Pearl Millet:
Crop Management and Seed Production Manual

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International Crops Research Institute for the Semi-Arid Tropics

All India Coordinated Pearl Millet Improvement Project (Indian Council of Agricultural Research)

भाकृअनुप ICAR

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Foreword

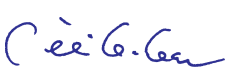
Pearl millet is a major warm season coarse grain cereal grown on 26 million ha in some of the harshest semi-arid tropical environments of Asia and Africa. India has the largest area (9–10 million ha) under this crop, ranking it third along with sorghum. It is cultivated in the most sandy, infertile soils and droughty environments (eg, arid Rajasthan) where no other cereal crop can survive. Even under these conditions, pearl millet yields 300–400 kg ha^{-1} of grain. Pearl millet hybrids maturing in 80–85 days, when cultivated as an irrigated summer season crop in parts of Rajasthan, Gujarat and Uttar Pradesh states of India, have been reported to give as high as 4000–5000 kg ha^{-1} of grain yield. Pearl millet grains have high protein content, balanced amino acid profile, and high levels of iron, zinc, and insoluble dietary fiber. Eggs produced from layers fed on a diet of pearl millet have much lower levels of LDL (the bad cholesterol) than those fed on a maize-based diet. These adaptive and nutritional features combined with high yield potential make pearl millet an important cereal crop that can effectively address the emerging challenges of global warming, water shortages, land degradation and food-related health issues.

Farmers cultivating pearl millet continue to be plagued by uncertain and low economic returns when production falls and also when production increases (due to low prices). This serves as a deterrent for farmers to invest in improved crop management, although the latter can play an effective dual role in increasing productivity and enhancing production stability. The demand for pearl millet grain is likely to increase with its increasing use as poultry and animal feed. This demand can further increase if pearl millet enters the commercial convenience foods channel, thereby increasing grain price. In turn, this will lead to greater investment in crop management and consequently productivity enhancement.

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and National Agricultural Research System (NARS) in India have played a pioneering role in developing a diverse range of improved breeding lines and parental lines of potential hybrids. These lines have been used extensively by breeding programs in both the public and private sectors to develop and commercialize a large number of hybrids (more than 70 were under cultivation in 2006). These hybrids are cultivated on 50% of the total pearl millet area, leading to 65% increase in grain yield during the past 20 years.

Since its inception in 1974, the All India Coordinated Pearl Millet Improvement Project (AICPMIP) has developed production-protection technologies specific to agro-ecoregions of different states. Their application holds the promise of further enhancing the productivity of improved cultivars to commercial farming scales, and hence increasing the profitability of their cultivation, similar to the one witnessed in the seed production sector.

This lucid and comprehensive manual on pearl millet crop management and seed production by AICPMIP and ICRISAT scientists delves into pearl millet biology, its distribution and climatic requirements; and various aspects of crop management and seed production. Though written primarily in the context of agriculture in India, its contents have a wider application for students, teaching and training personnel, extension workers and farmers interested in development, crop management and seed production and marketing of pearl millet.



William D Dar
Director General
ICRISAT

Preface

WHAT this manual is about

The manual describes the concepts, principles and good agricultural practices for increasing the yield and strengthening the seed production and delivery chain of pearl millet.

WHO this manual is for

The manual is for the use of students, teachers/trainers, extension officers and farmers interested in crop management and seed production of pearl millet.

WHY this manual

Pearl millet yields are low in farmers' fields, but the yield potential of popular varieties is high. One of the reasons for this anomaly is lack of knowledge/information on production technologies that can help to tap the high yield potential of pearl millet. Further, pearl millet hybrid seed production has become a highly dependable and income generating enterprise. Therefore, there is a need:

- To learn and adapt a well organized, sequenced and documented teaching material for teachers/trainers to use in their academic or training programs.
- To be aware of, and adopt the good agricultural practices by agricultural extension officers.
- For more self-study system so that students can learn independently.
- To learn and adopt the good agricultural practices by farmers.

HOW is this manual structured

The manual is structured into Modules and Lessons within each Module. Sometimes a Lesson may have Units. At the end of each Module is a quiz available for the user to assess the understanding of the subject. Answers are given at the end of the manual.

