TRAINING MODULE

ADVANCED TRAINING ON MILLETS SEED PRODUCTION, PROCESSING AND CERTIFICATION FOR PARA-SEED WORKERS

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Revitalising Rainfed Agriculture
The RRA Network

Contents

ADVANCED TRAINING ON MILLETS SEED PRODUCTION, PROCESSING AND CERTIFICATION FOR PARA-SEED WORKERS

1. Introduction

Millet cultivation is major livelihood of tribal farmers in high land and plain lands in north coastal and Rayalaseema regions of Andhra Pradesh. Millets like sorghum, finger millet, foxtail millet, barnyard millet, proso millet are popular among folklore. They consume and sell in local markets. Though farmers are interested, there is scarcity of seed, particularly high yielding varieties. Majority of farmers using farm saved millet seed, which are traditional varieties. Considering farmers interest and market demand there is urgent need to set up a sustainable seed system that can provide desired seed within sowing window.

2. Importance of Para Seed Workers

Though the supply of foundation seed and supply of certified seed is done by Govt. agencies there is no proper mechanism to check the quality both at production and post harvest level. Para-Seed Workers are recruited to fulfill above mentioned task. The process of Seed Certification ensures quality parameters of seed and completes legal procedures. It also assures seed producing farmers and builds confidence among seed consuming farmer groups. Para seed workers s bridge gap between seed producers and seed consumers. They Help both State Seed Certification Agency and CBOs in maintaining quality seeds. They play pivotal role between govt. departments and community organizations.

3. Importance of Training

Since all Para seed workers s are coming from low education back ground, without much knowledge on technically sound seed production and legally ensured certification, hence there is a need of training in theoretical and practical aspects of seed production and certification.

3.1. Training needs of Para Seed Workers

- Skill development in seed production.
- Capacity building in seed certification.
- Ability to planning , organizing and coordinating
- To acquaint with govt. departments and their protocols.
- Respect for rules and regulations.
- Institutional development and organization building.
- Expertise in seed quality parameters/ testing.
- Environment consciousness and eco-friendly approaches
- Data generation and management.

3.2. Selection of Candidates

- He/she must belong to that local area, should familiarize with local agricultural practices and social customs.
- He/she should from agriculture family or agriculture labor family and well versed with millet cultivation.
- Minimum educational qualification is 10^{th} class or 12^{th} class. Persons who completed graduation in any discipline are an additional advantage.
- Preference will be given to those candidates who worked earlier with programs like agriculture, watershed development and NREGA.

3.3. Duration of the Training

- 8 days (64 hours)

3.4. Who are Trainers (Resource Persons)

Resource person would be

- Authorized trainer from Sate Seed Certification Agency
- Scientists/Subject Matter Specialists from KVK
- Best farmers or Resource farmers from FPOs
- Officers from Department of Agriculture
- Scientists from ARS, Agriculture Research Institutions
- Scientist/Professor from State Agriculture University
- Resource person from NGOs.

3.5. Method of Teaching / Training

The classroom cum practical teaching classes will be conducted. Field visits will be organized within selected village of their respective FPOs.

Field level training will be organized to meet the crop calendar of Millets. Candidates will get hands-on experience on seed production, field inspection and processing and certification procedures at field level. They will maintain record book for observations and data collections.

At the end of training, participants submit assignment workbooks, record books, posters etc., which are generated during training. On gradation day, while conducting written test, instructor evaluate the performance of the candidate and grade their marks.

3.6. What We can expect from this Training (Outcome)?

This certificate program aims at building relevant capacities (knowledge, skills and attitudes) of the participants so that they can perform the role of "seed Certifier". Since the seed certification is a legal process which is mandated to State Seed Certification Agency (SSCA), the certification would be done by SSCA only.

By the end of the advanced training on Millets seed production, processing and certification; the participants would be able to,

- Support farmers and FPOs in seed production.
- Submit application forms and helps in registration.
- Complete form-1 filling and submission processes.
- Provide technical support in seed production.
- Ensuring isolation distance and roughing of off types.
- Ensure quality harvest and separate threshing of the seed produced.
- Collect samples and submit to SSCA through Mandal Agriculture Officer

It is expected that the above capacities convert any individual into a good seed certification professional and thus strengthen the seed production in community managed system.

3.7. About Training Module

After successful training of basic level (five days) on concepts of seeds, seed quality and seed certification, and first phase of advanced training on pulses, participants will undergo advance training (8 days) on Millets seed production, processing and seed certification.

The training course is designed to prepare technically sound Para seed workers who can able to distinguish seed and grain, check all quality parameters in the fields and fulfill desired formalities in certification. The module is designed in such a way that the participant can implement his knowledge and skill immediately after the course. Theoretical classes are followed immediately with practical sessions/field visits. Participants get technical content / training material at the time of training. At the end of each phase, participants knowledge is measured by written tests. Best performer will be awarded with memento. All participants receive certificates.

4. FINGER MILLET (*Eleusine coracana)*

Finger millet is an annual robust grass, mainly grown as a grain cereal in the semi-arid tropics and subtropics of the world under rainfed conditions. It is a staple food crop in the drought prone areas in the world, and is considered as an important component of food security. Finger millet grain can be stored for years without storage pests, which makes it a perfect food grain commodity for famine-prone areas. While grains are used for human consumption, the crop residues are excellent source of dry matter for livestock especially in dry season. Finger millet straw makes good fodder and contains up to 61% total digestible nutrients.

4.1. Classification

Kingdom	:	Plantae
Division	:	Magnoliophyta
Class	:	Liliopsida
Order	:	Cyperales
Family	:	Poaceae
Genus	:	Eleusine
Species	:	*Eleusine coracana*

- **Origin:** Finger millet is believed to have been domesticated in the highlands of East Africa about 3000 B.C., and in the same period it was introduced in India; origins for the crop can therefore be linked to Africa and India.
- **Biology:** Morphology: Finger millet is a tufted annual crop, growing to a height of 30– 150 cm and maturing in 75–160 days. Leaves are narrow, grass-like and capable of producing many tillers and nodal branches. The panicle consists of a group of digitally arranged spikes often referred to as fingers. The spikelets are made up of 4–10 florets arranged serially on the finger. All florets are perfect flowers with the exception of the terminal ones which may sometimes be infertile. The grain is oblong to round and oval, reddish brown in colour with the grains‟ surface finely corrugated. Typically a tropical, rainfed crop, it is one of the best suited for dry farming. Finger millet is very adaptable and thrives at higher elevations than most other tropical cereals.
- **Floral biology:** Complete emergence of inflorescence in finger millet required about 10 days and flowering attains 7-8 days. The flower open between 1 to 5 AM and progress from top to bottom in a finger, however, in a spikelet the order is reversed and proceeds from bottom to top and bigger to smaller flower. The stigma is receptive for a very short period after its emergence from the glumes. The period of anthesis being very short, is conducive for self-pollination and cross pollination is very rare.
- **Season:** The best season for seed production is December – January. Pollination should not coincide with rains for quality and effective seed setting. The temperature of 37°c is

favorable for seed setting. Average and well distributed rainfall of 450-500 mm is optimum for rainfed ragi.

- **Land selection:** Ragi can be grown in poor to fertile soil. The crop can tolerate salinity better than any other crops. The selected land should be free from volunteer plants. The land should not be cultivated with same crop in the previous season. Land should be ploughed 2 - 3 times to get fine tilth and levelled.
- **Seed selection & Sowing:** The percentage of minimum physical purity of certified and foundation seeds should be 97% with a minimum of 75% of germination capacity and 12%of moisture content. The presence of inert matter should not exceed 2.0%.Ragi is a season bound crop and the best season to take up sowing is December - January and June - July.
- **Seed rate:** Recommended seed rate is 2 kg/acre (5 kg/ha). Selected seeds should be treated with Azospirillum @ 125gms/kg of seeds.
- **Sowing:** Seed hardening: Soak seeds in water for 6 hours. Use one litre water for every kg seed for soaking. Drain the water and keep the seeds in wet cloth bag tightly tied for two days. At this stage, the seeds will show initial signs of germination. Remove seeds from the wet cloth bag and dry them in shade on a dry cloth for 2 days. Use the above hardened seeds for sowing. Line sowing is ideal and seed drills giving spacing of 22.5 – 30 cm between rows should be used. Finger millet seeds are very small (400 seeds/g) and the recommended seed rate of 15-20 kg per hectare will contain about 4 million seeds. Therefore, even when seed drill is used thinning within the row leaving a spacing of 7.5 – 10 cm between plants, must be followed. Sowing by seedcum- fertilizer drill is advantageous for line sowing.

4.2. Crop Management

- **Nursery preparation:** Nursery should be raised in an area of 500m2 to plant one hectare of main field (200m2 per acre). Selected nursery plot should be ploughed for two to three times to have fine tilth of soil. Raised beds should be formed and shallow rills are formed over the beds by passing the fingers vertically. Seed should be broadcasted and covered with a thin layer of farmyard manure @ 500 kg/ha (200 kg/acre).
- **Irrigation: (Bed stage)** Adjust the frequency of irrigation according to the soil type. Provide one inlet to each nursery unit. Allow water to enter through the inlet and cover all the channels around the beds. Allow the water in the channels to raise till the raised beds are wet and then cut off water. Do not allow cracks to develop in the nursery bed by properly adjusting the quantity of irrigation water.

No. of irrigations	Red Soils	Heavy Soils
1st	Immediately after sowing	Immediately after sowing
2nd	3rd day after sowing	4th day after sowing

3rd	7th day after sowing	9th day after sowing
4th	12th day after sowing	16th day after sowing
5th	17th day after sowing	..

- **Main field preparation:** The main field is prepared with 2 – 3 ploughing to make it a fine tilth and formed into ridges and furrows. During final plough apply compost or farmyard manure @ 5 tonnes/acre (12.5 tonnes/ ha) and incorporate into the soil.
- **Transplanting:** Let water into the bed, level the bed, if it is not levelled. Plant 2 seedlings per hill. Plant the seedlings at a depth of 3 cm. Plant 18 to 20 days old seedlings. Adopt a spacing of 30x10 cm for planting. Adopt 22.5 x 10 cm spacing for direct Sowing.

4.3. Nutrient Management

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

4.4. Pest Management

- **Roguing:** Roguing should be done often to remove the off- types, volunteer plants and diseased plants from the seed production field to avoid the genetic contamination. Roguing should be done upto the flowering stage. Maximum percentage of off- type permitted at the final inspection is 0.05% for foundation and 0.10% for certified seed production.
- **Field inspection:** A minimum of two inspections should be done between flowering and maturity stages by the Seed Certification Officer. The first inspection is done at the time of flowering to check the isolation and off-types and the second done during the maturity stage prior to harvest to check the off-types and to estimate the yield.

4.5. Water Management

Regulate irrigation according to the following growth phases of the crop

Stages	No. of irrigations	80 days	Crop duration 100 days	120 days
Vegetative Phase (Nursery)		1 to 16	1 to 18	1 to 20
Vegetative phase (in main field)		1 to18	1 to 20	1 to 22

Stages	No. of irrigations	80 days	Crop duration 100 days	120 days
Flowering phase		19 to 40	21 to 55	23 to 69
Maturity phase		Beyond 40 days	Beyond 55 days	Beyond 69 days
Heavy soils				
Establishment	1	1st day	1st day	1st day
(1-7 days)	2	5th day	5th day	5th day
Vegetative phase	1	18th day	20th day	20th day
(8-20 days)	2	31st day	33rd day	30th day
Flowering phase	1	41st day	42nd day	37thd ay
(21-55 days)	2	51st day	52nd day	44th day
	3	--	--	63rd day
Maturity phase	1	61st day	62nd day	78th day
(56-120 days)	2	--	--	93rd day
Stop irrigation Thereafter				
Light soils				
Establishment	1	1st day	1st day	1st day
(1 – 7 days)	2	5th day	5th day	5th day
Vegetative phase	1	15th day	16th day	16th day
(8 - 20 days)	2	26th day	28th day	28th day
Flowering phase	1	36th day	36th day	36th day
(21 - 55 days)	2	45th day	45th day	45th day
	3	..	54th day	54th day
Maturity phase	1	58th day	69th day	78th day
(56 - 120 days)	2	70th day	85th day	93rd day
Stop irrigation thereafter				
NOTE: The irrigation schedule is given only as a general guideline. Regulate irrigation depending upon the prevailing weather conditions and receipt of rain.				

- **Harvesting and processing:** Harvest is done once the earheads are physiologically mature. Physiologically mature earheads will turn from brown to green colour. Harvesting is done in two pickings since, the maturation of the earheads are not uniform because of the tillering habit of the crop. Second harvesting should be done seven days after the first one.
- **Threshing:** Green earheads if harvested will contaminate the seeds with immature seeds

and interfere cleaning, drying and grading. Dry earheads until seed moisture content is 15% and separate manually by threshing with bamboo stick or machine thresher.

- **Drying and storage:** The cleaned seeds should be sun dried to attain a safe moisture level of 12%. Care should be taken while drying to avoid mechanical injury to the seeds and contamination. Seeds can be stored upto 13 months under proper storage conditions. Field standards:

  Ragi is a self-pollinated crop and should be raised in isolation. To maintain the genetic purity the isolation distance between the varieties is 3 metres for both foundation and certified seed production.

- **Isolation distances:**

Contaminants	Minimum distance (meters)	
	Foundation	Certified
Fields of other varieties of grain and dual-purpose sorghum	3	3
Fields of the same variety not conforming to varietal purity requirements for certification	3	3

- **Specific standards:**

Contaminants	Maximum permitted (%)*	
	Foundation	Certified
Off-types at any one inspection at and after flowering	0.050	0.10

- **Seed standards:** The percentage of minimum physical purity of certified and foundation seeds should be 97% with a minimum of 75% of germination capacity and 12% of moisture content. The presence of inert matter should not exceed 2.0%.

S.No	Factor	Standard of each Class	
		Foundation Seed	Certified Seed
1	Pure seed (minimum)	97.0%	97.0%
2	Inert matter (maximum)	3.0%	3.0%
3	Other crop seeds (maximum)	10/kg	20/kg
4	Weed seeds (maximum)	10/kg	20/kg
5	Germination including hard seeds (minimum)	75%	75%
6	Moisture (maximum)	12.0%	12.0%
7	For vapour-proof containers (maximum)	8.0%	8.0%

5. FOXTAIL MILLET (*Setaria italic)*

Foxtail millet (Setaria italica) is a well-known small millet variety belonging to the family Gramineae. Foxtail millet is mostly grown mixed with other crops like cotton, castor, pigeon pea, bajra, groundnut and finger millet. It is also grown as a pure crop, particularly in black cotton soils where it is followed by a rabi crop like coriander in favourable seasons or by safflower or horsegram in years of less rainfall. The crop can be grown upto an altitude of 200 meters. The crop can be grown successfully in areas receiving750 mm of annual rainfall.

5.1. Classification

Kingdom	:	Plantae
Division	:	Magnoliophyta
Class	:	Liliopsida
Order	:	Cyperales
Family	:	Poaceae
Genus	:	Setaria
Species	:	*Setaria italica (L.) Beauv*

- **Origin:** Foxtail millet (Setaria italica) is also known as Italian or German-Hungarian or Siberian millet. Foxtail millet was considered to be do mesticated inthe highlands of central China. The main productionregions of the world include China, parts of India, Afghanistan, Central Asia, Manchuria, Korea, and Georgia. It is also one of the specialty crops in Japan. In Asia it is mainly grown for human consumption.
- **Biology:** Foxtail millet is grown mainly as a dry land crop in semi-arid regions receiving an annual rainfall of less than 125mm. The time of planting typically ranges from May through July. The crop cycle depends on the cultivar and on growth conditions; it may range from 60 to 120 days with a productivity ranging from 800 to 900 kg/ha of grain and about 2500 kg/ha of straw. If the crop is grown for hay or silage it should be harvested when in bloom, since the protein concentration at that stage peaks around 12 – 14%.
- **Season:** Best season for seed production is June – July and February – March.The pollination should not coincide with rains for quality and effective seed setting. Early sowing in the monsoon always produces higher yields than latersowings. The longer duration varieties gave higher fodder yield when sown early.
- **Land selection:** Foxtail millet needs moderately fertile soil for good yield. The selected land should be free from volunteer plants. The land should not be cultivated with same crop in the previous season. Land should be ploughed 2 - 3 times to get a fine tilth and levelled.

