in the plumular areas in the form of thickened or flattened plumules or, coleoptiles.
The phytotoxicity of the sand substrata can also be measured by the procedure outlined as above. However, care need to be exercised that the sand substrata should be moistened with the measured quantity of the water and the seeds are planted on the top of sand (TS). The pH of the substrata can be measured with the help of pH paper or pH meter as follow:

1. Soak the paper or sand in water for 16-18 hrs.
2. Decant the water.
3. Measure the pH with litmus paper or pH meter.

If the, sand substrata are found to be acidic or alkaline, wash it thoroughly with the water and sterilize before use.

Capillary rise:

The capillary rise in paper can be checked as follows*:*

1. Cut four strips of germination paper 10 mm wide; two in machine direction and the other two in cross machine direction.
2. Take distilled water in small glass beakers.
3. Immerse one end of each strip in the water to a depth of 20 mm.
4. Wait for 2 minutes and then measure the height to which water has risen in the strip to the nearest mm.
5. Commute the average for the two strips cut in machine direction or cross machine direction separately.
6. The lower value of the two averages should be considered as capillary rise.

Bursting strength:

The bursting strength of the paper is measured with equipment; however, it can be checked as follows:

1. Hold the two ends of the germination paper and exert the pressure by stretching the paper with mid force.
2. Soak the paper in water for 1-2 hours.
3. The paper of desired bursting strength would not tear off easily.

Test conditions

Moisture and aeration:

The moisture requirements of the seed will vary according to its kind. Large seeded species require more water than the small seeded species. It is essential that the substratum must be kept moist throughout the germination period. Care need to be taken that the substratum should not be, too moist. The excessive moisture will restrict the aeration and may cause the rotting of the seedlings or development of watery seedlings. Except the situations, where a high moisture level is recommended (e.g. Paddy and jute), the substratum should not be so wet that a film of water forms around the seeds. In situations where low level of moisture is recommended (e.g. Cucurbitaceous seeds), the moist substratum should be pressed against the Dry blotters or towel paper, to remove excess moisture. The water used for moistening the substratum must be free from organic and inorganic impurities. Normally the tap water is used. However, it is essential to measure the pH .of water before its use. The pH of the water should be in the range of 6.5- 7.5. Under the situations where pH of the water is not satisfactory, distilled water or de-ionized water may be used. Under such situation care need to be exercised to aerate the tests frequently to provide oxygen supply to the germinating seedlings because oxygen level in distilled water is very low.

The initial quantity of water to be added to the substratum will also depend on its nature and dimensions. Subsequent watering, if, any may be left to the discretion of the analyst but it should be avoided as far as possible because it may cause the variation in germination results. In order to reduce the need for additional watering during the germination period, the relative humidity of the air surrounding the seeds should be kept at 90-95 % to prevent loss of water by evaporation.

Special measures for aeration are not usually necessary in case of top of paper (TP) tests. However, in case of 'Roll towel' tests (BP) care should be taken that the rolls should be loose enough to allow the presence of sufficient air around the seeds. In case of sand media, the sand should not be compressed while covering the seeds.

Temperature:

The temperature is one of the most important and critical factors for the laboratory germination tests. The temperature requirement for germination is specific according to the kind of crop or species. This can vary within the species and with the age of seeds. At very low or high temperatures, the germination is prevented to a larger extent. The temperature should be uniform throughout the germinator and the germination period. The variation in temperature inside the germinator should not be more than 1°C. The prescribed temperature for germination of agricultural, vegetable or horticultural seeds, provided in the Rules for Seed Testing can be broadly is classified into two groups, viz. constant temperatures and alternate temperatures.

Constant temperature:

Wherever, the constant temperatures are prescribed or recommended for the germination tests, the tests must be held at the specific temperature during the entire germination period.

Alternate temperature:

Wherever, the alternating- temperatures are prescribed, the lower temperature should be maintained for 16 hours and the higher for 8 hours; a gradual changeover lasting 3 hours is

usually satisfactory for non-dormant seeds. However, a sharp change over lasting 1 hour or less, or transfer of test to another germinator at lower temperature, may be necessary for seeds, which are likely to be dormant.