WHAT this manual contains

Thirteen Modules on crop management and seed production practices:
Module 1: About pearl millet
Module 2: Area and distribution of pearl millet
Module 3: Soils and climatic requirements
Module 4: Field preparation

Module 5: Pearl millet plant nutrition
Module 6: Plant nutrient deficiency symptoms
Module 7: Cropping systems
Module 8: Seeds and sowing
Module 9: Weeds and weed control
Module 10: Soil moisture relationships and irrigation
Module 11: Harvesting and storage
Module 12: Diseases of pearl millet
Module 13: Seed production, processing and marketing

WHAT will be the outcome for the user

After successful completion of 13 Modules in this manual, the user will have learned to:

- Appreciate the yield potential, nutritive value, adaptive features and multiple uses of pearl millet
- Identify proper soil types to grow pearl millet
- Explain the climatic requirements for pearl millet crop
- Describe field preparation for pearl millet crop
- Choose and efficiently apply manure and fertilizers for pearl millet
- Recognize pearl millet plant nutrient deficiency symptoms
- Choose suitable cropping system practices for pearl millet
- Follow proper sowing techniques to get optimum plant stand in the field
- Identify weeds and implement strategies for their control
- Understand soil moisture relationships in pearl millet cultivation
- Implement practices for proper harvesting and storage practices
- Understand seed production-marketing chain

– Authors

Module 1: About Pearl Millet

There are three Lessons in Module 1: (1) Importance of pearl millet; (2) Uses and nutritional value of pearl millet; and (3) Growth of pearl millet plant.

After completing three Lessons in this Module, you will learn to:

- Explain the importance of pearl millet.
- Describe the uses of pearl millet.
- Recognize the nutritional value of pearl millet.
- Illustrate the growth and development of a pearl millet plant.

Lesson 1: Importance of pearl millet

After completing Lesson 1, you will learn to answer:

- Why pearl millet cultivation is important?
- Why are pearl millet yields low and where is this crop important?
- Is there a scope for pearl millet farmers to increase their income and how?

Pearl millet (*Pennisetum glaucum* (L.) R.Br.) is one of the most extensively cultivated cereals in the world, ranking sixth after rice, wheat, maize, barley and sorghum in terms of area planted to these crops. It is a principal cereal cultivated in drought-prone semi-arid regions of Africa and the Indian subcontinent, mostly for food uses (Fig. 1.1). In USA, Australia, Southern Africa, and South America, pearl millet is grown on limited scale as a forage crop. In addition to grain and forage uses, pearl millet crop residues are used as fodder, building material and fuel for cooking, particularly in dryland areas (Fig. 1.2).

Figure 1.1. Making of roti *(flat bread) with pearl millet dough.*

Figure 1.2. Pearl millet crop residue used as fodder.

Pearl millet crop has wide adaptability to local environments. It is a hardy crop and can be grown in areas which are very hot and dry, and on soils too poor for crops like maize and sorghum (Fig. 1.3). Pearl millet is considered more efficient in utilization of soil moisture and has a higher level of heat tolerance than sorghum and maize.

Pearl millet is usually grown with low or no external inputs (Fig. 1.4); hence yields are generally very low (300–800 kg ha^{-1} grain yield). However, when cultivated as an irrigated crop with 60–80 kg ha^{-1} applied nitrogen, pearl millet hybrids have produced 4000–5000 kg ha^{-1} of grain yield during the summer season in parts of India (Fig. 1.5).

Figure 1.3. Pearl millet crop in desert environment.

Figure 1.4. Pearl millet crop with low/no inputs.

A majority of the subsistence farmers who typically cultivate this crop are unable to take advantage of high yield potential of pearl millet because of the lack of application of improved management practices. Pearl millet productivity can be increased by growing varieties/hybrids with improved tolerance to drought, resistance to diseases, and with fertilizer applications and soil moisture management.

Figure 1.5. Pearl millet hybrid grown under good management.

Of late, food habits of people eating pearl millet are changing towards rice and wheat products. Consumer's preference for pearl millet has fallen due to irregular supplies and rising income, particularly in urban areas. The opportunity cost of women's time has encouraged the shift from pearl millet to readily available processed foods (milled rice, wheat flour, etc) that are far quicker and more convenient for food preparation. However, there is opportunity to improve farmers' income from pearl millet cultivation in dry areas through the adoption of improved cultivars and crop management technologies.