- **Field preparation:** The main field should be ploughed for 2 – 3 times to make it a fine tilth and formed into ridges and furrows. During final plough apply compost or farmyard manure @ 5 tonnes/ acre (12.5 tonnes/ ha) and incorporate into the soil.
- **Seed selection and sowing:** Seeds used for seed production should be of good quality certified seeds from an authentic source. Seeds should be healthy with required germination percentage. Recommended seed rateis 2 kg/acre (5 kg/ha).

  Selected seeds should be treated with Azospirillum @ 125 gms/kg of seeds. Treated seeds should be sown with a spacing of 30 x 10 cm at a depth of 3 – 4 cm.
- **Sowing method:** Seeds can be sown in the ridges at a depth 3 - 4 cm with a spacing of 30 × 10 cm.
- **Main field preparation:** The main field should be ploughed for 2 – 3 times to make it a fine tilth and formed into ridges and furrows. During final plough apply compost or farmyard manure @ 5 tonnes/ acre (12.5 tonnes/ ha) and incorporate into the soil. Seeds can be sown in the ridges at a depth 3 - 4 cm with a spacing of 30 × 10 cm.

5.2. Nutrient Management

Before final ploughing compost or farmyard manure @ 5 tonnes/acre (12.5 tonnes/ha) should be applied and ploughed into the soil. Instead of this cattle penning can also be practiced. 50 kg neem cake and 500 kg vermicompost per acre (125 kg neem cake and 1250 kg vermicompost per hectare) should be applied as basal manure. For rainfed crop, apply 50 kg/acre (125 kg/ hectare) of pungam cake and 250 kg/acre(600 kg/hectare) of vermicompost as basal manure just before sowing.

After first weeding at 20 – 25 days after sowing top dressing should be done using enriched vermicompost (2 kg Azospirillum, 2 kg Phosphobacterium and 2 litres Panchagavya mixed with 250 kg vermicompost and kept covered for a week and then used) @ 250 kg/acre (600 kg/ha).

During flower initiation stage 10% tender coconut solution (1 litre tender coconut water + 9 litres of water) should be sprayed. All the above-mentioned inputs should be applied to the rainfed crop only when the soil is wet.

5.3. Weed Management

The seed production field should be maintained weed free. Weeding can be done with a tyne harrow when the crop is 30 days old. Allow the weeds to dry for 2 - 3 days after hand weeding.

5.4. WATER MANAGEMENT

- **Irrigation**: Kharif season crop does not require any irrigation. It is mostly grown as a rainfed crop. However, if the dry spell prevails for longer period, then 1 - 2 irrigations should be given to boost the yield. Summer crop requires 2 - 5 irrigations depending upon soil type and climatic conditions. During heavy rains the excess water from the field should be drained out.

5.5. PEST MANAGEMENT

- **Roguing:** Roguing should be done often to remove the off- types, volunteer plants and diseased plants from the seed production field to avoid the genetic contamination. Roguing should be done upto the flowering stage. Maximum percentage of off- types permitted at the final inspection is 0.05% for foundation and 0.10% for certified seed production.
- **Field inspection:** A minimum of two inspections should be done between flowering and maturity stages by the Seed Certification Officer. The first inspection is done at the time of flowering to check the isolation and off- types and the second inspection is done during the maturity stage prior to harvest to check the off-types and to estimate the yield.
- **Harvesting and processing:** Harvest is done once the earheads are physiologically mature. Normally crop is ready for harvest in 80 - 100 days after sowing. Physiologically mature earheads will start to dry. Plants are either harvested intact with earheads or earheads alone. The earheads are dried beforethreshing. The earheads are threshed by stone roller or trampling under the feet of bullocks. The threshed grains are further cleaned by winnowing.
- **Drying and storage:** The cleaned seeds should be dried under the sun to attain a safe moisture level of 12%. Care should be taken while drying to avoid mechanical injury to the seeds and contamination. Seeds can be stored upto 13 months under proper storage conditions.

5.6. FIELD STANDARDS

Isolation distances.

Contaminants	Minimum distance (meters)	
	Foundation	Certified
Fields of other varieties	3	3
Fields of the same variety not conforming to varietal purity requirements for certification	3	3

Specific standards.

Contaminants	Maximum permitted (%)*	
	Foundation	Certified
Off-types at any one inspection at and after flowering	0.050	0.10

Seed standards:

S.No	Factor	Standard of each Class	
		Foundation Seed	Certified Seed
1	Pure seed (minimum)	97.0%	97.0%
2	Inert matter (maximum)	3.0%	3.0%
3	Other crop seeds (maximum)	10/kg	20/kg
4	Weed seeds (maximum)	10/kg	20/kg
5	Germination including hard seeds (minimum)	75%	75%
6	Moisture (maximum)	12.0%	12.0%
7	For vapour-proof containers (maximum)	8.0%	8.0%

The percentage of minimum physical purity of certified and foundation seeds should be 97% with a minimum of 75% of germination capacity and 12% of moisture content. The presence of inert matter should not exceed 2.0%.

6. SORGHUM (*Sorghum bicolor)*

Sorghum (Sorghum bicolor) is one of the important major millet belonging to the family Poaceae. The best season for seed production is November – December. The pollination should not coincide with rains. Rains prevent quality and effective seed setting. The temperature of 37oc is favorable for seed setting.

6.1. Classification

Kingdom	:	Plantae
Division	:	Magnoliophyta
Class	:	Liliopsida
Order	:	Cyperales
Family	:	Poaceae
Genus	:	Sorghum
Species	:	*Sorghum bicolor*

- **Origin:** Sorghum bicolor (L.) Moench origin anddomestication has taken place in Africa about 5000 – 8000 years ago. Indian subcontinent is the secondary origin of sorghum.
- **Sorghum plant morphology** The leaf sheaths have overlapping margins and encircle the internodes, depending on internode length. The leaf blade may be 1.5 to 13 cm wide and 30 to 135 cm long. Leaf number can vary from7 to 30 depending on the cultivar and its growth duration. The uppermost internode bears the inflorescence and is called as peduncle. Sorghum is known as short–day plant, hence, long nights (dark period) are required for floral initiation; and each cultivar needs a specific critical period of darkness for transformation of its vegetative bud into a floral bud. Length of maturity in sorghum is governed by four major genes (Ma1, Ma2, Ma3, and Ma4) called as maturity genes with multiple alleles at each of the four loci. Plant height is similarly controlled by four major genes called dwarfing genes (Dw1, Dw2, Dw3, and Dw4), which effect plant height due to reduction in internodal length.
- **Floral biology:** The sorghum panicles may be 4–25 cm long and 2–20 cm wide, which may be short and compact or loose and open. The inflorescence isa raceme consisting of one or several spikelets.
- **Anthesis and pollination:** The floral initiation (Primordial formation) starts at 30 to 40 days after germination (but may range from 19 to 70 days or more) Floral initiation marks the end of the vegetative growth and the meristematic activity.

  Sorghum usually flowers in 55 to 70 days in warm climates, but it could be as early as 30 days or as late as 100 days or more. The flowering (anthesis) in a panicle starts from the

top and it travels successively to lower whorls. Flowering is completed over a period of 4 to 5 days (6-8 days under cooler conditions).

Sorghum has 2 pistils and 3 stamens. Each fluffy stigma is attached to a short and stout style extending to the ovary. Pollen is usually available for a period of 10 to15 days because the heads in a field do not flower at the same time. Sorghum is predominantly a self-fertilized crop, but the cross pollination may occur to an extent of 2 to 10 percent.

Table 1: Variability in different plant morphological characters and seed traits in sorghum

S.no	Character	Stage	Variation
1	Plant height	Vegetative	Tall (> 225 cm) / medium (< 225 cm)
2	Plant color	Vegetative	Pigmented (gray, brown groups) / Tan (yellowish)
3	Juiciness	Vegetative	Juicy / Corky
4	Leaf	Vegetative	Erect / semi-erect / droopy
5	Leaf midrib color	Vegetative	White / dull green / greenish yellow / brown purple
6	Leaf color	Vegetative	Dark green / green / light green
7	Leaf sheath waxyness	Vegetative	Less waxy/ Medium waxy/ Highly waxy
8	Stem thickness	Vegetative	Thin (< 3 cm) / medium (3-8 cm) / thick (> 8 days)
9	Internode covering	Vegetative	Covered/ Slightly exposed/Completely exposed
10	Days to 50% flowering	Reproductive	Early (< 60 days) / late (> 75 days)
11	Panicle compactness	Reproductive	Very lax / very loose with erect primary branches / very loose drooping primary branches / loose erect primary branches / loose drooping primary branches / semi-loose erect primary branches / semi-loose drooping primary branches
12	Panicle shape	Reproductive	semi compact elliptic / compact elliptic / compact oval / half broom corn / broom corn/ Broader at upper/ Broader at Lower/ Pyramidal/ Symmetric
13	Panicle exertion	Reproductive	Completely exerted / Partially exerted / Minimal exertion with and without flag leaf attachment to the panicle base.
14	Glume color	Maturity	White / sienna / mahogany / red / purple / black / gray.
15	Seed	Maturity	25% of grain covered / 50% grain covered / 75% grain covered / grain fully covered / glumes longer than

	covering		grain.
16	Awns	Maturity	Awned / awnless.
17	Days to maturity	Maturity	Early (< 90 days) / medium (90-120 days) / late (9-120 days)
18	Shattering	Maturity	Very low / low / intermediate / high / very high.
19	Seed color	Maturity	White / yellow / red / brown / buff.
20	Seed luster	Maturity	Lustrous / non-lustrous.
21	Seed sub coat	Maturity	Present / absent.
22	Seed plumpness	Maturity	Dimple / plump.
23	Seed form	Maturity	Single / twin.
24	Endosperm texture	Maturity	Completely corneous / mostly corneous / intermediate / starchy.
25	Endosperm color	Maturity	White / yellow.
26	Endosperm type	Maturity	Normal / waxy (Corneous) / sugary (Starchy).

- **Sowing season:** In the other sorghum growing areas it is taken in rabi or summer season. Seed produced in seasons other than kharif always produce seeds with good germination and vigor. During kharif, infections due to grain molds deteriorate the seed quality and marketable value of the seed. The sowings are usually carried out before the end of June and September in kharif and rabi seasons respectively. Early sowing wards off shoot fly attack and seed crop passes through its life cycle at the most optimum environmental regime promoting better nicking and seed development.
    - **Kharif:** Immediately after commencement of Monsoon and not later than I week of July.
    - **Rabi:** II Fortnight of Sept.

- **Land selection:** The land selected should be free from volunteer plants and wild grass varieties like Johnson grass, sudan grass and other forage types. The land should not be cultivated with the same crop in the previous season. Land should be fertile with good drainage facility. The land should be well prepared to a fine tilth by deep ploughing, three to four harrowings followed by leveling for uniform germination and plant stand.
- **Seed treatment:** Shoot fly can be effectively controlled by treating the seed with 50% soluble powder of carbofuran @ 100g per kg of sorghum seed.
- **Sowing method:** Maintenance of male sterile line (A- line) involves sowing of two parents i.e., A- line (male sterile) and B- line (male fertile). The borders rows (4 - 6) should be sown

with male line all round the seed production plot. To facilitate frequent rouging operation, a spacing of 60 cm (row to row) and 15 - 20 cm (plant to plant) is advisable. Precautions should be taken to avoid admixing parental lines at the time of sowing. For A- line seed production the seed rate is 7.5 Kg/ha of A- line and 5 Kg/ha of B- line. The usual planting row ratio of A- & B- lines is 4: 2 for breeder seed production.

- **Isolation distance:** The isolation distance prescribed for seed production of sorghum crops is as followed.

Crop	Isolation Distance (m) Foundation	Isolation Distance (m) Certified
Jowar	a-200	100- For other Jowar Variety
	b-400	400- For Johnson Grass
	c-400	200- For forage sorghum

6.2. Nutrient Management

Before final ploughing compost or farmyard manure @ 5 tonnes/acre (12.5 tonnes/ha) should be applied and ploughed into the soil. Instead of this cattle penning can also be practiced. 50 kg neem cake and 500 kg vermicompost per acre (125 kg neem cake and 1250 kg vermicompost per hectare) should be applied as basal manure.

For rainfed crop, 50 kg pungam cake and 250 kg vermicompost should be applied as basal manure just before sowing. First top dressing should be done at 20 – 25 days after sowing using 250 kg/ acre of enriched vermicompost. At 40 – 45 days after sowing apply 25 kg pungam cake and 250 kg vermicompost per acre (60 kg pungam cake and 600 kg vermicompost per hectare) as second top dressing. Spray 10% tender coconut water at the time of flower initiation. All the above mentioned inputs should be applied to the rainfed crop only when the soil is wet.

6.3. Weed Management

Sorghum is slow growing in the early stages and is adversely affected by weeds. Hence, the field should be maintained weed free upto 45 days. However hand weeding on the 10th day of transplanting is a must. Hoe or hand weeding between30 – 35 days after transplanting and between 35 – 40 days for a direct sown crop is necessary.

6.4. Water Management

- **Irrigation:** The crop should be irrigated once a week to increase the percentage of seed setting. Irrigation during primordial initiation, vegetative, milky and maturity stages are very critical. When irrigation during critical stages are withheld that will result in poor seed setting and reduced size of the seeds.

6.5. Pest and Disease Management

- **Roguing:** Roguing should be done in the vegetative phase. Off-types and volunteer plants should be uprooted and removed before they start shedding pollen. Off-types are identified based on the plant height, leaf shape, leaf colour, stem pigmentation, days for flowering etc. Rogue other plants like Johnson grass, sudan grass, forage plants and diseased plants of kernel smut and head smut. Maximum percentage of off-types permitted at the final inspection is 0.01% for foundation seed production and 0.05% for certified seed production.
- **Field inspection:** A minimum of three field inspections should be done between vegetative and harvesting stages by the Seed Certification Officer. First inspection is done during the vegetative stage to check isolation requirement, off-types, volunteer plants and diseased plants. Second inspection is done during the flowering stage to check off-types, isolation and other relevant factors. The third inspection should be scheduled at the time of maturity prior to harvest to check for designated diseases, true nature of plants, head and seed.
- **Harvesting:** Seeds attain physiological maturity 40 – 45 days after 50% flowering. A black layer formed over the seeds is a sign to confirm the physiological maturation of the seeds. After confirming the maturity the earheads should be harvested. At this time the moisture content would be around 20 – 25%.
- **Threshing and processing:** Harvested earheads should be dried further for a safe moisture level of 15 – 18% before threshing. After drying, the earheads are beaten with bamboo stick to separate the seeds. In case of mechanical thresher care should be taken to prevent the seeds from mechanical damage. Threshed grains are winnowed and cleaned. Cleaned seeds are further dried to attain a safe moisture content of 8%.
- **Storage:** Seeds canbe stored upto 12 months under open storage conditions and up to 18 months in moisture vapour proof containers.
- **Field standards:**

  Isolation distances.