Light:

Seeds of most of the species can germinate, in light or darkness. It is always better to illuminate the tests for the proper growth of the seedlings. Under the situations where light is essential for germination, tests should be exposed to the natural or "artificial source of light. However" care must be made to ensure that an even intensity is obtained over the entire substrate, and that any heating from the source does not affect the prescribed temperature. Seeds that require light for germination must be illuminated with cool fluorescent light for at least 8 hours in every 24 hours cycle. Under the situation where testing of the seed is required to be undertaken at alternating" temperatures together with light, the tests should be illuminated during high temperature period.

Laboratory procedures

The working sample for germination test consists of 400 pure seeds randomly drawn either manually or with the help of counting devices. The seed for germination test must be drawn as follows in accordance with the following two situations:

a) When both purity and germination tests are required.

1. Seeds for germination tests must be taken from the pure seed fraction after conducting the physical purity analysis.
2. The counting of the seed must be made without discrimination as to the size and appearance.

b) Only germination test is required.

1. If, the percentage of pure seed is estimated or determined to be above 98 per cent, the pure seed for germination test shall be taken indiscriminately from a representative portion of the submitted sample;
2. If, the pure seed is found to be less than 98 percent, the seeds for germination test must be obtained by separating the sample into two components, namely

• The pure seed and
• Seeds of other species and inert matter.

For this purpose, at least one-fourth of the quantity required for regular purity analysis must be used after proper mixing and dividing the submitted sample.

Number of replications:

Four replication of 100 seeds, A minimum of 3 replication of l00 seeds may be used under unavoidable situations or Eight or six replications of 50 seeds or Sixteen/twelve replication of 25 seeds according to the kind of and size of containers.

Paper substrata:

Before use of paper following be checked:

1. Check the quality of germination paper before accepting the supplies.
2. Measure the pH, capillary rise, bursting strength and phytotoxicity of the germination paper.

3. Store the germination paper under hygienic conditions and protect it from dust and micro flora.
4. Very old stock should not be used as they often get contaminated. Such paper usually shows phytotoxic symptoms.

Between paper (BP) media (roll towel test): The following steps be followed:

1. Soak the towel paper in water.
2. Remove the water.
3. Wash the paper with running water.
4. Remove extra moisture by pressing the soaked paper by hand and holding it in plastic/surgical trays placed on the tabletop in slanting position.
5. Place two layers of wet paper toweling as substratum.
6. Check Test number provided on the Analysis Card sample and label tally each other.
7. Record the test number, crop and date of putting on the wax paper or tag.
8. Arrange seeds spaced properly.
9. Place one layer of wet towel paper over the seed.
10. Turn up two inches of the bottom edge.
11. Roll firmly from left to right and secure with rubber band in the center.
12. Place the prepared roll towel in roll towel stand or baskets.
13. Transfer the basket or roll towel stand in the germinator maintained at the desired temperature.

Top of paper (TP) media: The following steps be followed:

1. Paper of known quality such as 'Sunlit' or 'Whatman' filter paper should be used.
2. Crepe Kraft (towel) paper or blotter paper of unknown quality should not be used for top of paper tests.
3. The paper should be cut in the form of circles/squares or rectangles according to the size and shape of Petridish/container.
4. Put 2-3 layer of filter paper in the petridish/ germination box having airtight lids.
5. Put enough water to moisten the filter paper.
6. Hold the petridish / germination box in slanting position in order to drain out the extra moisture.
7. Record the test number and date of putting on the lid of the container or on die paper slip.
8. Space the counted seeds on the moist blotter/filter paper.
9. Cover the lid
10. Transfer the test in the germinator maintained at the desired temperature.

Sand substrata(s): The following steps are followed:

1. Properly graded and sterilized sand free from impurities and toxic chemicals should be used.
2. Sand should not be stored in the stores where fertilizers and chemicals are stored.
3. Grade, the sand with a sieve set of 0.8 mm x 0.05 mm (mesh).
4. Sand retained over Q05 mm sieve should only be used.
5. After each test, the sand should b~ dried and sterilized.
6. If required, the sand may be washed before sterilization.