In addition to its use as a food crop, there are possibilities of other alternative uses of pearl millet grain such as novel foods, processed foods, and as feed for dairy animals and poultry. Thus, commercialization of alternative food, feed and industrial products is one of the ways to increase the demand for pearl millet and increase farmers' income.

With this, Lesson 1 on the importance of pearl millet in this Module is concluded. In the next lesson in this Module, you will learn briefly about uses and nutritional value of pearl millet.

Lesson 2: Uses and nutritional value of pearl millet

After completing Lesson 2, you will learn to answer:

- What is the major food value for which pearl millet is cultivated?
- What are the various uses for which pearl millet is grown?
- Why is pearl millet crop popular as a fodder crop?
- Describe the nutritional features of pearl millet grain.

Uses of pearl millet

The use of pearl millet as a food crop is limited to the developing countries in Asia and Africa. It is estimated that over 93% of pearl millet grain is used as food, the remainder being divided between animal and poultry feed (7%). Other uses include bakery products and snacks, to a very limited extent. With a texture much like brown rice, pearl millet can be cooked like rice. When soaked in water for a couple of hours, whole pearl millet grain cooks like rice in about 20 minutes. Increasing in volume more than any other grain, a cup of dry pearl millet expands to three cups of cooked pearl millet. The cooked pearl millet will be fluffy and delicate cereal. Pearl millet is traditionally used for food products like *roti* (flat bread), *bhakri* (stiff *roti*) and porridge or gruel (Fig. 1.6). Pearl millet flour mixed with wheat flour is used for making baking products like breads, cakes, muffins, cookies and biscuits (Figs. 1.7 and 1.8).

Figure 1.6. Pearl millet porridge.

Figure 1.7. Preparation of pearl millet cookies.

Figure 1.8. Cookies and cakes made with pearl millet flour.

The crop residue (stover) after grain harvest is a valuable source of fodder for livestock (Fig. 1.9). Utilization of grain as feed for milch animals or poultry is not significant (at present 7%) in India but in future, it will be a crop of choice for animal and poultry feed (Fig. 1.10). Pearl millet is also cultivated for forage, mostly in North India (Fig. 1.11).

Figure 1.9. Transporting stover of pearl millet.

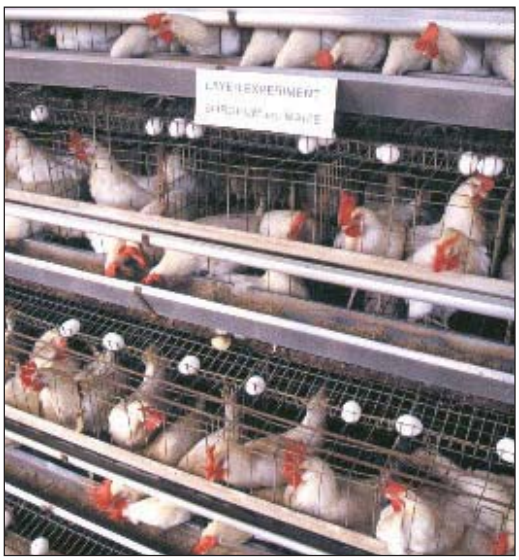


Figure 1.10. Pearl millet grain used as poultry feed.

Figure 1.11. Forage pearl millet.

Nowadays, several varieties and a few hybrids are available exclusively for forage purposes. Utility of pearl millet as green forage and dry fodder is given in Table 1.1. Forage pearl millet is fed to animals as a green chop (Fig. 1.12) or hay (quickly dried fodder).

Table 1.1. Utility of pearl millet as green forage and dry fodder.

Crop	Green forage yield (t ha^{-1})	Dry forage yield (t ha^{-1})	Crude protein (%)
Sorghum	32.7	7.7	6.0
Pearl millet	37.6	8.5	8.7
Maize	30.9	6.5	5.5
Pigeonpea	40.6	12.6	23.7

Figure 1.12. Chopping of forage pearl millet for animal feeding.

Nutritional value of pearl millet

Pearl millet is a principal source of energy, protein, vitamins and minerals for millions of poorest people in the regions where it is cultivated. It generally has 9 to 13% protein, but large variation among genotypes ranging from 6 to 21% has been observed (Table 1.2).