Contaminants	Minimum distance (meters)	
	Foundation	Certified
Fields of other varieties of grain and dual-Purpose sorghum	200	100
Fields of the same variety not conforming to varietal purity requirements for certification	200	100
Johnson grass (Baru) Sorghum halpense L.) Pers.)	400	400

Forage sorghum with high tillering and Grassypanicle	400	400

Seed standards

S.NO	Factor	Standard of each Class	
		Foundation Seed	**Certified Seed**
1	Pure seed (minimum)	98.0%	98.0%
2	Inert matter (maximum)	2.0%	2.0%
3	Other crop seeds (maximum)	5/kg	10/kg
4	Weed seeds (maximum)	5/kg	10/kg
5	Ergot, sclerota, seed entrely or partallymodifed as Scelerota, broken Sclerota,or ergoted seed (Sphecelia sorghi-Mc Rae, & Claviceps spp) (maximum)	0.020% (by number)	0.040% (by number)
6	Other distinguishable varieties (maximum)	10/kg	20/kg
7	Germination including hard seeds (minimum)	75%	75%
8	Moisture (maximum)	12.0%	12.0%
9	For vapour-proof containers (maximum)	8.0%	8.0%

7. PEARLMILLET (*Pennisetum glaucum)*

Pearl millet (Pennisetum glaucum) is a major warm season coarse grain cereal grown on 26 million ha in some of the harshest semi-arid tropical environments of Asia and Africa. India has the largest area (9–10 million ha) under this crop, ranking it third along with sorghum. It is cultivated in the most sandy, in fertile Soils and droughty environments. The best season for seed production is October - December. The temperature favourable for seed setting is 37oc. The pollination should not coincide with rains. Rain affect effective seed setting and production of quality seeds.

7.1. Classification

Family	:	Poaceae
Subfamily	:	Panicoideae T
Subtribe	:	Panicinae
Section	:	Panicillaria
Genus	:	Pennisetum
Species	:	*Pennisetum glaucum*

- **Origin:** Pearl millet originated in tropical western Africa some 4000 years ago. The greatest numbers of both wild and cultivated forms of this species occur in this region.
- **Floral Biology:** Seed production procedure in crop species depends on its mode of pollination which corresponds to its floral biology. The salient features of floral biology and mode of pollination in pearl millet are given briefly as under: Pearl millet inflorescence is a compound terminal spike or panicle. The sequence of flowering practically excludes self-pollination in the same inflorescence, but it may occur between the inflorescences of the same plant. By the time anther emergence commences, all stigmas will have emerged, and been pollinated, which avoids selfing under open- pollination conditions. The emergence of the first anther usually begins about three to four days after the first stigma has emerged. Protogyny and the time lag between stigma emergence and anther dehiscence favours cross-pollination, but asynchronous flowering of tillers prevents its full realization. The protogyny in the pearl millet is exploited for controlled cross pollination without resorting to emasculation.

  The inflorescence to be used as a female or male is covered with the glassine paper bag before any stigma is visible. Generally the safest stage is when about one third of the inflorescence is out of the flag leaf sheath. When all stigmas have emerged, the panicle can be considered ready for cross pollination. If selfed seed of the male parent is not required, pollen from it can be collected by bagging even those inflorescences in which stigmas have completely emerged. Fresh pollen from dehiscing anthers, visible as yellow

powder in the transparent selfng bags, is collected by tapping the bagged inflorescence. The pollination is carried out by quickly removing the bag from the female inflorescence, dusting the pollen collected from the male inflorescence, and then rebagging the pollinated inflorescence again.

- **Season:** The suitable season for bajra seed production is October - December. The temperature favourable for seed setting is 37°C. The pollination should not coincide with rains. Rain affects effective seed setting and production of quality seeds. Optimum period for sowing of seed plots of Bajra, is upto 15 th July in Kharif season.
- **Nursery preparation and sowing Seed rate:** Seed rate is 3 kg/acre (8 kg/ha). Add the selected seeds to the salt water (1 kg salt in 10 litres of water) and remove the floating seeds affected by Ergot and Sclerotia. Wash the seeds in fresh water for 2 – 3 times to remove the salt and shade dry. Selected seedsshould be treated with Azospirillum @ 250 gms /3 kg of seeds (600 gms / 8 kg of seeds). Seeds can be sown directly in the main feld in ridges and furrows or seedlings can be raised in the nursery and transplanted to the main feld.
- **Nursery preparation:** Seeds are sown in the nursery and then the seedlings are transferred to the main field. Select an area of 7.5 cents for raising nursery for one hectare (3 cents for one acre). Plough the plot thoroughly and add farmyard manure or compost@ 750 kg / 7.5 cents (300 kg / 3 cents) and incorporate it into the soil by ploughing. Seeds are sown in raised bed nursery in lines. Cover the seeds with farmyard manure @ 500 kg / 7.5 cents(200 kg / 3 cents). 20 – 25 days old seedlings are then transplanted to the main field. The spacing between the plants should be 45 x 20 cm.
- **Main field preparation** The main field is prepared with series ploughing to make it a fine tilth (Tilth is the physical condition of the soil that is soft, friable and properly aerated) and formed into ridges and furrows. Apply compost or farmyard manure @ 5 tonnes/acre (12.5 tonnes/ ha). Seedlings can be transplanted from the nursery or from the directly sown hill. The extra seedlings from each hill should be pulled out at 20 – 25 days after sowing and transplanted. To ensure optimum plant populations (120,000 plants) in a hectare, with 45 cm between rows and 12 cm between plants.

7.2. Nutrient Management

Before final ploughing compost or farmyard manure @ 5 tonnes/acre (12.5 tonnes/ha) should be applied and ploughed into the soil. Instead of this cattle penning can also be practiced. 50 kg neem cake and 500 kg vermicompost per acre (125 kg neem cake and 1250 kg vermicompost per hectare) should be applied as basal manure. After first weeding at 20 – 25 days after sowing first top dressing should be done using enriched vermicompost (2 kg Azospirillum, 2 kg Phosphobacterium and 2 litres Panchagavya mixed with 250 kg vermicompost and kept covered for a week and then used) @ 250 kg/ acre (600 kg/ha) followed by the second topdressing at 40 – 45 days after sowing using25 kg neem cake and 250 kg vermicompost per acre (60 kg neem cake

and 600 kg vermicompost per hectare).

During flower initiation stage 10% tender coconut solution (1 litre tender coconut water + 9 litres of water) should be sprayed.

For rainfed crop, 50 kg pungam cake and 250 kg vermicompost should be applied as basal manure just before sowing. First top dressing should be done at 20 – 25 days after sowing using250 kg/acre of enriched vermicompost. At 40 – 45days after sowing apply 25 kg pungam cake and250 kg vermicompost per acre (60 kg pungam cake and 600 kg vermicompost per hectare) as second top dressing. Spray 10% tender coconut water at the time of flower initiation. All the above mentioned inputs should be applied to the rainfed crop only when the soil is wet.

7.3. Water Management

- **Irrigation:** The field should be irrigated soon after sowing and life irrigation is done on the third day of sowing. Irrigation should be done once in 10 days. Irrigation during tillering, milky stage and maturation stage are very critical. Proper irrigation during critical stages increases the seed setting and quality of the seeds.

  Water is an essential input to ensure good seed yield. The most critical stages to irrigate pearl millet seed crop are tillering, flowering and seed development. Moisture stress at any of these stages reduces seed yield considerably.

7.4. Weed Management

The seed production field should be maintained weed free from the initial stage. The first weeding should be done at 30 – 35 days after sowing. Subsequent weeding can be done depending upon the intensity of the weeds. Weeds claim major share of soil moisture and nutrients, and reduce yield of seed crop. They may act alternate hosts for various diseases and pests, and also create problems during harvesting and threshing.

7.5. Pest and Disease Management

- **Jerking** Jerking is a process of removing the early formed earheads of the first formed tillers to facilitate uniform flowering in all the tillers. It is done at 20 – 25 days after transplanting or 30 – 40 days after sowing.
- **Roguing** Intensive roguing should be done at three growth stages like seedling, tillering and seed setting. To maintain genetic purity of the crop, off-types and diseased plants are rogued out periodically based on the colour and waviness of leaves, plant height, shape

and size of the earhead and colour of the grains etc. The rogues should be either pulled out as a whole plant or cut off at the base. Plants affected by green ear, ergot and grain smut diseases should be removed and discarded from time to time.

- **Field inspection** A minimum of three field inspections should be conducted between pre flowering and harvesting stages by the Seed Certification Officer. First inspection is done before flowering to check isolation, volunteer plants, off-types, downy mildew etc. The second inspection would be made during 50% flowering to determine relevant factors. The final inspection would be made at the maturity stage before harvesting to determine the true nature of the crop and other relevant factors. Maximum percentage of off-types permitted at the final inspection is 0.050% for foundation seed production and 0.10% for certified seed production.
- **Harvesting** Seeds attain physiological maturation 30 - 35 days after 50% flowering. The physiological maturation can be identified by change in the colour of the seeds from green to straw yellow. A dunken layer also forms at the point of attachment to the panicle. The moisture content of the seeds at this stage is 30 – 35%. Harvestingis done in two pickings since, the maturation of the earheads are not uniform because of the tillering habit of the crop. Pearl millet should be harvested as early as possible to minimize losses due to birds and bad weather. At moisture levels higher than 25%, the seeds are too soft to withstand the threshing pressure. The ideal moisture content for harvesting grain pearl millet is below 20%.
- **Threshing and processing** Harvested earheads should be dried for two to three days to attain a safe moisture content of15 - 18% for threshing. Threshing is carried out either manually or mechanically. Normally the dried earheads are threshed by beating with a bamboo stick. Threshed grains are cleaned by winnowing. Threshed and cleaned grains are graded using round perforated metal sieve of4/64” size OSAW cleaner cum grader.
- **Drying and storage** The cleaned and graded seeds can be stored up to 12 months with proper pre-storage treatment. The panicles should be dried to 12% moisture content.
- **Field standards:** Bajra is a highly cross-pollinated crop with 80% of cross- pollination. The crop should be raised in isolation and seeds should be allowed to set by open-pollination. The isolation distance maintained between the varieties is 400 meters for foundation seed and 200 meters for certified seed production.

  Isolation distances:

Contaminant s	Minimum distance (meters)	
	Foundation	Certified
Fields of other varieties	400	200
Fields of the same variety not conforming to varietal purity requirements for certification	400	200

* Differential blooming dates for modifying isolation distances are not permitted.

Specific standards:

Contaminants	Maximum permitted (%)*	
	Foundation	Certified
Off-types at any one inspection at and After flowering	0.050	0.10
*Plants infected by Downy mildew/Green ear (Sclerospora graminicola (Sacc.) Schroet) diseaseat any one inspection	0.050	0.10
**Ergotted earheads (Claviceps microcephala(Fr.) Tul.) at final inspection	0.020	0.040
***Earheads infected by Grain smut (Tolyposporium pencillariae Brefeld and T.senegalense Speg.) at final inspection	0.050	0.10

* Complete stool shall be considered as one infected unit.

** Seed from such fields that have been reported to contain the ergot infection even within the prescribed limits at field stage shall be subjected to floatation treatment with brine to become eligible for certification.

*** Seed fields with incidence of grain smut more than the maximum permissible level can, however, be certified if such seed is treated with an approved organo-mercurial fungicide not earlier than a month prior to its sowing.

- **Seed standards:** The percentage of minimum physical purity of certified and foundation seeds should be 98% with a minimum of 80% of germination capacity and 5- 12% of moisture content. The presence of inert matter should not exceed 2.0%.

S.No	Factor	Standard of each Class	
		Foundation Seed	Certified Seed
1	Pure seed (minimum)	98.0%	98.0%
2	Inert matter (maximum)	2.0%	2.0%
3	Other crop seeds (maximum)	10/kg	20/kg
4	Weed seeds (maximum)	10/kg	20/kg
5	Ergot sclerotia, seed entirely or partially modified as sclerotia, broken sclerotia, or ergotted seed (maximum)	0.020% (By number)	0.040% (By number)
6	Germination including hard seeds (minimum)	75%	75%
7	Moisture (maximum)	12.0%	12.0%
8	For vapour-proof containers (maximum)	8.0%	8.0%

8. KODO MILLET (*Paspalum scrobiculatum)*

Kodo millet (Varagu) (Paspalum scrobiculatum) is a well-known minor millet belonging to the family Gramineae. This coarse millet is highly resistant to drought and can also be cultivated in the areas with 400 - 500 mm annual rainfall. It is grown in gravelly and stony upland poor soils to loamy soils. Seed production can be done in June – July and February – March. The pollination should not coincide with rains for quality and effective seed setting.

8.1. Classification

Kingdom	:	Plantae
Division	:	Magnoliophyta
Class	:	Liliopsida
Order	:	Cyperales
Family	:	Poaceae
Genus	:	Paspalum
Species	:	*Paspalam srobiculatum*

- **Origin:** Kodo millet is a native of India and is in cultivation since time immemorial. Greater diversity of Paspalum species in the Hindustan centre. The crop was domesticated in southern Rajasthan and Maharashtra some 3000 years ago. The crop is known to be spread throughout the tropical regions of the world.
- **Biology:** Kodo is an annual tufted grass that grows to 90 cm high. Some forms have been reported to be poisonous to humans and animals, possibly because of a fungus infecting the grain. The grain is enclosed in hard, corneous, persistent husks that are difficult to remove. The grain may vary in color from light red to dark grey. Compared to other small millets, it has a long-crop cycle, ranging from 105 to 120 days. Kodo millet is one of the hardiest among the small millets and grows well in shallow as well as deep soils; it is also adopted to waterlogged soils. The seeds can remain dormant and be stored for many years.

  Kodo millet is an annual herb with adventitious root arises from lower nodes with numerous thin roots. Branched roots spread laterally and profusely, remain functional throughout the life. Stem is erect, rarely ascending with 60-90cm height, tufted on a very short rhizome. Glabrous stem with swollen nodes and fully sheathed internodes. Nodal bands become purple at later stage. First node is hairy and the other nodes are glabrous with solid internodes. The length of internodes increases gradually from bottom to top in any tillers. The number of tillers varies from 5 to 18 according to genotypes.

The Leaf is simple, alternate, bifarious, erect or sub-erect, finely acuminate, glabrous or sometimes soft hairy. Sheaths long, compressed, loose, the mouth hairy with very short membranous ligule.

- **Floral biology:** Inflorescence is a spike or spike like racemes. Each spikelet consists of 1 or 2 flowers and bears at the base bracts or glumes, one placed a little above and opposite the other. These two are empty while a third one called lemma is flowering i.e. it enclosed a flower in its axil. Opposite the flowering glume or Lemma, there is somewhat smaller, two nerved glumes called Palea. Spikes 2-6, sessile usually distant and spreading, rachis herbaceous, broad with ciliate margins. Spikelets usually 2 ranked, 2-3 mm diameter, sessile or shortly pedicilate, broadly elliptic or suborbicular imbricate.
- **Season:** Seed production can be done in June – July and February – March. The pollination should not coincide with rains for quality and effective seed setting.
- **Field standards:** Kodo millet is a self-pollinated crop. The crop should be raised in isolation. The isolation distance maintained between the varieties is 3 metres for both foundation and certified seed production to maintain the varietal purity.

8.2. Crop Management

- **Land selection:** The selected land should be free from volunteer plants. The land should not be cultivated with the same crop in the previous season. Land should befertile with good drainage facility.
- **Main field preparation:** The main field should be ploughed before the onset of monsoon to enable the soil to hold the moisture. At the onset of monsoon field should be ploughed for 2 – 3 times to make it a fine tilth and formed into ridges and furrows. During final plough apply compost or farmyard manure @ 5 tonnes/acre (12.5 tonnes/ha) and incorporate into the soil. Seeds can be sown in the ridges with a spacing of 30 × 10 cm.
- **Seed selection and sowing:** Seeds used for seed production should be of good quality certified seeds from an authentic source. Seeds should be healthy with required germination percentage. In North India, sowing should be done in mid June to mid July and in South India during September – December. Recommended seed rate is 4 kg/acre (10 kg/ha). Selected seeds should be treated with Azospirillum@ 60 gms/kg of seeds. Treated seeds should be sown with a spacing of 30 x 10 cm. Seeds should be sown at the depth of 3 – 4 cm.