7. If the sand found to be heavily contaminated or changed in colour after repeated use it should be replaced with fresh stocks.
8. The pH of the sand should be within the range of 6.0- 7.5.
9. The sand should also be checked if its phytotoxicity
10. Determine the, moisture holding capacity of the sand.
11. Put required quantity of water to moisten the sand.
12. The moisture level of the sand will vary according to the kind of seed.
13. Place moist sand in plastic germination boxes. The depth of sand bed should be approx. 2".
14. Space the counted seed on the sand bed contained in the germination boxes.
15. Cover the seed with moist sand layer, approximately 1/4" in thickness.
16. Put the cover on the germination boxes and place them under prescribed controlled temperature conditions.

Germination environment

After placing the seeds on the prescribed substrata, the test should be transferred to the controlled temperature condition maintained in the cabinet or walk-in-germinator for prescribed period, which varies according to the species (ISTA Seed Testing Rules). In the Rules for Seed Testing, two kinds of temperature conditions are provided. A single numerical indicate the constant temperature and numerical separated by a dash (-) indicate an alternating temperature.

If temperatures cannot be conveniently altered over weekends or holidays, the tests must be kept at the lower temperature. The daily alternation of temperature either brought out manually by transferring the test from one germinator to another or by changing the temperature of the chamber (Automatic Seed Germinator).

Methods to improve germination

Hard seeds:

For many species where hard seeds occur, some special treatment is essential. This treatment may be applied prior to the commencement of the germination test or, if it is suspected that the treatment may adversely affect non-hard seeds, it should be carried out on the hard seeds remaining after the prescribed test period. The treatments are as below:

Soaking*:*

Seeds with hard seed coats may germinate more readily after soaking for up to 24-48 hours in water or for *Acacia* spp. after plunging seeds in about three times their volume of near boiling water until it cools. The germination test is commenced immediately after soaking.

Mechanical scarification*:*

Careful piercing, chipping, filing or sand papering of the seed coat may be sufficient to break the dormancy condition. Care must be taken to scarify the seed coat at a suitable part in order to avoid damaging the embryo. The best site for mechanical scarification is that part of the seed coat immediately above the tips of the cotyledons.

Acid scarification*:*

Treating with in concentrated Sulphuric acid (H_2SO_4) is effective with some species (*e.g.Macroptilium* sp., *Brachiaria* sp., *Sesbania* sp.). The seeds are moistened with in the acid until

the seed coat becomes pitted. Digestion may be rapid or take more than one hour, but the seeds should be examined every few minutes. After digestion, seeds must be thoroughly washed in running water before the germination test is commenced. In the case of *Oryza sativa* scarification may be performed by soaking the seed in one normal nitric acid (HNO_3) for 24 hrs. (after preheating at 50°C).

Inhibitory substances:

Naturally occurring substances in the pericarp or seed coat, which act as inhibitors of germination may be removed by washing the seeds in running water at a temperature of 25°C before the germination test is made. After washing, the seeds should be dried back at a maximum temperature of 25°C (e.g. *Beta vulgaris*). Germination of certain species is promoted by removing outer structures such as involucre of bristles or lemma and palea of certain *Poaceae (Gramineae)*.

Disinfection of the seed*:*

For samples of Arachis hypoagea and Beta vulgaris only, a fungicide treatment may be applied before planting the seed for germination, when the seed lot is known not to have received such a treatment. When a fungicide pretreatment is used, the name of the chemical, the percentage of active ingredients and the method of treatment shall be reported on the certificate.