Pearl millet contains more calories than wheat, probably because of its higher oil content of 5%, of which 50% are polyunsaturated fatty acids. It is rich in calcium, potassium, magnesium, iron, zinc, manganese, riboflavin, thiamine, niacin, lysine and tryptophan (Table 1.3).

Pearl millet grain is gluten-free and thus is the only grain that retains its alkaline properties after being cooked which is ideal for people with gluten allergies.

Table 1.2. Composition of pearl millet grain.

Constituent	Range	Mean
Protein (%)	5.8–20.9	10.6
Starch (%)	63.1–78.5	71.6
Crude fiber (%)	1.1–1.8	1.3
Fat (%)	4.1–6.4	5.1
Soluble sugars (%)	1.4–2.6	2.1

Table 1.3. Nutritional composition of pearl millet grain.

Constituent	Content
Calories (Kcal)	360
Minerals (mg $100g^{-1}$ grain)	
Calcium	38.0
Potassium	370
Iron	8.8
Zinc	5.0
Magnesium	106
Amino acids (g $100g^{-1}$ protein)	
Tryptophan	1.74
Lysine	3.01
Methionine	1.82
Vitamins (mg $100g^{-1}$ grain)	
Thiamine	0.33
Riboflavin	0.25
Niacin	2.30

Pearl millet feed value

Pearl millet grain compares favorably with maize and sorghum as high-energy and high-protein ingredient in feed for poultry, pigs, cattle and sheep. Several studies indicated that, compared to maize, pearl millet is 8–60% higher in crude protein, and 40% richer in amino acids such as lysine and methionine. Oxalic acid in pearl millet forage reduces the bioavailability of calcium and hence has a negative impact on milk production and fat content. However, genetic variability for oxalic acid has been found, and pearl millet varieties with acceptable levels of oxalic acid can be developed. Pearl millet forage has also been found to have higher levels of protein content than sorghum and maize.

With this, Lesson 2 on the uses and nutritional value of pearl millet in this Module is concluded. Next is Lesson 3, which is about the growth of pearl millet plant.

Lesson 3: Growth of pearl millet plant

After completing Lesson 3, you will learn to answer:

- How is pearl millet a better crop than other cereal crops like maize, wheat, etc?
- In how many days do pearl millet seeds germinate?
- Describe the root system in pearl millet.
- Describe the shoot system in pearl millet.
- What is boot stage and how can you identify this stage in pearl millet?
- How can you identify flowering in pearl millet?
- What is physiological maturity in pearl millet?
- How can you identify physiological maturity in pearl millet?
- In how many days does the pearl millet plant mature?
- What is the optimum stage to harvest pearl millet?

Pearl millet is a member of the grass family and it was originally a wild plant in Africa (Fig. 1.13). The evolution of pearl millet under the pressures of drought and high temperatures imparted the ability to tolerate drought, soil toxicities and extremes of temperature more effectively than other cereals like wheat and rice.

Figure 1.13. Wild pearl millet species.

Germination

At optimum temperatures (25 to 30°C) and moisture, pearl millet seed germinates in 2 to 3 days. When pearl millet seed is sown in moist soil, the seed swells due to moisture absorption. The seed coat breaks and a small shoot (coleoptile) and a primary root (radicle) develops (Fig. 1.14). Initially, the young seedlings take nutrients from the endosperm of the seed.

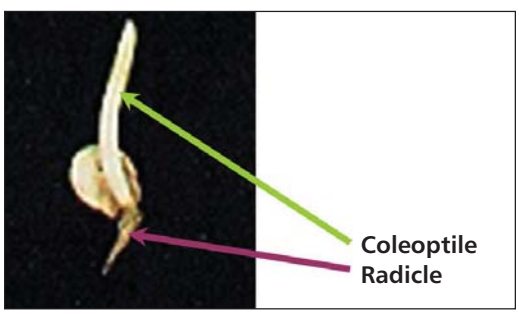


Figure 1.14. Pearl millet germination.

Root system

Primary roots

Primary roots, also called seminal roots, are basically elongation of the radicle. Over time, they deteriorate and finally die (Fig. 1.15a).