8.3. Nutrient Management

Before final ploughing compost or farmyard manure @ 5 tonnes/acre (12.5 tonnes/ha) should be applied and ploughed into the soil. Instead of this cattle penning can also be practiced. 50 kg neem

cake and 500 kg vermicompost per acre (125 kg neem cake and 1250 kg vermicompost per hectare) should be applied as basal manure. For rainfed crop, apply 50 kg/acre (125 kg/ hectare) of pungam cake and 250 kg per acre (600 kg/ hectare) of vermicompost as basal manure just before sowing. After first weeding at 20 – 25 days after sowing top dressing should be done using enriched vermicompost (2 kg Azospirillum,2 kg Phosphobacterium and 2 litres Panchagavya mixed with 250 kg vermicompost and kept covered for a week and then used) @ 250 kg/acre(600 kg/ha). During flower initiation stage 10% tender coconut solution (1 litre tender coconut water + 9 litres of water) should be sprayed. All the above-mentioned inputs should be applied to the rainfed crop only when the soil is wet.

8.4. Weed Management

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

8.5. Water Management

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

8.6. Pest and Disease Management

- **Roguing:** Roguing should be done often to remove the off-types, volunteer plants and diseased plants from the seed production field to avoid the genetic contamination. Roguing should be done upto the flowering stage. Maximum percentage of off- type permitted at the final inspection is 0.05% for foundation and 0.10% for certified seed production.
- **Field inspection:** A minimum of two inspections should be done between flowering and maturity stages by the Seed Certification Officer. The first inspection is done at the time of flowering to check the isolation and off-types and the second done during the maturity stage prior to harvest to check the off-types and to estimate the yield.
- **Field standards:** Kodo millet is a self-pollinated crop. The crop should be raised in isolation. The isolation distance maintained between the varieties is 3 metres for both foundation and certified seed production to maintain the varietal purity.

- **Isolation distances**

Contaminants	Minimum distance (meters)	
	Foundation	Certified
Fields of other varieties	3	3
Fields of the same variety not conforming to varietal purity requirements for certification	3	3

- **Specific standards**

Contaminants	Maximum permitted (%)*	
	Foundation	Certified
Off-types	0.050	0.10

- **Seed standards**

S.No	Factor	Standard of each Class	
		Foundation Seed	Certified Seed
1	Pure seed (minimum)	97.0%	97.0%
2	Inert matter (maximum)	3.0%	3.0%
3	Other crop seeds (maximum)	10/kg	20/kg
4	Weed seeds (maximum)	10/kg	20/kg
5	Germination including hard seeds (minimum)	75%	75%
6	Moisture (maximum)	12.0%	12.0%
7	For vapour-proof containers (maximum)	8.0%	8.0%

- **Harvesting and processing:** Harvest is done once the earheads are physiologically mature. Normally crop is ready for harvest in 100 days. Physiologically mature earheads will turn from brown to green colour. Plants are cut close to the ground level, bundled and stacked for a week before threshing. The earheads are threshed by trampling under thefeet of bullocks. The threshed grains are further cleaned by winnowing.
- **Drying and storage** The cleaned seeds should be sun dried to attain a safe moisture level of 12%. Care should be taken while drying to avoid mechanical injury to the seeds and contamination. Seeds can be stored upto 13 months under proper storage conditions.
- **Seed standards** The percentage of minimum physical purity of certified and foundation seeds should be 97% with a minimum of 75% of germination capacity and 12% of moisture content. The presence of inert matter should not exceed 2.0%.

9. LITTLE MILLET (*Panicum sumatrense)*

Little millet (Samai) (Panicum sumatrense) belongs to the family Gramineae. The crop can grow well in drought conditions and considered as a good famine food as it can produce some grain even under severe drought conditions when all the other crops fail to produce. It is a typical dryland crop suitable for the areas with low rainfall and poor soils. Seed production can be done during June – July and February – March. The pollination should not coincide with rains for quality and effective seed setting.

9.1. Classification

Kingdom	:	Plantae
Division	:	Magnoliophyta
Class	:	Liliopsida
Order	:	Cyperales
Family	:	Poaceae
Genus	:	Panicum
Species	:	*Panicum sumatrense*

- **Origin:** The origin of this crop is not well documented except for the probable Indian origin since it is endemic to India and has a name in all vernacular languages of India
- **Biology:** It is an annual grass, with culm 30-90 cm. high, rather slender, erect or base geniculate, simple or branched; leaves linear 15 to 50 cm. or more in length,12to 25 cm, broad, gradually tapering from a broad base, glabrous or finely hairy; Sheath- rarely hairy with tubercled base hairs; Ligule- an arrow row of hairs; Node- glabrous; Panicle- very compound, contracted of thyrsiform, often nodding,15 to 45 cm. long; Spikelet- glabrous, rather flattened, suddenly cuspidate, 3- 4.5mm, long, mostly paired on unequal pedicels, but often solitary at the end of the branchlets, lanceolate in flower, elliptic or broadly elliptic in fruit. Glume I- very broadly ovate, subtruncate, then suddenly acute, or scarcely acute, about 1/3 the spikelet, white, membranous, 3-5 nerved, nerves arching and anastomising. Glume II - herbaceous, ovate, lanceolate, 11-13 nerved, almost as long as the spikelet. Glume III- herbaceous, broadly ovate, 9 nerved, slightly shorter than glume II, palea as long as the glume (3-4 mm.) flower neuter or rarely with 3 stamens. Glume IV- narrow elliptic, or elliptic oblong to broadly ovate, acute, shining white or pale brown or dark brown, often 3-5 streaked dorsally; Fruit caryopsis enclosed tightly within the fourth glume and its palea (2.5 to 3.5 mm).
- **Floral biology and pollination:** The hermaphrodite flowers which open in basipetallic pattern have brief and rapid anthesis period. The glumes open for not more than 2-3

minutes, and self-pollination is a rule. There is hardly any natural cross pollination. Under Indian conditions, the flowers open between 9 AM and 12 noon. Emasculation and artificial pollination is difficult in view of small flower size but not impossible in some cases. However, most encouraging results have been obtained by the contact method of crossing.

- **Season:** Seed production can be done during June –July and February – March. The pollination should not coincide with rains for quality and effective
- **Field standards:** Little millet is a self-pollinated crop and should be raised in isolation. The isolation distance maintained between the varieties is 3 metres for both foundation and certified seed production to maintain the varietal purity.
- **Land selection:** Little millet can be cultivated in both rich and poor soils. Well drained loam or sandy loam soils rich in organic matter are ideal for cultivation. The selected land should be free from volunteer plants. The land should not be cultivated with same crop in the previous season.
- **Main field preparation:** The main field intended for little millet seed production should be harrowed for 2 – 3 times to make it a fine tilth and levelled. The leveled field is formed into ridges and furrows. During final plough apply compost or farmyard manure @ 5 tonnes/acre (12.5 tonnes/ha) and incorporate into the soil. Seeds can be sown in the ridges at a depth of 3 - 4 cm with a spacing of 30 × 10 cm.
- **Seed selection and sowing:** Seeds used for seed production should be of good quality certified seeds from an authentic source. Seeds should be healthy with required germination percentage. Recommended seed rate is 4 kg/acre (10 kg/ha). Selected seeds should be treated with Azospirillum @ 60 gms/kg of seeds. Treated seeds should be sown with a spacing of 30 x 10 cm. Seeds should be sown in June – July at the onset of monsoon rains. Summer crop should be sown in the month of February – March. Seeds are broadcast manually or by seed driller in furrows at a depth of 3 – 4 cm.

9.2. Nutrient Management

Before final ploughing compost or farmyard manure @ 5 tonnes/acre (12.5 tonnes/ha) should be applied and ploughed into the soil. Instead of this cattle penning can also be practiced. 50 kg neem cake and 500 kg vermicompost per acre (125 kg neem cake and 1250 kg vermicompost per hectare) should be applied as basal manure. For rainfed crop, apply 50 kg/acre (125 kg/ hectare) of pungam cake and 250 kg/acre (600 kg/hectare) of vermicompost as basal manure just before sowing. After first weeding at 20 – 25 days after sowing top dressing should be done using enriched vermicompost (2 kg Azospirillum,2 kg Phosphobacterium and 2 litres Panchagavya mixed with 250 kg vermicompost and kept covered for a week and then used) @ 250 kg/acre (600 kg/ha). During flower initiation stage 10% tender coconut solution (1 litre tender coconut water + 9 litres of water) should be sprayed. All the above mentioned inputs should be applied to the rainfed crop only when the soil is wet.

9.3. Water Management

- **Irrigation:** Kharif season crop does not require any irrigation. However, if the dry spell prevails for longer period at least one irrigation should be given at the tillering stage to boost the yield. First irrigation should be given 25 - 30 days after sowing followed by the second one at 40 – 45 days after sowing. Summer crop requires2 - 4 irrigations depending upon soil type and climatic conditions. During heavy rains the excess water from the field should be drained out.

9.4. Weed Management

The seed production field should be maintained weed free at least upto 35 days after sowing for retaining the soil moisture and nutrients. Subsequent weeding should be done at an interval of 15 – 20 days. Weeding can be done with hand hoe or wheel hoe.

9.5. Pest and Disease Management

- **Roguing** Roguing should be done often to remove the off-types, volunteer plants and diseased plants from the seed production field to avoid the genetic contamination. Roguing should be done upto the flowering stage. Maximum percentage of off- types permitted at the final inspection is 0.05% for foundation and 0.10% for certified seed production.
- **Field inspection** A minimum of two inspections should be done between flowering and maturity stages by the Seed Certification Officer. The first inspection is done at the time of flowering to check the isolation and off- types and the second inspection is done during the maturity stage prior to harvest to check the off-types and to estimate the yield.
- **Field standards:** Little millet is a self-pollinated crop and should be raised in isolation. The isolation distance maintained between the varieties is 3 metres for both foundation and certifed seed production to maintain the varietal purity.
- **Isolation distances.**

Contaminants	Minimum distance (meters)	
	Foundation	Certified
Fields of other varieties	3	3
Fields of the same variety not conforming to varietal purity requirements for certification	3	3

- **Seed standards**

S.No	Factor	Standard of each Class	
		Foundation Seed	Certified Seed
1	Pure seed (minimum)	97.0%	97.0%
2	Inert matter (maximum)	3.0%	3.0%
3	Other crop seeds (maximum)	10/kg	20/kg
4	Weed seeds (maximum)	10/kg	20/kg
5	Germination including hard seeds (minimum)	75%	75%
6	Moisture (maximum)	12.0%	12.0%
7	For vapour-proof containers (maximum)	8.0%	8.0%

- **Harvesting and processing** Harvest is done once the earheads are physiologically mature. Normally crop is ready for harvest in 80 - 85 days after sowing. The crop should be harvested when two thirds of the seeds are ripe. The harvested earheads are threshed by hand or trampling under the feet of bullocks. The threshed grains are further cleaned by winnowing.
- **Drying and storage** The cleaned seeds should be sun dried to attain a safe moisture level of 12%. Seeds can be stored up to 13 months under proper storage conditions.

10. PROSO MILLET (*Panicum miliaceum)*

Proso millet (Pani varagu) (Panicum miliaceum) is a common and important minor millet belonging to the family Gramineae. This short duration millet variety is widely grown in India. The crop is able to evade drought by its quick maturity. The crop is ready for harvest in 70-80 days. It is specially adapted to hot summers in tropical and high altitudes areas. Among grain crops, the common millet has the lowest water requirement. Best season for seed production is June - July and February March. The pollination should not coincide with rain for quality and effective seed setting.

10.1. Classification

Kingdom	:	Plantae
Division	:	Magnoliophyta
Class	:	Liliopsida
Order	:	Cyperales
Family	:	Poaceae
Genus	:	Panicum
Species	:	*Panicum miliaceum*

- **Biology:** Proso millet growth and development characteristics are explained in detail in three different phases; vegetative, reproductive, and ripening, which may be further sub-divided into physiologically distinct stages. The vegetative phase covers the period from germination to panicle initiation, depending on the cultivar used and climate in the area, may be completed 16 to 20 days after planting. An increase in number of leaves, tiller buds, and plant height are characteristics of this phase. The period, about 20 to 25 days, from panicle differentiation to flowering of the main culm is the reproduction phase. Proso millet stems and leaves are covered with slight hairs. The leaves may grow up to 30 cm long with a short ligule but no auricles. The stem is terminated by a drooping panicle 10 to 45 cm long that may be open or compact. Common millet is an annual reaching to a height of 90 to 120 cm. with a shallow adventitious rooting system. The stems are slender, glabrous or slightly hairy, with hollow internodes, branching occasionally and tillering weakly. But, the Indian cultivars are strongly hairy with profuse branching and tillering.

  Proso plants generally mature between 60-90 days after planting and can be grown successfully in poor soil and hot dry weather. Proso is an easy crop to grow and it seems to be better adapted than most crops to primitive agricultural practices.
- **Floral Biology:** The perfect flower contains two lodicules, three stamens and an ovary with two long styles and feathery stigmas. The flowers are almost completely self-fertilized,

and produce a nearly globular grain, enclosed tightly in the persistent lemma and palea.

Flowers open between 10 AM and 12 noon, as the day temperature rises. The spikelets open and close within about seven minutes and hence self- pollination is predominant, though a very small amount of cross pollination cannot be ruled out. Anthesis is basipetallic.

- **Season:** Best season for seed production is June – July and February – March. The pollination should not coincide with rain for quality and effective seed setting. Proso germinates well at temperatures of 10deg. to 45°C, but does not germinate at 5° or 50°C. The highest rate of germinations is between 35° and 40°C. Seeds without melanopathy (blackening due to infection by a seed pathogen) are important grain quality parameters. In general, dry climate with clear sky and high temperature help attaining good seed quality.
- **Land selection** Proso millet can be cultivated in both rich and poor soils. Well drained loam or sandy loam soils rich in organic matter are ideal for cultivation. The selected land should be free from volunteer plants. The land should not be cultivated with same crop in the previous season.
- **Main field preparation** The main field should be harrowed for 2 – 3 times to make it a fine tilth and levelled. The levelled field is formed into ridges and furrows. During final plough apply compost or farmyard manure @ 5 tonnes/acre (12.5 tonnes/ha) and incorporate into the soil.
- **Seed selection and sowing** Seeds used for seed production should be of good quality certified seeds from an authentic source. Seeds should be healthy with required germination percentage. Recommended seed rate is 4 kg/acre (10 kg/ha).
- Selected seeds should be treated with Azospirillum@ 60 gms/kg of seeds. Treated seeds should be sown with a spacing of 30 x 10 cm. Seeds should be sown in June – July onset of monsoon rains. Summer crop should be sown in the month of February – March. Seeds are broadcast manually or by seed driller in furrows at a depth of 3 – 4 cm.

10.2. Nutrient Management

Before final ploughing compost or farmyard manure @ 5 tonnes/acre (12.5 tonnes/ha) should be applied and ploughed into the soil. 50 kg neem cake and 500 kg vermicompost per acre (125 kg neem cake and 1250 kg vermicompost per hectare) should be applied as basal manure. For rainfed crop, apply 50 kg/acre (125 kg/ hectare) of pungam cake and 250 kg/acre (600 kg/hectare) of vermicompost as basal manure just before sowing. After first weeding at 20 – 25 days after sowing top dressing should be done using enriched vermicompost (2 kg Azospirillum,2 kg Phosphobacterium and 2 litres Panchagavya mixed with 250 kg vermicompost and kept covered for a week and then used) @ 250 kg/acre(600 kg/ha).