Prechilling*:*

In some seeds having physiological dormancy pre chilling is required for inducing germination. Replicates for germination are placed in contact with the moist substratum and kept at a low temperature for an initial period before they are removed to the temperature as reported (ISTA Seed Testing Rules - Table 2). Agricultural and vegetable seeds are kept at a temperature between 5°C and 10°C for an initial period up to 7 days. Tree seeds are kept it a temperature Between 3°C and 5°C, for a period, varying with the species, from 7 days to 12 months. In some, cases it may be necessary to extend the prechilling period or to rechill. The prechilling period is not included in the germination test period but both the duration and the temperature should be reported on the analysis card.

Pre-drying*:*

The replicates for germination should be heated at a temperature not exceeding 40°C with free air circulation for a period of up to 7 days before they are placed under the prescribed germination conditions. In some cases it may be necessary to extend the pre-drying period. Both the duration and the temperature should be reported on the Analysis Certificate.

Chemical treatments

Potassium nitrate (KNO_3):

The germination substratum may be moistened with a 0.2% solution of KNO3, as reported (ISTA Seed Testing Rules - Table 2). The substratum is saturated at the beginning of the test but water is used for moistening it thereafter. The use of this treatment should be noted on the analysis certificate. The procedure for preparing solutions and soaking blotters is as follows:

1. Preparation of stock KNO_3, solution (2%): Place 20 gm KNO_3 crystals in 1000 ml water shake until dissolved. This must be diluted before being used to soak blotters.

2. Preparation of 0.2% KNO_3 solution for soaking blotters: Add 90 ml water to 10 ml of stock solution
3. Procedure for soaking blotters:

a) Take the blotters representing the sample and place into the prepared solution,(0.2%)-one at a time.
b) Turn blotters over in one movement, but ensuring that they are still free moving in the solution.
c) Remove one at a time, in order of placing in solution and place on tray.

Gibberellic acid (GA_3):

Moisten the germination substratum with 50 ppm solution of GA, which can be prepared by dissolving 500 mg of GA_3 in 1000 ml of water. Place the seed for germination under prescribed temperature conditions.

Duration of testing

The duration of the test is determined by the time prescribed for the, final count (ISTA Seed Testing Rules, Table 2) but the chilling, periods before or during the test, which is required to break dormancy, is not included in the test period. If at the end of the prescribed test period some seeds have just started to germinate, the test may be extended for an additional period up to 7 days. A test may be terminated prior to the prescribed time when the analyst is satisfied that the maximum germination of the sample has been obtained. The time for the, first count is approximate and a deviation of 1- 3 days is permitted. The First count may be delayed to permit the development of root hairs in order to be certain that root development is normal, or may be omitted. Intermediate counts may be at the discretion of the analyst to remove seedlings, which have reached a sufficient state of development for evaluation, to prevent them becoming entangled. But the number of intermediate counts should be kept to a mini- mum to reduce the risk of damaging any seedlings that are not sufficiently developed. Seedlings may have to be removed and counted at more frequent intervals during the prescribed period of the test when a sample contains is infected with 'fungi or bacteria. Seeds that are obviously dead and decayed, and may, therefore, be a source of contamination for healthy seedlings, should be removed at each count and the number recorded.

Evaluation of germination test

The germination tests need to be evaluated on the expiry of the germination period, which varies according to the kind of seed. However, the seed analyst may terminate the gern1ination test on or before the final count day or extend the test beyond the period de-pending on the situation. First and second counts are usually taken in case of Top of Paper (TP) and Between Paper (BP) media; however, a single final count is made in case of sand tests. At the first and subsequent counts, only normal and dead seeds (which are source of infection) are removed and recorded.

In evaluating the, germination test, the, seedlings and seeds are categorized into normal seedlings, abnormal seedlings, dead seeds, fresh ungerminated and hard seeds. The fresh ungerminated or hard seeds and abnormal seedlings should be evaluated at the end of germination. The stage of development of the essential structures must be sufficient to permit

detection of any abnormal seedlings. It may also be necessary to remove the seed coat and separate the cotyledons In order to examine the plumule in species where essential structures are still enclosed at the end of the test.