Secondary or adventitious roots

Secondary or adventitous roots start appearing 6–7 days after seedling emergence and occupy 5 to 15 cm area in the soil around the base of the stem (Fig. 1.15b). Adventitious roots are small, uniform, and form a small portion of the root system.

Another type of permanent adventitious roots develop from the second internodes and above (Fig. 1.15c). These roots are branched laterally (about 1 m^2) interlacing the soil vertically and mainly supply nutrients to the plant.

Pearl millet roots can grow more than 2 m in pursuit of water and soil nutrients.

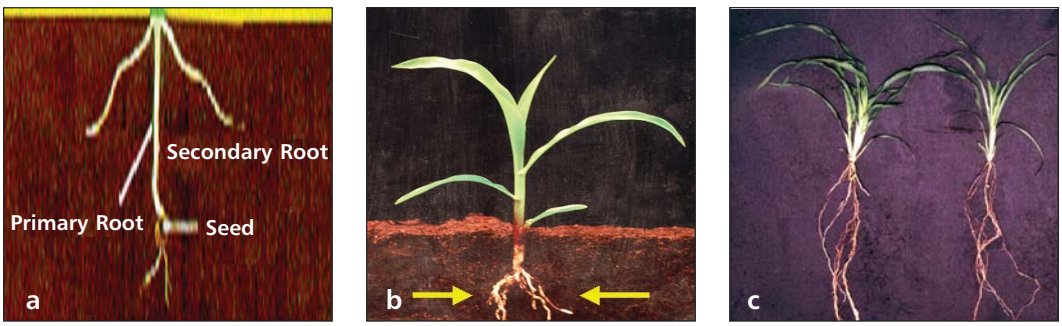


Figure 1.15. Root system of pearl millet: (a) Primary root; (b) Secondary roots; and (c) Permanent adventitious roots.

Shoot system

Seedling development occurs during the first two to four weeks, and later rapid stalk development occurs. Pearl millet often tillers, producing profuse leaf growth. There are different types of tillers: primary, basal, secondary and nodal (Fig. 1.16). Tillering may be extensive in sparse population particularly if good soil moisture is available. About 6 to 8 days before flowering, the boot forms a bulge in the sheath of the flag leaf (uppermost leaf). This stage is called boot leaf stage (Fig. 1.17). Pearl millet usually flowers in 40 to 55 days. Some of the photoperiod sensitive types may take longer to flower, while others may not flower at all when exposed to longer daylength of 14–16 hours.

Figure 1.16. Tillering in pearl millet.

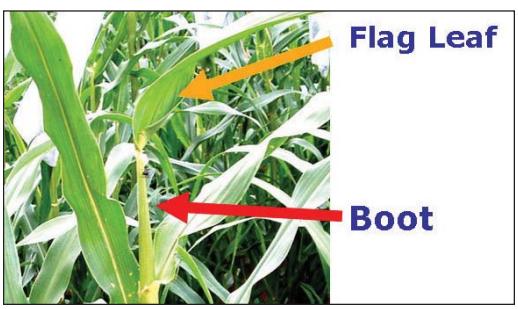


Figure 1.17. Boot leaf stage.

Panicle development

The flower structure (inflorescence) in pearl millet is a compound terminal spike, also called panicle or earhead (Fig. 1.18). In cultivated pearl millets, the panicle starts developing from 22 to 28 days after germination. Each spike consists of 800–3000 spikelets, depending on the size of the spike, and each spikelet consists of two florets. Those florets which are hermaphrodite (bisexual) contain both stamens (male organs) and pistils (female organs). There are florets which only have stamens. Stamens have anthers and pistils have stigmas. Stigmas emerge first (Fig. 1.19) and anthers 3–4 days later. This flowering behavior called protogyny makes pearl millet a highly cross-pollinated crop. It makes both selfing and crossing easy in this crop because selfing just requires covering the spike with a paper bag when it is emerging from the boot. Crossing does not require emasculation. It just requires collecting pollen from the bagged panicles of one line and dusting it on the panicle of the other line when stigmas have fully emerged.

Figure 1.18. Pearl millet panicle.

Figure 1.19. Flowering in pearl millet.