During flower initiation stage 10% tender coconut solution (1 litre tender coconut water + 9 litres

of water) should be sprayed. All the above mentioned inputs should be applied to the rainfed crop only when the soil is wet.

10.3. Weed Management

The seed production field should be maintained weed free at least upto 35 days after sowing for retaining the soil moisture and nutrients. Subsequent weeding should be done at an interval of 15 – 20 days. Weeding can be done with a hand hoe or wheel hoe.

10.4. Water Management

- **Irrigation:** Kharif season crop does not require any irrigation. However, if the dry spell prevails for longer period 1 - 2 irrigations should be given at the tillering stage to boost the yield. First irrigation should begiven 25 - 30 days after sowing followed by the second one at 40 – 45 days after sowing. Summer crop requires 2 - 4 irrigations depending upon soil type and climatic conditions. During heavy rains the excess water from the field should be drained out.

10.5. Nutrient Management

- **Roguing** Roguing should be done often to remove the off- types, volunteer plants and diseased plants from the seed production field to avoid the genetic contamination. Roguing should be done up to the flowering stage. Maximum percentage of off- types permitted at the final inspection is 0.05% for foundation and 0.10% for certified seed production.
- **Field inspection** A minimum of two inspections should be done between flowering and maturity stages by the Seed Certification Officer. The first inspection is done at the time of flowering to check the isolation and off-types and the second inspection is done during the maturity stage prior to harvest to check the off-types and to estimate the yield.
- **Field standards:**

  Isolation distances.

Contaminants	Minimum distance (meters)	
	Foundation	Certified
Fields of other varieties	3	3
Fields of the same variety not conforming to varietal purity requirements for certification	3	3

- **Seed Standards:**

S.No	Factor	Standard of each Class	
		Foundation Seed	Certified Seed
1	Pure seed (minimum)	97.0%	97.0%
2	Inert matter (maximum)	3.0%	3.0%
3	Other crop seeds (maximum)	10/kg	20/kg
4	Weed seeds (maximum)	10/kg	20/kg
5	Germination including hard seeds (minimum)	75%	75%
6	Moisture (maximum)	12.0%	12.0%
7	For vapour-proof containers (maximum)	8.0%	8.0%

- **Harvesting and processing** Harvest is done once the earheads are physiologically mature. Normally crop is ready for harvest in 65 - 75 days after sowing. The crop should be harvested when two thirds of the seeds are ripe. The harvested earheads are threshed by hand or trampling under the feet of bullocks. The threshed grains are further cleaned by winnowing.
- **Drying and storage** The cleaned seeds should be sun dried to attain a safe moisture level of 12%. Seeds can be stored upto 13 months under proper storage conditions.

11. BARNYARD MILLET (*Echinochloa frumentacea)*

Barnyardmillet (Echinochloa frumentacea) is an important minor millet grown in India. This millet crop belongs to the Family Gramineae. The crop is able to evade drought by its quick maturity. Best season for seed production is September – October and February – March. The pollination should not coincide with rains for quality and effective seed setting. Barnyard millet is the fastest growing of all millets; it produces a crop in six weeks. It is one of the quickest growing short duration crop, some cultivars come to harvest at 6-8 weeks. The crop is able to evade drought by its quick maturity.

11.1. Classification

Kingdom	:	Plantae
Division	:	Magnoliophyta
Class	:	Liliopsida
Order	:	Cyperales
Family	:	Poaceae
Genus	:	Echinochloa
Species	:	*Echinochloa frumentacea*

- **Biology:** The height of the plant varies between 50 and 100 cm. The inflorescence is 15cm long, densely branched, and usually has purple-ting with awnless scabrous spikelets. It can mature in less than 40 days, and yields about 700-800 kg grain, and 1000-2000 kg of straw per hectare.

  It has coarse leaves and varies from one to five feet in height depending on available moisture and fertility. The seed - head is a compact panicle – type inflorescence four to eight inches long, purplish in color, with awnless seed. Conversely, wild barnyard grass has seed with conspicuous awns and a more.
- **Season:** The crop is able to evade drought by its quick maturity. Best season for seed production is September, October and February – March. The pollination should not coincide with rains for quality and effective seed setting.
- **Land selection** Barnyard millet can be cultivated in both rich and poor soils with variable texture. Well drained loam or sandy loam soils rich in organic matter are ideal for cultivation. The selected land should be free from volunteer plants. The land should not be cultivated with same crop in the previous season.
- **Main field preparation** The main field should be harrowed for 2 – 3 times to make it a fine tilth and levelled. The levelled field is formed into ridges and furrows. During final plough apply compost or farmyard manure @ 5 tonnes/acre (12.5 tonnes/ha) and incorporate

into the soil.

- **Seed selection and sowing** Seeds used for seed production should be of good quality certified seeds from an authentic source. Seeds should be healthy with required germination percentage. Recommended seed rate is 4 kg/acre (10 kg/ha).

  Selected seeds should be treated with Azospirillum@ 60 gms/kg of seeds. Treated seeds should be sown with a spacing of 30 x 10 cm. Seeds should be sown in September - October at the onset of monsoon rains. Summer crop should be sown in the month of February – March. Seeds are broadcast manually or by seed driller in furrows at a depth of 3 – 4 cm.

11.2. Nutrient Management

For rainfed crop, apply 50 kg/acre (125 kg/ hectare) of pungam cake and 250 kg/acre (600 kg/hectare) of vermicompost as basal manurejust before sowing. After first weeding at 20 – 25 days after sowing top dressing should be done using enriched vermicompost (2 kg Azospirillum, 2 kg Phosphobacterium and 2 litres Panchagavyamixed with 250 kg vermicompost and kept covered for a week and then used) @ 250 kg/acre(600 kg/ha). During flower initiation stage 10% tender coconut solution (1 litre tender coconut water + 9 litres of water) should be sprayed. All the above mentioned inputs should be applied to the rainfed crop only when the soil is wet.

11.3. Weed Management

The seed production field should be maintained weed free at least upto 35 days after sowing for retaining the soil moisture and to get high yields. Subsequent weeding should be done at an interval of 15 – 20 days. Weeding can be done with a hand hoe or wheel hoe.

11.4. Water Management

- **Irrigation:** Kharif season crop does not require any irrigation. However, if the dry spell prevails for longer period at least one irrigation should be given at the tillering stage to boost the yield. First irrigation should be given 25 - 30 days after sowing followed by the second one at 40 – 45 days after sowing. Summer crop requires 2 - 4 irrigations depending upon soil type and climatic conditions. During heavy rains the excess water from the field should be drained out.

11.5. Pest and Disease Management

- **Roguing:** Roguing should be done often to remove the off-types, volunteer plants and diseased plants from the seed production field to avoid the genetic contamination. Roguing should be completed within the flowering stage of the crop. Maximum percentage of off-types permitted at the final inspection is 0.05% for foundation and 0.10% for certified seed production.
- **Field inspection:** A minimum of two inspections should be done between flowering and maturity stages by the Seed Certification Officer. The first inspection is done at the time of flowering to check the isolation and off-types and the second inspection is done during the maturity stage prior to harvest to check the off-types and to estimate the yield.
- **Field standards:**

  Isolation distances.

Contaminants	Minimum distance (meters)	
	Foundation	Certified
Fields of other varieties	3	3
Fields of the same variety not conforming to varietal purity requirements for certification	3	3

Specific standards.

Contaminants	Maximum permitted (%)*	
	Foundation	Certified
Off-types	0.050	0.10

Seed Standards:

S.No	Factor	Standard of each Class	
		Foundation Seed	Certified Seed
1	Pure seed (minimum)	97.0%	97.0%
2	Inert matter (maximum)	3.0%	3.0%
3	Other crop seeds (maximum)	10/kg	20/kg
4	Weed seeds (maximum)	10/kg	20/kg
5	Germination including hard seeds (minimum)	75%	75%
6	Moisture (maximum)	12.0%	12.0%
7	For vapour-proof containers (maximum)	8.0%	8.0%

- **Harvesting and processing** Harvest is done once the earheads are physiologically mature. Normally crop is ready for harvest in 75 - 90 days after sowing. The crop should be harvested when two thirds of the seeds are ripe. The harvested earheads are threshed by hand or trampling under the feet of bullocks. The threshed grains are further cleaned by winnowing.

12. PEST OF MILLETS AND THEIR MANAGEMENT

12.1. Pests of Millets

- **Shoot flies:** Insect species that cause damage to wide range of millets. Following are some host specific species.

Sorghum, Finger millet	:	*Atherigona soccata rondani*
Pearl millet	:	*A. Approximata malloch*
Proso millet, Kodo millet	:	*A. Simplex thompson*
Fox tail millet	:	*A. Atripalpis malloch*
Barnyard millet	:	*A. Falcata thompson*
Little millet	:	*A. Pulla wiedmann*

Host crops: Sorghum, Pearl, Finger, Proso, Kodo, barnyard and little millet, maize and members of Poacea.

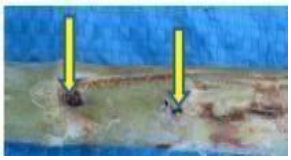
Symptoms: It is a seedling pest normally occurring in the 1st - 6th week after germination. Maggot feeds on the growing tip causing wilting of leaf and later drying of central leaf giving a typical appearance of dead heart. If the infestation occurs a little later, damaged plants produce side tiller which are again infested. In case of Pearl millet pest attacks the crop both in seedlings and boot leaf stage. It causes dead hearts in young pearl millet seedlings and chaffy grains in terminal portion of panicle in the mature crop.

Identification: Fly is a small 3-4 mm long, dark grey housefly like. A female fly lays whitish cigar shaped (eggs singly on lower surface of the leaves. On hatching the maggot enters the seedling and destroys the growing point causing dead heart formation. Mature larva is yellowish and pupation takes place either at the plant base. The fly population tends to increase in July and reaches the peak in August. From September onwards the population gradually declines and remains at a moderate level till March

Stem borers: Among them Spotted stem

borer, Chilo partellus Swinhoe and Pink stem borer, Sesamia inferens Wlk. are major ones. S. inferens infest finger millet in India. Pearl millet appears to be immune to borer attack at initial stages of crop growth but at later stages, it is prone to internodes injury.

Spotted stem borer Chilo partellus Swinhoe (Pyralidae Lepidoptera)



Host crops: Sorghum, Pearl millet, finger millet, sugarcane, rice, Sorghum halepense.

Symptoms: It infests the crop from 2nd week after sowing till the crop maturity.

Initially, the larvae feed on the upper surface of whorl leaves leaving the lower surface intact as transparent windows. As the severity of the feeding increases, blend of punctures and scratches of epidermal feeding appears prominently. Sometimes, `dead hearts" symptoms also develop in younger plants due to early attack. Subsequently, the larvae bore into the stem resulting in extensive stem tunneling.

Identification: The female lays nearly 500 eggs in masses of 10-80 on the under surface of the leaf near the mid rib. The eggs hatch in 4-5 days the larval period lasting for 19 - 27 days. Pupation takes place inside the stem and the adult emerges in 7-10 days. During the dry season, the larva enters into diapauses and survives in harvested stalks/stems as well as stubbles left in the field. As the rainy season starts the diapause brakes down and pupation takes place. The moth is medium size and straw colored.

Ragi stem borer: Sesamia inferens Walker (Noctuidae:Lepidoptera)

Host crops: Sorghum, maize, rice, wheat, sugarcane, bajra and ragi, barley, guinea grasses.

Symptoms: The pink larvae are gregarious in nature, congregate inside the leaf whorls and feed on the central leaves causing typical "pin hole" symptom. The central shoot turns brownish and dries out, although the lower leaves remain green and healthy, called as „dead heart". Bored holes are plugged with excreta. White ear head symptom appears during panicle initiation stage, the empty panicles become very conspicuous in a field because they remain straight and whitish.

Identification: The adult moth is pale pink colored, with dark brown streaks on the fore wings and white hind wings. The female lays about 150 creamy-white and hemispherical eggs that are arranged in two or three rows between the leaf sheath and the stem of the host plant. Egg period remains till 7 days. The fully grown larvae measures about 25 mm and is pale yellow with a purple pink tinge and a reddish- brown head. Pupation occurs in the larval tunnel in the stem and the adult emerges in 12 days. The life cycle is completed in 45-75 days. There are 4-6 generations per year.

White stem borer Saluria inficita Walker (Noctuidae: Lepidoptera)

Host crops: Ragi

Symptoms: This is specific pest of Ragi in southern India. The creamy coloured caterpillar attacks the base of the tillers close to soil causing dead hearts. The larvae pupate in the stem.

Identification: Adult is a medium sized dark brown moth with a pale white band along the costal margin of each fore wing. The hind wings are white in colour. The female lays eggs in batches of about 100 and are covered with silky greyish hairs; they resemble the eggs of the yellow stem borer. The incubation period is about 8 days. The female white stem borer lays the eggs near the tip of the leaf blade.

Red hairy caterpillar: Amsacta albistriga Walker (Arctiidae: Lepidoptera)

Host crops: Sorghum, Ragi, Pearl millet, maize, Barley cotton, castor, cowpea, bajra.

Damage symptoms: They infest young plants. Crop grown in red soils are prone to attack. Due to gregarious habit and voracious feeding, complete defoliation of millet plants or destruction of seedlings may occur in a short time. Dark larvae feed gregariously on the lower surface of leaves scraping for 4-5 days. In about 10 days, they turn ashy brown and slowly spread from plant to plant feeding voraciously. The large larvae have many blackish hairs on a reddish body. The larvae migrate from one field to other for feeding.

Identification: Moth is medium sized having white forewings with brownish markings and streaks and white hind wings with black spots. There is a yellow band on the head and a yellow streak along costal margin of the forewings in A. albistriga while the band on the head and streak along costal margin of the wing are red in A. moorei. Oviposition is spread over 2-3 days. Eggs are cream or bright yellow and are laid in masses on young foliage or on the soil, clods of earth, stones or occasionally on other vegetation. A single female lays about 1000 eggs in clusters of 50-100. Larvae hatch in about 3-4 days Larvae become full grown in about 40-50 days. On either end of the body, larva has black bands enclosing a red band in between.



Black hairy caterpillar Estigmene lactinea Huebner (Arctiidae: Lepidoptera).

Host crops: Sorghum, Pearl millet, Finger millet


Damage symptoms: Black hairy larvae feed on the young leaves leading to defoliation. They scrape the green matter of leading leaving plant veins. The larvae also attack the panicles

Identification: 100 – 150 creamy white coloured eggs are laid on the leaf surface. The eggs hatch in 6- 7 days; the larval period is from 23 - 25 days, pupal period of 11.00 days, total life cycle of 40 - 45 days and adult longevity of 8.5 days. The fecundity per female about 113 eggs. The eggs hatch to black hairy caterpillars which pupate in soil. The adult is large white moth with crimson markings on head, body and wings. The hind wings have black spots.

Cut worms and Army worms: Mythmina seperata Walker, Spodoptera litura (Fab) (Noctuidae: Lepidoptera)




Host crops: Sorghum, Ragi, Maize, Pearl millet and members of Poaceae.

Symptoms: Caterpillars are defoliatiors feeding on foliage. Outbreaks of the noctuids Mythimna separata, M. albistigma have been reported. The noctuids attacked and defoliated finger millet Setaria and various grasses. The larvae feed on the leaves especially in the nursery of Ragi. It

scraps the green matter of the leaf tissue and the leaves shows as skeletonized appearance. The young cutworm feeds on plant without cutting off the stems or leaves. Later it begins to cut off foliage, panicles. They emerge at night to feed on the roots and shoots of ragi plants and hide in the soil during day time. The field looks as if grazed by cattle.