Normal seedlings:

It is necessity to separate the normal seedlings, which are counted in the percentage germination, from any abnormal seedlings. To achieve uniformity in evaluating normal seedlings, they must conform to one of the following definitions:

1. Seedlings, which show the capacity for continued development into normal, plants when grown in good quality soil and under favourable conditions of water supply, temperature and light.
2. Seedlings that possess all the following essential structures when tested on artificial substrata:
3. A well-developed root system including a primary root-, except for those plants (*eg.* ceftt1in species of *Gramineae*) normally producing seminal roots of which there still are at least two.
4. A well-developed and intact hypocotyl without damage to the conducting tissues.
5. An intact plumule with a well-developed green leaf, within or emerging through the coleoptile, or an intact epicotyl with a normal plumular bud.
6. One cotyledon for seedlings of monocotyledons and two cotyledons and seedlings of dicotyledons.
7. Seedlings with the following slight defects provided they show vigorous and balanced development of the other essential structures:
8. Seedlings *of Pisum, Vicia, Phaseolus, Lupinus, Vigna, Glycine, Arachis, Gossypium, Zea* and all species of *Cucurbitaceae*, with a damaged primary root but with several secondary roots of sufficient length and vigour to support the seedlings in soil.
9. Seedlings with superficial damage or decay to the hypocotyl, epicotyl or cotyledons, which is limited in area and does not affect the conducting tissues.
10. Seedlings of dicotyledons with only one cotyledon.
11. Seedlings of tree species having epigeal germination when the radicle is four times the length of the seed provided all structures that have developed appear normal.
12. Seedlings which are seriously decayed by fungi or bacteria, but only when it is clearly evident that the parent seed is not source of infection and it can be determined that all the essential structures were present.

Abnormal seedlings:

Abnormal seedlings are those, which do not show the capacity for continued development into normal plants when grown in good quality soil and under favorable conditions of water supply, temperature and light. Seedlings with the following defects shall be classed as abnormal:

1. Damaged seedlings; seedlings with no cotyledons; seedlings with constrictions, splits, cracks or lesions which affect the conducting tissues of the epicotyl, hypocotyl or root; seedlings without a primary root of those species where a primary root is an essential structure, except for *Pisum, Vicia, Lupinus, Vigna, Glycine*, *Arachis, Gossypium, Zea* and all species' of *Cucurbitaceae*, when several vigorous secondary roots have developed to support the seedlings, in soil.

2. Deformed seedlings: Seedlings with weak or unbalanced development of the essential structures such as spirally twisted or stunted plumules, hypocotyls or epicotyls; swollen shoots and stunted roots; split plumules or coleoptiles without a green leaf; watery and glassy seedlings, or without further development after emergence of the cotyledons.
3. Decayed seedlings: seedlings with any of the essential structures so diseased or decayed that normal development is prevented, except when there is clear evidence to show that the cause of injection is not the seed itself.
4. Seedlings showing cotyledon development from the micropyle, or radicle development from a part of the seed other than the micropyle.

Special categories of abnormal seedlings The 3 main categories of abnormality, damage, deformity and decay, outlined in the previous section, can be further classified into categories as follows:

Roots

1. No roots, in *Avena, Hordeum, Secale* and *Triticum* or one seminal root only.
2. Primary root (or seminal roots in *Gramineae*) short and stunted.
3. Primary root thin and weak, too short or too long.
4. Primary root short and stunted, or short and weak, or spindly, secondary roots weak.
5. No primary root or no well developed secondary roots.
6. Seminal roots short and weak, or spindly, or watery.
7. Primary root split longitudinally, or damaged with secondary roots weak,
8. Radicle with no root hairs.
9. Radical or primary root brown in colour.

Hypocotyls and epicotyl

1. Hypocotyl short and thick, or twisted, or curled over or watery.
2. Epicotyl or stem with constriction, grainy lesion, or open split likely to interfere with the conducting, tissues.
3. Hypocotyl with constriction, grainy lesions or open split likely to interfere with the conducting tissues.
4. Epicotyl or stem short and thick, or twisted around the main axis, *ie.* No terminal bud.
5. Two shoots which are short and weak, or spindly.
6. No primary leaves, with or without terminal or auxiliary buds, or with more than half the total area of the primary leaves missing or not capable of functioning normally, or with one primary leaf and evidence of damage to the shoot apex.