Identification: The larvae migrated even during the day. They cut tender stems of young and growing plants. Larvae hide during day time in the soil and become active at dusk. In severe cases, entire leaf is eaten. The adults of Mythimna separata are brownish in colour, there are black spots in the middle of fore wing. The caterpillars of Spodoptera exigua are serious pests in ragi nurseries feeding on leaves causing extensive defoliation. The grownup larva coils with slightest touch and drops down. The adults are brownish in colour. Fore wings are articulated with margin at border.

Shoot bug: Peregrinus maidis Ashmead (Delphacidae, Hemiptera)

Host crops: Sorghum, maize, rice, millets, members of Poaceae

Symptoms: Infestation in kharif begins 30 days after germination. However, heavy infestation is seen on the Rabi crop, when rain occurs at seedling stage. Both the adult types (Brachypterous and Macropterous) and nymphs suck the plant sap causing reduced plant vigour and yellowing. In severe cases, the younger leaves start drying and gradually extend to older leaves. Sometimes, complete plant death occurs. Heavy infestation at vegetative stage may twist the top leaves and prevent either the formation or emergence of panicles. It is also known to be vector for transmitting stripe disease of maize.

Identification: The adult is yellowish brown to dark brown with translucent wings. The brachypterous female is yellowish while macropterous female is yellowish brown and male dark brown. It lays eggs in groups of 1-4 inside the leaf tissue and covered with a white waxy substance. The fecundity of the bug is 97 eggs / female. The egg period lasts for seven days. The nymphal stage undergoes five instars in 16 days. The total life cycle is completed in 18-31 days. Being a sporadic pest, under favourable conditions, it produces several generations and can cause heavy damage to sorghum.

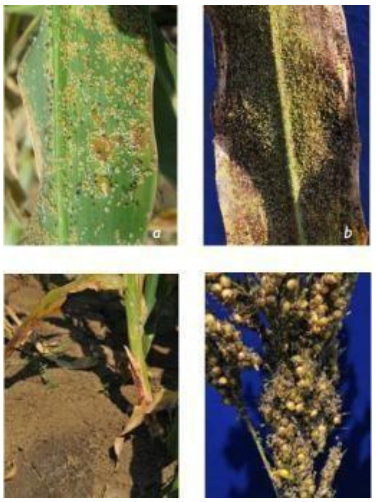
Aphids

Green aphid : Rhopalosiphum maidis, Fitch (Aphididae: Homoptera)
Sugarcane aphid : Melanaphis sacchari Zehntner, (Aphididae: Homoptera)
Plum/ Ragi aphid : Hysteroneura setariae Thomas, (Aphididae: Homoptera)
Ragi root aphid : Tetraneura nigroabdominalis Sasaki, (Pemphigidae: Homoptera)

Host crops: Sorghum, Ragi, Maize, members of Poaceae

Symptoms: Rhopalosiphum maidis: Colonies of aphid is dark bluishgreen and somewhat ovate seen in central leaf whorl, stems, or in panicles. It is 2 mm long, with black legs, cornicles, and antennae. Winged and wingless forms occur. Females give birth to living young without mating and a generation requires only a week or so. During Rabi, the adult is yellow coloured with dark green legs. Female gives birth to young ones and a generation takes 7 days.

The colonies are typically found deep inside the plant whorl of the middle leaf on the ventral surface of the leaves, stem and panicle. The young and adults suck the plant juice. This frequently causes yellowish mottling of the leaves and marginal leaf necrosis. The aphid produces abundant of honeydew on which molds grow. In panicles, honeydew may hinder harvesting. The aphid also transmits mosaic virus.



Melanaphis sacchari: The sugarcane aphid is yellow to buff in colour. Numbers increase rapidly during dry spells or at the end of the rainy season.

Symptoms: Both the nymphs and adults suck the sap from foliage. As a result, the leaves tur yellow and in severe infestation, the plants remain stunted and leave dries. Severe damage is noticed under moisture stress conditions resulting in drying of leaves as well as plant death. Honeydew is excreted by aphids and the sooty mold develops and the leaves turn black. Excess honeydew falls on the soil. The honeydew excretion hinders harvesting process and result in poor quality grain. The female of the wingless form deposits 60-100 nymphs within its reproductive period of 13-20 days. They reproduce parthenogenetically. The winged form produces slightly fewer nymphs. The life cycle is completed in 5.5-7.0 days during the dry season. In general, a generation is completed in about two weeks. Both adults and nymphs such the plant sap and cause stunted growth.

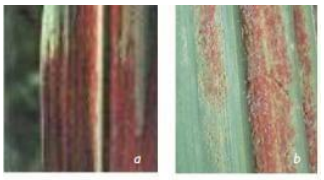
Hysteroneura setariae: Adults and nymphs suck sap from the tender leaves and spikelets and spread to entire plants. The plant becomes stunted with reduced vigour. The leaf aphid is also called rusty plum aphid. It is brown coloured, when crop is caught in dry spell infestations continue throughout crop growth stage. In severely infested crop the earheads are colonized by the aphids.

The ragi aphid completes life cycle in 31-35 days with fecundity of 35-78 nymphs when females are derived from apterous parents. In females from alate female life cycle ranges from 39 – 46 days with fecundity of 52 nymphs.

Spider mites: Oligonychus indicus (Tetranychidae: Arachnida)

Host crops: Sorghum, maize, rice, millets, members of Poaceae

Symptoms: Although found early in the growing season rapid population increases occurs only after the panicle emergence. They suck the plant sap first on the under surface of the functional leaves and the infested areas initially are pale yellow, but later turn to reddish (in purple pigmented cultivars) or brownish tan (in tan pigmented plants) on the upper leaf surface. This extends to the entire leaf area which spreads upwards through the plant affecting plant growth and seed development. The underside of the heavily infested leaves has dense deposits of webbing and in severe infestations they may invade and web even the sorghum panicle



Identification: Female and immature stages feed on the foliage. They thrive under web on the under surface of the leaves. Adults of sorghum spider mite are deep red or maroon and the nymphs are also slightly reddish.

Grain Midge

Sorghum midge:

Stenodiplosis sorghicola Coquilett (Cecidomyiidae: Diptera)

Pearl millet midge:

Geromyia penniseti Harris (Cecidomyiidae: Diptera)

Hosts crops: Sorghum, Pearl millet and wild graminaceous hosts

Symptoms: The maggot feeds on the developing grains and pupates there. Maggots destroy the ovaries seriously, affecting the development of seeds, leading to chaffy panicles. White pupal cases protruding out from the chaffy grains with exit holes are seen. Pupal cases can be seen attached to the glumes of damaged spikelet. Midge complete four to five generations in a season with overlapping generations. The pearl millet midge occurs in pockets of Tamilnadu.

Identification: The adult fly is small, fragile with a bright orange abdomen and a pair of transparent wings. A female lay about 30- 35 eggs at the rate of 6-10 in each floret. The incubation period is 3-4 days. The maggot has four instars with duration of 8-10 days. Larvae are colorless, but, when fully grown, they are dark orange. Larval period 9- 11 days. The larval stage undergoes diapauses in a cocoon during December - January within a spikelet. It pupates beneath the glumes. When the adult emerges the white pupal skin remains at the tip of the spikelet. A generation is completed in 14-16 days

Gram caterpillar:

Helicoverpa armigera Hubner (Noctuidae: Lepidoptera)

Host crops: Cotton, sorghum, lab lab, soybean, pea, safflower, chillies, tomato, groundnut, tobacco, gram, okra, maize etc.

Symptoms: Larvae hide within the ear heads and feeds on the grains. Ear heads are partially eaten and appear chalky. Fecal pellets are visible within the ear head.

Identification: Eggs are round in shape and creamy white in colour. Larva is green with dark broken grey lines and dark pale bands It shows colour variation of greenish to brown Adult is brown coloured moth with a “V” shaped speck on forewings and dull black border on the hind wing.

Semilooper: Eublemma silicule Swinhoe (Noctuidae: Lepidoptera)

Host crop: Sorghum, pearl millet, finger millet

Symptoms: Extensive webbing of grains and presence of broken grains can be seen on the ear head.

Identification: The egg period is four days. Eggs are laid on spikelet and grain. Larva is pale yellow. Larval period lasts for 12-13 days. It pupates within the gallery for about 12 days. The adult moth is small with reddish buff colored wings having wavy lines.

Tussock caterpillar

Euproctes subnotata Walker (Noctuidae: Lepidoptera)

Host crops: Pearl millet Sorghum, finger millet

Symptoms: The pest attacks at panicle stage. The caterpillars feed on developing grain and destroy the grains in panicles at milky, soft dough stage. They produce web of silken threads. The compact panicles are prone to damage. The affected panicles are filled with frass.

Identification: Spherical transparent whitish eggs are laid in masses (5 – 25 eggs) and covered by orange yellow hairs. The hairy caterpillar is smaller, dark brown with a wide yellow band and less hairy. An orange red line runs along the yellow band. The larval period lasts for 15 – 40 days. The larva pupates in soil the pupal period last for 25-30 days. The adult moths have brown forewings with dark scales. The hind wings are yellowish.

Earhead bug

Calocoris angustatus Lethiery (Miridae: Hemiptera)

Host crops: Pearl Millet, maize, tenai, sugarcane and grasses

Symptoms: The adults and nymphs damage the earheads by feeding on them. They suck the juice from the grains when they are in the milky stage. The sucked out grains, shrink and turn black in colour and become ill filled (or) chaffy. Older grain shows distinct feeding punctures that reduce grain quality. Extent of damage usually depends on the number of bugs per panicle, duration of infestation and stage of grain development and decreases as the grain develop towards hard dough stage. Grain mold damage is severe in bug affected panicles.

Identification: Adult male is green in colour and female is green with a brown margin Blue cigar shaped eggs are laid under the glumes or into the middle of the florets. Each insect lays between 150 and 200 eggs. The egg period is seven days. Nymphs are slender, green in color. First instar is orange in color. The nymphal period is 10 - 14 days. The life cycle from egg to adult occupies less than 3 weeks. At least 2 generations of the bug can feed on the same crop when the panicles do not ripen at the same time.

White grubs: Holotrichia sp., Anomola sp, (Melolonthidae: Coleoptera)

Host crops: Pearl Millet, Maize, Groundnut, Sugarcane and grasses

Symptoms: H. consanguinea devastates Pearl millet crop in large areas in central India. The grubs cut the roots resulting in wilting of plants in patches and die. Even three to four grubs may attack the same plant. Infested seedlings remain stunted and produce no seeds.

Identification: In general eggs hatch in 1-3 weeks and grubs develop in 8-22 weeks. The grubs are creamy white in colour and „C" shaped. Pupal period lasts for 1-8 weeks and 13- 20 mm long beetles emerge by November- December if climatic conditions are favorable, otherwise the pest overwinters and adults are active during May-July of the following Year. Late sown millets generally escape attack, but crops may be infested severely later in the season. Adults are oblong in shape and fore wing (elytra) are hard, brownish in colour.

Termites or white ants

Odontotermes spp, Microtermes spp., Macrotermes spp. (Termitidae: Isoptera)

Host range: Pearl millet, sorghum, Finger millet, maize, wheat, sugarcane, upland rice.

Damage symptoms: Termites also attack the roots of maize and sorghum, and the damaged plants topple. They eventually disrupt the movement of nutrients and water through the vascular system resulting in death of the plant. The dead plants are sheathed with soil.

Identification: Termites are found in dry and semidry areas. Termite damage starts soon after sowing and continues till the growing stage. The leaves of damaged plant droop later they wither and dry off. Such plants are easily uprooted. They build underground nests which can be difficult to locate. They will attack weak plants that are wilting or damaged. 7- 10 days after aerial flight the female lays the first batch of eggs numbering 100-130. These eggs hatch in 40-42 days. The female termite then swells to become queen and lays up to 30,000 eggs per day. The members of this group are social insects and are composed of workers, soldiers, king and queen.

12.2. Pest Management

Cultural methods: Collect and burn stubbles and chaffy earheads, and feed the stalks to cattle before the onset of monsoon rains. This will prevent carryover of overwintering pest. Deep

ploughing one month prior to planting will expose the immature stages of insects and serve as a food for predators. Adopt synchronous and timely/early sowings of cultivars with similar maturity to reduce /the damage of shoot fly, midge, and head bugs. Rotate sorghum and millets with cotton, groundnut, or sunflower, to reduce the damage by shoot fly, midge, and head bugs. Intercropping sorghum with pigeonpea, cowpea, or lablab also reduces the damage by stem borers.

Mechanical method: Set up light traps till mid night to monitor, attract and kill adults of stem borer, grain midge, June beetle and other moth pests. Set up the fishmeal traps impregnated with Arpocarbinsecticides @ 12/ha till the crop is 30 days old.

Biorational methods: Applying balanced nutrients to the soil promotes better plant growth, which results in reducing damage by shoot fly and stem borers. Set up sex pheromone trap at 12/ha to attract male moths Helicoverpa sp. from flowering to grain hardening.

Botanical Concoctions and Solutions: T.

Shoot fly:

- Take up early sowing of monsoon to escape from shoot fly incidence. Use more seed rate than recommendation
- Spray aloe vera Kashyam - 3liters/acre to control the adult fly
- Spray Neemastram- 200 liters/acre to destroy the eggs & adult will not lay the eggs or spray neem oil-3ml/liter of water
- Tricho cards-4 per acre(each tricho card containing 20000 eggs of trichogramma,
- Tricho adults will eat the eggs laid by pest

Stem borer:

- Use 8 pheromone traps for estimating the infestation and if we are able to arrange upto 15,then it can control the adults
- Sowing the lab lab / cowpea as an intercrop to minimise stem borer damage (Sorghum: Lab lab /cowpea 4:1).
- Set up of light traps till mid night to monitor the pest. It attract and kill adults of stem borer, grain midge and Earhead caterpillars
- Use Agnastram 3 liters/acre for control to control the larvae

Midge:

- Spray Neemastram-200 liters/acre to destroy the eggs & it will also act as repellant and adult will not lay the eggs or spray Neem oil- 3ml/liter of water

- The sowing should be completed in as short a time- to avoid continuous flowering which favours grain midge and Earhead bug multiplication in an area.
- Spray Brahmastram - 3ltr/acre to control the larvae

Earhead bugs and head caterpillars:

- For bugs-use beauveria-3ml/liter or 3gm/liter to control caterpillars. A fungus infects both nymphs and adults.
- Among the biological control agents, small wasps parasitize the eggs and the meadow grasshoppers prey on them.
- Both the adults and nymphs prey on spiders, coccinellid beetles and dragonflies.
- For Cutworms and Spodoptera use 8 pheromone traps for estimating the pest infestation and 15 for control
- Spray Agnastram- 3 liters/acre for control the larvae

Web worms (Helicoverpa, semilooper):

- Use pheromone traps-8/acre to monitor the pest and 15 traps for controlling the adults - (For trapping the adult)
- Use Brahmastram -3 liters/acre to control the larvae
- Use Agnastram-3 liter/acre to control the larvae

Sucking pest (shoot bug, aphids):

- Use White and yellow sticky plates-15/acre
- Use Neemastram-200 liters/acre to control the adults and will prevent hatching of eggs
- Use Neem oil-3ml/acre
- Use Vavilaku Concoction (vitex negundo) solution -3-5 liters/acre for controlling the adults
- Tobaaco Concoction – 1lt of cocntions / 10 lt of water

Mite:

- Spray Neem oil -3ml/liter
- Spray Onion Concoction -3liters/acre

Termites:

- Flood irrigation at the time of planting, it stops termite attack due to excess moisture
- Fill the gaps in the field to compensate the population
- Use Neem cake 200-300 kgs along with FYM to prevent the infestation

White grub:

- Soil drenching of Imidacloprid 17.8% SL @ 300 ml/ha or mixing Chlorpyriphos 20% EC or Quinolphos 25% EC @ 4 L /ha along with irrigation water in standing crop after three weeks of emergence of beetle is suggested.
- Provide adequate irrigation, Stagnating water for 24hrs in the field then the grub will come out from the soil
- Deep ploughing immediately after harvesting.
- Avoid ratoon cropping
- Apply Beauveria brongniortii @ 2.5 kg/ha (1*109 cfu/g) entopathogenic fungal formulation along with FYM at the time of planting in endemic regions.