Coleoptile (Gramineae)

1. No green leaves
2. Short leaves extending less than half the length of coleoptile
3. Leaves shattered or split longitudinally and/or coleoptile with a split easily visible to the naked eye or abnormal coleoptile development due to damage.
4. Plumule short and thick, usually with short or stunted seminal roots.

Cotyledons (Dicotyledonous species)

1. None
2. One, with evidence of damage to the shoot apex.
3. Poorly developed leaf-like cotyledon in *Allium*, without a definite bend, or "knee".
4. Enlarged, with short hypocotyl. e. Physiological necrosis

5. Grey in colour
6. Swollen and blackened
7. More than half the total area broken off, or covered with spots or darkened areas, or with open splits if development as a whole is out of proportion compared with that of a normal seedlings germinated at the same time.

Decay

1. Decayed cotyledons.
2. Decayed hypocotyl.
3. Decayed epicotyl or stem.
4. Decayed plumule, or decay at point of attachment between seedlings and endosperm or discoloration of the coleoptile which has penetrated to the leaves.
5. Decayed primary root (except secondary infection by *Phoma betae*) or seminal roots in the *Gramineae*.
6. Decay or discoloration at point of attachment between cotyledons and seed- lings axis, or adjacent to the shoot apex.
7. Completely delayed seedling.

Other abnormalities

1. Seedlings short and weak, or spindly, or watery.
2. Frost damaged seedlings with grainy coleoptile or a plumule, which is weak and spirally twisted.
3. Entirely white seedling in the *Gramineae* and *Liliaceae*.
4. Completely shattered seedling.

Calculation and expression of result

Results are expressed as percentage by number.

$$\text{Germination (\%)} = \frac{\text{Number seeds germinated } \mathbf{x}\ 100}{\text{Number seeds on tray}}$$

When four l00-seed replicates of a test are within the maximum tolerated range, the average represents the percentage germination to be reported on the Analysis Certificate. The average percentage is calculated to the nearest whole number. The total % of all the category of seeds (normal, abnormal. dead hard, fresh un germinated) should be 100.

Retesting

The result of a test shall be considered unsatisfactory and shall not be reported and a second test shall be made by the same or an alternative method, under the following circumstances:

1. When dormancy is suspected (fresh ungerminated seeds).
2. When the result may not be reliable because of phytotoxicity or spread of fungi or bacteria
3. When there is difficulty in deciding the correct evaluation of a number of seedlings.
4. When there is evidence of errors in test conditions, seedling evaluation or counting.
5. When the range for the 100-seed replicates exceeds the maximum tolerated range

Reporting of result

The following items shall be entered in the appropriate space of the analysis certificate when reporting the result of a germination test:

1. Kind of variety
2. Date of testing
3. Duration of test
4. Percentage of normal seedlings, abnormal seedlings, hard seeds, fresh seeds and dead seeds. If the result for any of these categories is found to be nil, it shall be entered as 0

The following additional information shall also be reported:

(a) In all cases

1. Substrate and temperature used.
2. Any special treatment or method used for promoting germination.
3. The germination percentage obtained within the prescribed time, if the germination period has been extended beyond the period indicated.
4. The second result obtained when duplicate tests are indicated in Table 5A.

(b) Upon request

1. The result of any additional test,
2. The viability of ungerminated seeds and method used to determine it.
3. Categories of ungerminated seeds and methods used to determine them.
4. With multi-germ seed units: number of normal seedling produced by 100 units; proportion of units producing one, two or more than two normal seedlings.

Reasons of variation in the germination test results

Germination test provides information about planting value of the seed under ideal conditions of temperature, moisture, light and substrata. In addition, germination test results are utilized for:

1. Labelling purposes
2. Seed certification
3. Seed law enforcement
4. Adjusting the seed rate for achievement of desired field establishment.