Key messages: Shootfly and stemborers are major pest cause economic damage to millets. Caterpillars of various pests cause damage to foliage and earheads of millets. Root grub and termites are soil dwelling pests that cause damage to root system. Earhead bugs, grain midge and gram pod borer are major pests that directly harm grains of millets.

Pest management includes cultural, mechanical, biological and Botanical / Inoculums - which are economically and environmentally viable in traditional millet grown areas.

Learning outcome: Participants would aquire knowledge and develop skill to identify various pests and learn management practices by using natural and chemical compounds.

Assignment for the participants:

- Write few important pests that casue damage to millets.
- How many stages are present in insect pests, what is economical damage stage?
- List out methods to manage pests

12.3. Diseases of Millets and their Management

Learning objectives: By end of this session, participants would able to

- Learn types of diseases that infest millets.
- Know causative agents and their spreading nature.
- Understand various methods to control diseases.

Methodology: Classroom teaching with interactive session, practicals within laboratory with help of live specimen of crops affected with diseases. Field study in nearby millet fields.

Materials required: Flip charts, marker board, marker pens, LCD projector. Plant material.

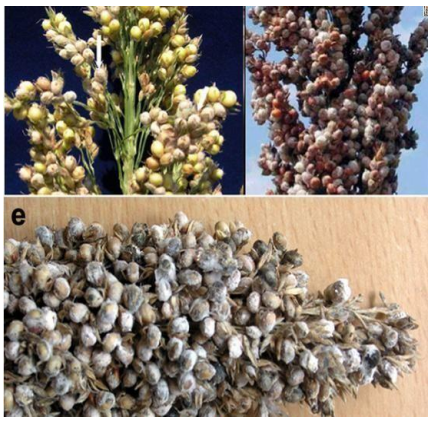
Resource person: Subject Matter Specialist/ Scientist/ Officer from Govt. departments.

Time frame: 6.00 hours (Topic-1: 4.00 hr, Topic-2: 2 hr, hours)

Place of learning: KVK Instructions to resource person

12.4. Disease of Millets

Grain mold



Causal organisms: Fusarium spp., Curvularia lunata, Alternaria alternate, Phoma sorghina, Bipolaris spp., Aspergillus spp.

Millet host: Sorghum, Pearl millet, Finger millet

Survival & spread: Crop residues, soil; air- borne Grain mold is a major disease in sorghum and occasionally may be observed on pearl millet and finger millet. First visible symptoms on sorghum appear on spikelet tissues aspigmentation of lemma, palea or glume or fungal growth on anthers and filaments. Infection results in blasted florets, poor seed set and production of small, shriveled grains. Color of fungal bloom on grain varies from whitish, pinkish, grayish, to shiny black. Internal fungal colonization sometimes induces sprouting of grain. On mature grain symptoms appear as pink, orange, gray, white, or black fungal growth on the grain surface. Discoloration of grain is less prominent on color than white-grain sorghum. Fungal growth starts at the hilar end and subsequently extends on the pericarp surface. Grain mold on pearl millet appears as pinkish or whitish fungal growth on mature grains, whereas on finger millet it is seen as brown to black discoloration of grains.

Sugary disease/ Ergot

Causal organisms:

- Sorghum ergot: Claviceps sorghi, C. Africana
- Pearl millet ergot: C. fusiformis

Millet host: Sorghum, Pearl millet

Survival & spread: Infected panicle, sclerotia in seed & soil, collateral host; seed-, soil-, air-borne First visible symptom of ergot infection is exudation of honeydew like viscous droplet from infected floret. Droplet can be seen on a single, few or all florets in a panicle depending on severity of infection. The fungal structure produced after infection is called sphacelium. Gradually a wart like fungal structure (sclerotium) evolves in place of grain. Honeydews fall on the leaf underneath

and often attract growth of saprophytic fungi, giving leaf surface a black coloration. Sclerotia of sorghum ergot are purple black to black in color, elongated in shape, hard in texture, and bigger than sorghum seed. Sclerotia of pearl millet ergot are light pink to dark brown or black in color, round or elongated in shape and brittle or hard in texture. They are larger than seed, and with a pointed apex which protrude from the florets.

Smut

Millet host: Sorghum, Pearl millet, Small millets Sorghum smut

Causal organisms:

Head smut : Sporisorium reilianum
Covered smut : Sporisorium sorghi
Loose smut : Sporisorium cruenta
Long smut : Tolyposporium ehrenbergii

Survival & spread: Head smut: soil-borne; Loose & covered smut: externally seed- borne; Long smut: airborne Loose smut infected plants become stunted, thin- stalked and flower earlier than healthy plants. All spikelets in a panicle get malformed. The membrane like fungal structure ruptures soon after head emergence and smut spores are blown away leaving the empty spikelet. In head smut, a sorus fully covered with a grayish-white membrane emerges from the boot leaf in place of normal panicle. Later the membrane ruptures and releases spore masses. In covered smut, a fungal sorus is formed in the place of grain. Most of the grains in an earhead are infected. The membrane like structure persists unless it is broken by mechanical force. In long smut, the sorus is covered by a whitish to dull yellow, fairly thick membrane. Sori are much longer (~4.0 cm) than those of the covered and loose smuts.

Udbatta

Causal organism: Ephelis oryzae

Millet host: Foxtail, Kodo & Little millet

Survival & spread: The pathogen can infect grasses like Cynadon dactylon, Pennisetum spp. and Ergostis tenufolia for survival; seed-borne Udbatta is a panicle disease commonly observed

on various small millets in India. Infected plants are usually stunted and occasionally the white mycelia and conidia form narrow stripes on the flag leaves along the veins prior to panicle emergence. The affected panicle is transformed into a compact, silver colored, cylindrical spike that looks like an incense stick much resembling an agarbatti or udbatta and hence the name. An infected panicle fails to produce the normal grain and becomes sterile.

Downy mildew / Crazy top

Millet host: Sorghum, Pearl millet,

Small millets

Sorghum downy mildew

Causal organisms:

Peronosclerospora sorghi (Syn., Sclerospora sorghi)

Survival & spread: Survive as oospores in host tissues and soil; Primary infection in soil, secondary infection through conidia. Symptom is visible as either systemic or localized infection. Systemically infected seedlings are pale yellow or have light-color streaking on the leaf, chlorotic and stunted and may die prematurely. First symptoms are visible on the lower part of the leaf blade, which later progress upward. In cool, humid weather, the lower surfaces of chlorotic leaves become covered by a white, downy growth consisting of conidia and conidiophores of the pathogen. The leaves emerging from the whorl subsequently exhibit parallel stripes of vivid green and white tissue. The infected striped areas die, turn brown, and disintegrate, resulting in a shredded appearance of the leaf. Conidia produced in the infected plants become air-borne and cause rectangular shaped local lesion on the leaf.

Blast

Millet host: Pearl millet, Finger, Foxtail, Barnyard, Proso & Little millets

Finger millet blast

Causal organisms: Pyricularia grisea (Perfect state: Magnaporthe grisea)

Survival & spread: survives in the crop residues and on other cereals. Initial inoculum comes from weeds or collateral hosts; spread by air-borne conidia Blast.

Symptoms can be observed on the seedling, leaf, peduncle and finger, depending on the stage of the crop. Elliptical or diamond shaped lesions on leaves with grey centers, water- soaking and chlorotic halo surrounding the lesions are characteristic symptoms. Under congenial conditions spots enlarge, coalesce and leaf blades give a blasted appearance.

Neck blast symptoms develop as elongated black color lesion mostly one-two inches below the ear. Finger blast symptom starts at the tip and proceeds toward the base of the finger, which becomes brown. Neck infection is the most serious phase of the disease that causes major loss in grain number, grain weight and increase in spikelet sterility.

Pearl millet & small millet blast

Causal organisms: Pearl millet, Barnyard, Proso & Little millets: Pyricularia grisea
Foxtail millet: P. setariae

Survival & spread: Survives on crop residues & other cereals and cause initial infection; spread by air-borne conidia Symptoms on pearl millet appear as grayish, watersoaked lesions on the foliage that turn brown upon drying. Lesions are elliptical or diamond shaped with grey centre and often surrounded by a chlorotic halo, which turns necrotic, giving the appearance of concentric rings.

Extensive chlorosis causes premature drying of young leaves. The symptom may appear on leaves, leaf sheath & stem. Lesions produce abundant spores under high humidity. Apart from finger and pearl millet, the blast can occur on foxtail, barnyard, proso and little millets and several grasses. Symptoms are similar to that on finger millet but neck and finger infections almost absent. The blast pathogen is highly specialized in its host range and the pathogen population that infects rice or any other hosts does not infect pearl millet and vice versa.

Anthracnose

Millet host: Sorghum

Causal organisms: Colletotrichum graminicola (Syn., C.sublineolum, Perfect state: Glomerella graminicola)

Survival & spread: survives on crop residues & wild sorghum; spread by air- borne conidia Initial symptoms of anthracnose on the leaf appear as small, elliptic to circular spots, with straw-color centre and wide margin. The lesion margin may be red, orange, blackish purple, or tan, depending on the pigment present in the cultivar (purple or tan). Adjoining spots may coalesce to give a blighted appearance on the leaf. A black dot like acervulus is often seen at the centre of the necrotic spot, which is the characteristic diagnostic symptom for leaf anthracnose. Apart from leaf the symptom may appear on the mid-rib, leaf sheath on the stalk and on spikelet tissues. In case of severe infection, plants get defoliated and die before reaching maturity. Infected mature stalks may develop reddish internal lesions, which may be continuous or discontinuous giving the stem a ladder-like appearance. Nodal tissues are rarely discolored. If the infection is early and severe, pre-emergence damping-off may occur and the seedlings wilt and die.

Rust

Millet host: Sorghum, Pearl millet, Small millets

Sorghum rust

Causal organisms: Puccinia purpurea

Survival & spread: survives on ratoon or successively grown sorghum, perennial & collateral hosts; spread by air-borne conidia Sorghum rust appears as reddish brown pustules first on both the surfaces of the lower leaves. Generally the upper half of the leaf gets more severe infection than the lower half. As the disease advances the infection spreads to the younger leaves. Several adjoining pustules may coalesce to form large patch on the leaves and the infected leaves die prematurely giving the plants an unhealthy appearance which becomes visible from a distance. The pustules may appear in any parts of the plant including midrib, peduncle and stem. The pathogen produces two types of spores in the pustules on sorghum viz., urediniospore and teleutospore.

Pearl millet & small millet rust

Causal organisms:

- Pearl millet: Puccinia substriata var. indica (Syn., P. substriata var. penicillariae)
- Kodo millet: P. substriata
- Finger millet: Uromyces eragrostidis
- Foxtail millet: U. setariae-italiae
- Little millet: U. linearis

Survival & spread: Survives on alternate host (Brinjal, Grasses); spread by air- borne spore Pearl millet rust appears on the leaf as round to elliptical reddish- orange pustule. The distal half of the leaf is infected first and then pustules spread over both the surfaces. The mature pustules rupture and release rusty spores. Symptoms may appear on the stem and other plant parts. Severely rusted plants look reddish-brown. Small millet rust is common on foxtail and finger millet and also noted on kodo and little millets. Symptoms appear as minute to small, dark brown, broken pustules linearly arranged on the upper surface of the top leaves. The disease is more on the upper leaf compared to lower and middle leaves. U. setariae-italicae produces light yellow and U. linearis black eleutospores. P. substriata develops small brown, oval spots on upper surfaces of leaf. Telia are produced on the lower surface of leaf.

Leaf blight

Millet host: Sorghum, Small millets

Causal organisms:

Sorghum: Exserohilum turcicum (Syn., Hel. turcicum; Bipolaris turcica; Dreschslera turcica, Perfect state: Trichometasphaeria turcica)

Kodo millet: Alternaria spp.

Survival & spread: persists as mycelia and conidia in the infected crop residues or in the soil; spread by air-borne conidia Leaf blight symptoms on sorghum are characterized by appearance of long, elliptical and necrotic lesions on the leaf. Centre of the lesion is straw-color and the margin is usually dark brown. Margin is not conspicuous in tan type ltivar. The size and shape of the lesions vary depending on the level of host resistance. The lesions, in a susceptible genotype, enlarge and coalesce to form purplish gray or tan color necrotic areas on the leaf. The symptoms first appear on the lower or older leaves and then progresses to the upper or younger leaves. The surface of the necrotic lesions appears dark-gray or black in color due to production of spores by the pathogen, especially under damp weather. A severe disease gives the crop a distinctly burnt appearance. Similar symptoms can be seen on kodo and little millets.

Helminthosporium leaf spot

Millet host: Sorghum, Pearl millet, Small millets

Causal organisms:

- **Sorghum:** Bipolaris sorghicola (Target leaf spot)
- Pearl millet: B. setariae
- Proso millet: B. panici-miliacei
- Finger & Little millets: Drechslera nodulosum (Perfect state: Cochliobolus nodulosus)
- Foxtail millet: Cochliobolus setariae

Survival & spread: Survive on crop residues, stray crops, collateral hosts and a few may be seed-borne; spread by air-borne conidia Target leaf spots on sorghum appear as oval to cylindrical, purple to red spots with irregular margin and straw-colored centre. Spots may coalesce to form large lesion. The disease is known as Bipolaris leaf spot on pearl millet and appears as small, brown flecks or oval to oblong or rectangular spots. Lesions may expand and coalesce. Lesions usually are tan or grayish brown with a more or less distinct dark brown border. On finger millet the disease is known as brown spot. The characteristic symptoms appear as brown to dark brown spots on leaf, sheath. Infection on the neck and fingers may occur. Early infection may cause seedling blight.

Cercospora leaf spot

Millet host: Sorghum, Pearl millet, Small millets

Causal organisms:

- Sorghum: Cercospora sorghi (Grey leaf spot)
- Pearl millet: C. penniseti
- Finger millet: C. eleusinis

Survival & spread: survive on crop residues, stray crops, collateral hosts and seed; spread by air-borne spore Grey leaf spots on sorghum appear narrow rectangular lesions delimited by veins;

longitudinally spot enlargement to develop irregular blotches; Lesions turn gray with age. On pearl millet it appears as oval lesion with dark brown margins and pale tan to grey or white centers, dotted with rows of black conidiophores. Lesions can be formed on stems. On finger millet the symptoms are usually observed on the older leaves and then spread to the younger leaves. Initial symptoms appear as reddish-brown specks with yellow halo. Later several such specks coalesce to form large lesions showing burnt appearance. During rains the fungus sporulates and produces grayish white growth at the centre of the spot and then it looks like brown spot.

Banded sheath blight

Millet host: Finger, Foxtail, Barnyard, Proso, Kodo & Little millets

Causal organisms: Rhizoctonia solani (Basidial state: Thanatephorus cucumeris)

Survival & spread: Survives as sclerotia attached with host tissue in soil, pathogen has wide host range Banded sheath blight is a common disease among small millets. It is characterized by oval to irregular light grey to dark brown lesions on the lower leaf and leaf sheath. Symptoms on millet-stalk can be easily observed on finger, kodo, proso , foxtail , barnyard and little millets. The centre of the lesion subsequently turns white with narrow reddish-brown margins. Later the spots get distributed irregularly on leaf lamina. Under favorable conditions, lesions enlarge rapidly and coalesce to cover large portions of the sheath and leaf lamina. At this stage symptom is characterized by a series of copper color bands across the leaves giving a banded appearance. In severe cases, symptoms appear on peduncles, fingers and glumes as irregular to oval, dark brown to purplish necrotic lesions. The mycelia growth along with sclerotia can be observed on and around the lesions.