Reasons for variation in germination test results

Chance alone

1. Poor sampling *ie;* non uniform representative sample, random sampling error
2. Poor equipment, including variation in temperature, light and humidity in germinator
3. Substrata quality: Toxicity or impurities in Paper or sand
4. Use of stored or old germination papers
5. Incidence of fungi or bacteria or others in the seed
6. Improper phytosanitary conditions of laboratory, containers and germinators
7. Effect of seed treatment
8. Untrained or inexperienced analysts
9. Inaccurate counting of seed or seedling
10. Observation before or after prescribed time
11. Interpretation of seedling performance: Normal/abnormal and dead and fresh un-germinated.

The variation in germination test results may be minimized by taking the following precautions:

Sampling:

A representative sample (working sample) of seed lot should be drawn by following prescribed sampling techniques.400 seeds should be taken from pure seed fraction for undertaking germination test.

Substrata:

Depending on the purpose of undertaking germination test substrata should be selected. If germination test results are required for assessment of seed quality paper should be used and for evaluation of seed vigour sand should be used.

Paper: The paper may be used two ways:

Between paper:

Conduct of germination test between paper rolled towel paper (crepe Kraft paper) is extensively used for undertaking germination test which contains toxins and affects germination results. The paper before use should be tested for toxicity and toxicity should be removed by soaking the paper overnight in water and washing for one hour in running tap water or by soaking the paper in water and changing the water frequently.

Top of paper method:

Filter paper circles of Sonar/Whatmann/Sunlit make are primarily used which are non-toxic. If other brand filter paper are used they should be tested for quality i.e. toxicity. Roll towels should neither be very tight to allow rotting due to poor aeration not very loose that the seeds move from place. Tight rolling has been reported to result in development of abnormal seedlings. Wax paper/polythene should be folded from lower end to retain moisture. If germination test is conducted in Petri plates then should be washed thoroughly after use and dried. Detergents used for cleaning should be removed thoroughly by washing.

Sand:

Sand used for test should be of recommended grade and size and should be washed and sterilised to remove impurities and microbes or spores. In top of paper and sand method lid should be tightly fixed to prevent moisture loss from the substratum. The use of cracked/broken lids leads to complete loss of moisture, thus affecting germination results.

Moisture:

Excess moisture in substrata causes poor aeration of seeds and rotting and insufficient moisture hampers germination test by development of abnormal seedlings. Thus optimum moisture should be provided to substrata. Tap water is generally used but if distilled water is used which is devoid of oxygen it should be supplemented with oxygen. Extra moisture should be drained off the towel by keeping in slanting position. In between top of paper method, individual paper circles after dipping in tap water with help of forceps should be dried to drain extra water.

Temperature:

The germination test should be conducted under recommended temperature i.e. at 20^{o}C, 25^{o}C or alternating temperature but never under room temperature.

Power supply:

Uninterrupted power supply should be available during conduct of germination test.

Placement:

The placement of seeds should be with counting board. If it is done with hand, seeds should be place dvertically as the roots get entangled and evaluation becomes difficult. Germination test in roll towels, seeds should not be placed near proximal end of paper as toxins gets accumulated at the base of paper and causes abnormal seedlings.

Evaluation:

Faulty evaluation may lead to faulty results and causes variation in germination results. Germination evaluation should be done as per seed testing rules. The variation can be minimized if the analyst is familiar with seed testing rules. Thus germination test results generated following above precautions under recommended conditions will be accurate and reproducible.

Germination Testing: Evaluation Sheet

	GERMINATION TEST RESULTS NSRTC Training Course				
	Reg. No.	**Lot No.**	**Crop**	**Variety/ Cultivar**	**Date**
Method used		Substrate	Temperature [°C]	First Count/ Final Count [d]	Treatment for promoting germination
Replicate	Normal Seedlings	Abnormal Seedlings	Hard Seeds	Fresh Seeds	Dead Seeds
Rep 1 [#]					
Rep 2 [#]					
Rep 3 [#]					
Rep 4 [#]					
Mean [%]					
Kind of Abnormal Seedlings					

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