Sheath rot

Millet host: Kodo millet

Causal organisms: Sarocladium oryzae

Survival & spread: The symptoms are characterized by appearance of large brown discolored patches on the stem-sheath. The disease is typically observed when kodo millet is grown after kharif rice. It was first observed in the Cuddalore district in Tamil Nadu. The fungus that infects rice also infects kodo millet. Other details about the disease are yet to be understood.

Foot rot

Millet host: Finger millet

Causal organisms: Sclerotium rolfsii (Perfect state: Pellicularia rolfsii)

Survival & spread: Survives as sclerotia attached with host tissue in soil, pathogen can infect more than 500 plant species The foot rot of finger millet is mostly observed in Tamil Nadu, Karnataka, Odisha and Gujarat.

The infection occurs in and around the collar region and the infected area remains restricted to

two to three inches above ground level. The basal portion of the affected plant appears water soaked that later turns brown and subsequently dark brown with a concomitant shrinking of the stem in the affected region. Profuse white cottony fungal growth occurs in this area with small roundish white velvety mustard seed like sclerotia bodies. Finally, the leaves lose their lustre, droop and dry and the plant dries up prematurely.

Charcoal rot

Millet host: Sorghum

Causal organisms: Macrophomina phaseolina (Perfect state: Rhizoctonia bataticola)

Survival & spread: Survives as sclerotia attached with host tissue in soil, pathogen can infect more than 500 plant species Initial infection takes place on the root in the soil. The first visible symptom above the ground appears in the form of discoloration at the base of the stalk. The infected root and stalk show water- soaked lesions that slowly turn brown or black. Infected stalks become soft at the base and often lodge even due to moderate wind or by bending the plants. Lodging of the crop and poor grain filling are the indications of charcoal rot infection. The pith and the cortical tissues in an infected stalk are disintegrated and the vascular bundles get separated from one another. The vascular tubes contain numerous minute, dark, charcoalcolored sclerotia of the pathogen, which gives the disease its name, charcoal rot. Normally the disease appears during post-flowering phase, but in some cases seedlings can be infected causing seedling blight.

Bacterial leaf spot

Millet host: Sorghum, Pearl millet, Finger millet

Causal organisms:

- Sorghum: Pseudomonas syringae pv. syringae
- Pearl millet: P. syringae
- Finger millet: Xanthomonas eleusinae

Survival & Spread: Survives on crop residues in soil; spread by rain-splash Bacterial spots is formed on the leaves of sorghum, pearl millet and finger millet. Initial symptoms on sorghum appear as small, elliptical or irregular shaped spots with straw color center and dark margin; spots coalesce to form large bands. On finger millet linear spots may be seen on both the surfaces of the leaf spreading along the veins. In the beginning, spots are light yellowish brown, but soon become dark brown. In advanced stage, the leaf splits along the streak giving a shredded appearance. All the leaves in a plant may be affected. The bacterium, mainly affects the leaves, but at times characteristic streaks may be found on the peduncle.

Bacterial leaf stripe

Millet host: Sorghum, Pearl millet, Finger millet

Causal organisms:

- Sorghum: Pseudomonas andropogoni
- Pearl millet: Ps. avenae
- Finger millet: Ps. eleusinae

Survival & spread: Survives on crop residues in soil; spread by rain-splash Stripes are formed on the leaves of sorghum, pearl millet and finger millet. Initial symptoms on sorghum appear as long, narrow, interveinal red stripes on leaves. Bacterial exudates may be seen on the lesions. The symptoms on the finger millet appear as brown coloration of the leaf sheath especially from base upwards. The affected portion of the lamina invariably involves the midrib and appears straw colored. This symptom spreads to about three- fourths the lamina and then abruptly stops or in some cases reaches the leaf tip. Occasionally the strips spread along the margin, leaving the central portion of the leaf, including the midrib. Infected culms show a light brown discoloration along one side. The discoloration mostly begins 5-7 cm above the base and extends to leaf sheath.

Bacterial leaf streak

Millet host: Sorghum, Pearl millet, Small millets

Causal organisms:

- Sorghum: Xanthomonas axonopodis pv. holcicola
- Pearl millet: X. a. pv. pennamericanum
- Finger millet: X. a. pv. coracanae
- Foxtail, Barnyard, Proso millets: Pseudomonas avenae

Survival & spread: Survives on crop residues in soil; spread by rain-splash Leaf streaks may be seen on sorghum, pearl millet and small millets viz., finger, foxtail, barnyard and proso millets. Initial symptoms on sorghum appear as narrow, interveinal, water-soaked streaks with tan centers and red margins. Profuse bacterial exudates may be seen on the lesions. On finger millet initial symptoms appear as water soaked, translucent, linear, pale yellow to dark greenish-brown streaks, running parallel to the midrib of the lamina. The hyaline streak later develops into a broad yellowish lesion and turns brown. Under severe infection entire leaf turns brown and withers away. If infection takes place during early stage of growth, the plants become yellow and show premature wilting.

Bacterial stalk rot

Millet host: Sorghum

Causal organisms: Erwinia chrysanthemi

Survival & spread: Survives on crop residues in soil; spread by rain-splash, irrigation water. The disease is also known as Erwinia soft rot. Initial symptoms are visible on the tip of the uppermost leaf in the form of longitudinal patches and premature withering of the leaf. Subsequently lower leaves develop drying symptoms and the whole plant turns brown. The top leaves come out easily when pulled up. The base of the stalk shows water-soaked symptoms that later turn reddish dark brown color. When the infected stalk is cut and put into clear water bacterial oozes are seen to come out slowly like a white thread. The infected stem pith is disintegrated and show slimy soft-rot symptoms with foul-smell and eventually the whole plant wilts. The rot may invade a few nodes or the entire stalk turning it brown, which finally dries up and its interior turns into a shredded mass of fibrous tissue. Early infection causes premature death of the plant while late infection induces widespread lodging of the crop.

Viral Diseases

Host crops: Sorghum, Pearl millet, Small millets

Causal virus:

- Maize stripe virus (Sorghum)
- Maize streak virus (Sorghum, Pearl millet, Finger millet)
- Maize mosaic virus (Sorghum)
- Maize dwarf mosaic virus (Sorghum, Pearl millet)
- Sugarcane mosaic virus (Sorghum, Finger millet)
- Ragi mottle streak virus (Finger millet)

Maize stripe Virus of Sorghum (MStV-S)

Transmission: Plant hopper

Peregrinus maidis

Characteristic symptoms on sorghum are appearance of continuous chlorotic stripes/ bands between the veins of the infected leaf, which become yellow with continuous stripes progressing from the base towards the tip of the leaves. Affected plants appear stunted and height depends on stages of infection. Infected plant often fails to exert earhead (arrow). The disease is also known as chlorotic stripe stunt or sorghum stripe disease.

Maize mosaic Virus of Sorghum (MMV-S) Transmission: Plant hopper Peregrinus maidis Appearance of fine, discontinuous, chlorotic streaks between the leaf veins and stunting of the plant characterize MMV infection (Plate 29a). The lesions become necrotic as the disease progresses. Early infected plant dies sooner or later without emergence of earhead.

Plants infected at later stages may develop earhead with or without grain. In case of infection of multiple viruses the symptoms may vary and that may create confusion at field level identification.

Red stripe Disease of Sorghum (SRSD) (Transmission): Mechanically by sap; Aphid The disease is characterized by systemic symptoms of mosaic followed by necrotic red stripe and temperature dependent red leaf and general necrosis in sorghum. A potyvirus naturally infecting sorghum grown in the proximity of sugarcane in Maharashtra was termed as sugarcane mosaic virus-Jg (SCMV-Jg). Later the virus has been named as sorghum red stripe virus-Indian isolate (SRSV-Ind). SRSV was related to potyvirus SCMV.

Viral Diseases of Ragi

Ragi severe mosaic (Transmission): Aphid, Longiunguis sacchari The virus induces mosaic symptoms on young leaves . Infected plants remain stunted; develop nodal roots, and the ears become malformed. They are pale yellow or brownish-white and produce few small seeds. The affected crop appears yellow from a distance. Disease severity decreases with age.

Ragi mottle streak (Transmission): Leaf hopper, Cicadulina bipunctella, C. chinai Symptoms are exhibited as regular dark-green areas along the leaf veins when the plants are 4-6 weeks old. Leaf chlorosis and streak are common. In the lower leaves, the symptoms are of mottle type in the form of white specks and the affected plants are generally stunted bearing small ears.

Ragi streak (Transmission): Leaf hopper, Cicadulina chinai . Symptoms appear on young leaves as pale specks or stripes, which coalesce forming chlorotic bands running parallel to midrib. Bands may be interrupted by dark green areas. Infected plants produce tillers and bear yellowish ears bearing few shriveled seeds.

12.5. Disease Management

Cultural practices: Many agricultural practices such as deep ploughing during summer season, cleaning of field bunds after crop season, removal of crop residues from the field, uprooting the diseased plant from the field and burning, regulating irrigation water from entering into other field, if followed regularly, reduce chances of disease occurrence.

Collateral and alternate hosts, weeds, volunteer and wild crop species harbor pathogen and serve as source of inoculums. Their timely removal helps to control diseases like ergot, downy mildew, rust, blast, leaf spots and bacterial and viral diseases.

Deep summer ploughing, destruction of crop residues and crop rotation with non- host plant help reducing inoculums of soil-borne diseases (downy mildew, smut, charcoal rot and a few fungal and bacterial leaf diseases).

Maintaining optimum plant spacing and regulating the amount of nitrogenous fertilizer reduces incidence of blast, downy mildew and charcoal rot.

Mechanical removal of sclerotia from seeds, by washing in 30% salt water reduces seed contaminated infection of ergot. In seed production plots, ensuring synchrony of flowering between A and R lines avoids the occurrence of ergot.

Management of smut diseases requires awareness among the farmers. Practice of clean cultivation like collecting smutted heads in cloth bags and dipping in boiling water to kill the pathogen will reduce the inoculum for the next year and minimize incidence.

Insect acts as vector for many viruses and injects virus inside the plant. Injury caused by insect in plants sometime help many bacteria to enter and cause disease. Insect control, therefore, helps in managing such diseases

Resistant cultivar: Host-plant resistance provides the most economic and environment friendly method of managing millet diseases. For poor farmers it is the only viable practice, as they hardly use any other methods of disease control in millets.

For grain mold management use of a cultivar that escapes the disease is the best option. Use of mold tolerant cultivar (CSH16, CSH27, CSH30, CSV20 and PVK801) and harvesting the crop at maturity is the second best option to avoid grain deterioration and weathering.

Though high level of genetic resistance is not available against charcoal rot the present day cultivars viz., CSV19R, CSV216R and DSV6 possess good tolerance. Drought tolerant, lodging resistant and non-senescing sorghum genotypes have good tolerance to charcoal rot.

All recently released cultivars of pearl millet (e.g., HHB 67, ICMH 356) possess tolerance to downy mildew as they are released only after multi-location testing.

Resistance sources against finger millet blast are rare in India and Nepal, and they need to be explored in land races from Africa. GPU 28 and GPU 48 is widely used cultivar highly resistant to neck and finger blast.

Barnyard millet genotypes PRB 402, TNAU 92 and VL 216 have resistance against the grain and head smut as well as brown spot diseases, while foxtail millet lines GPUS 27, SiA 3039, SiA 3059, SiA 3066, SiA 3088, TNAU 213 and TNAU 235 remain free from brown spot.

Biological control: Soil-borne diseases of millets (e.g., charcoal rot in sorghum, foot rot and sheath rot in small millets), for which adequate host resistance is lacking, use of biocontrol agents are useful. Seed treatment with talc formulation of Pseudomonas chlororaphis SRB127 reduces charcoal rot incidence and increase seed weight. Bio- control agents especially strains of Trichoderma and Pseudomonas are useful for foot rot and sheath rot in small millets.

Chemical control: Chemicals are not generally used for disease management in millet, because of involvement of high cost of chemical and labor. However, sometimes its use in combination with resistant cultivar becomes necessary. Fungicides are mostly used either as seed treatment or foliar spray. However, combination of them gives better management.

Downy mildew:

- Rogue infected plants up to 45 days of sowing
- spray fungicides-Sour butter milk-6 liter/acre, and LAB liquid-3-5ml/liter of water
- Apply Trichoderma Viridae-1to 2 kgs along with FYM for prevention
- Spray pseudomonas -3ml/liter of water

Loose and covered smuts:

- Seed treatment with Azatobacter and Trichoderma viridae as seed coatings for prevention
- Cow dung, urine and Asafetida solution – 3lt /Ac to control the disease
- Sour Butter milk – 6lt / Ac at the time of starting infection
- LAB – 3-5ml/ lt

Banded sheath blight:

- Seed treatment with Pseudomonas fluorescens @ of 10g/kg of seed followed by seedling dip @ of 2.5 kg or products/ha dissolved in 100 litres and dipping for 30 minutes.
- Soil application of P.fluorescens @ of 2.5 kg/ha after 30 days of transplanting (This product should be mixed with 50 kg of FYM/Sand and then applied).
- Foliar spray of Pseudomonas fluorescens at 0.2% concentration ,commencing from 45 days after transplanting at 10 days interval for 3 times depending upon the intensity of disease.

Blast:

- Use disease free seeds
- Proper plant spacing and transplanting is advisable
- Early sowing (July month) reduces the blast severity

- Spray Pseudomonas fluorescens (Pf1) at 2 g/lit of water. First spray immediately after noticing the symptom. Second and Third sprays at flowering stage at 15 days interval
- Treat the seed with Pseudomonas fluorescens @ 6g/Kg seed and spray the extracts of Prosopis juliflora leaf extract (10%), Ipomoea carnea leaf extract (10%)
- Cow dung, urine and asafetida – 3lt/ ac; to be diluted in 100 lt of water
- Sour butter milt – 6 lt./Ac; to be diluted in 100 lt of water

Ergot:

- spray fungicides-Sour butter milk-6 liter/acre,LAB liquid-3-5ml/liter of water
- Apply trichoderma viridae-1to 2 kgs along with FYM

Rust:

- Spray sulphur containing concoctions / solutions -Sour butter milk-6 liter/acre to be diluted in 100lt of water
- LAB liquid-3-5ml/liter of water
- Apply Trichoderma viridae-1to 2 kgs along with FYM
- Sowing during December - May result in less incidence.
- Adopt control measures when there is rust incidence in the early stages as spread of infection to top leaves results in poor grain filling.

Insect vector will spread the virus diseases:

- Vectors are majorly-Thrips,aphids and jassids..
- These can be controlled by arranging of white and yellow sticky traps 15/acre
- Spray Neemastram -200 liters/acre (without dilution)
- Neem Oil-3ml/liter

Key messages: Majority of diseases are caused by fungi. Grain molds, rgor, smut, cause direct damage to earheads and grins. Rust, leafblight, anthracnose, leafspots, sheath blight affect leaves of millet plants.

Cultural practices play key role disease management. Chemical control with fungicides is most effective in preventing the spered. Use of disease resistant varieties, crop rotation are also important practices in disease management.

Learning outcome: Participants would learn diseases and their causative agents. They understand spreading nature of microorganisam, favourable conditions etc. Participants would understand various methods to manage diseases of millets.

Revitalising Rainfed Agriculture Network (RRA N)

Watershed Support Services and Activities Network (WASSAN)

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