Seed development

The pearl millet seed is a caryopsis. The grain matures in 25 to 30 days after fertilization. Pearl millet seeds may be pearly white, pale yellow, brown, gray, slate blue or purple (Fig. 1.20). The shape may be obovate, lanceolate, elliptical, hexagonal or globular. The 1000-seed mass can vary from 2.5 to 20 g, but most of the improved cultivars have 7–12 g of 1000-seed mass.

Figure 1.20. Pearl millet seeds.

Physiological maturity

Total dry weight of the plant reaches maximum at physiological maturity. Uptake of nutrients also mostly ceases at this stage. So, if there are problems like bird damage, grain molds, etc, it is advantageous to harvest the crop at this stage. Like in sorghum, physiological maturity can be determined by the development of a small dark layer at the bottom of the grain and this occurs about 30 days after flowering. As the seed moisture at this stage will be about 20%, proper drying of the seeds is important.

The growth and development of pearl millet can be divided into three major phases:

Growth phase 1

The seedling establishment with root, leaf and tiller development takes place during this phase. Panicle initiation also begins (Fig. 1.21a).

Growth phase 2

Elongation of all the leaves, emergence of all tillers, floral initiation in tillers, and stem elongation take place during this phase. The elongation of the panicle and formation of floral parts are found in this phase. This phase ends with the emergence of stigmas on the panicle (Fig. 1.21b).

Growth phase 3

This phase begins with the fertilization of florets and continues up to maturity of the plant (Fig. 1.21c). The dry matter accumulation is mainly in grain formation and partly in the enlargement of stem and leaves of the tillers. The end of this phase is physiological maturity, indicated by the development of dark layer at the bottom of the grain.

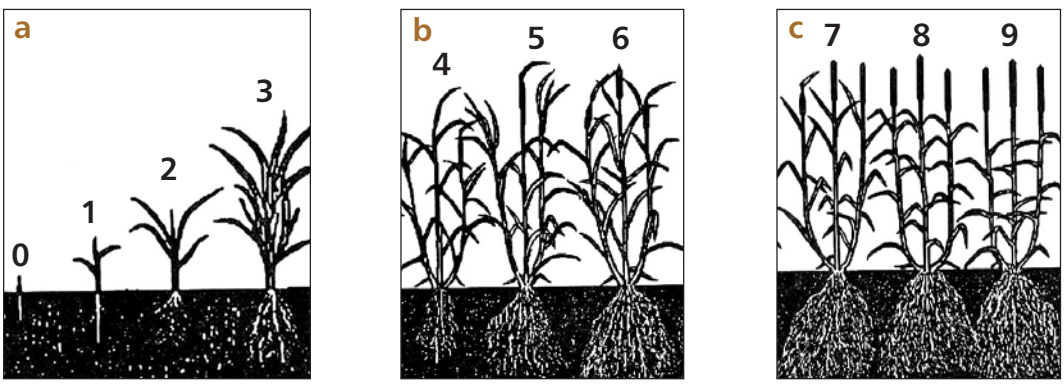


Figure 1.21. Growth and development of pearl millet: (a) Growth phase 1; (b) Growth phase 2; and (c) Growth phase 3.

Growth stages and phases in short-duration and long-duration cultivars are summarized in Tables 1.4 and 1.5. The three growth phases are the averages for environmental

conditions during June–September at Hyderabad, India (17° North latitude). Developmental rates are a function of the environmental conditions and the variety that is grown. The duration of growth phases may vary across locations and varieties.

Table 1.4. Summary of growth stages in short-duration and long-duration cultivars.

		Approximate days after emergence	
Growth stage	Character	Short duration	Long duration
0	Coleoptile visible	0	0
1	3rd leaf stage	6	6
2	5th leaf stage	14	15
3	Panicle initiation	22	28
4	Flag leaf visible	33	43
5	Boot stage	36	47
6	50% stigma emergence	40	50
7	Milk stage	49	59
8	Dough stage	58	68
9	Physiological maturity	70	80

Table 1.5. Growth phases in short-duration and long-duration cultivars.

	Approximate days	
Major growth phase	Short duration	Long duration
Growth phase 1	22	28
Growth phase 2	18	22
Growth phase 3	30	30

With this Lesson, Module 1 concludes. To check your understanding of the subject in this Module, please answer the following questions:

1. Pearl millet is the most important cereal crop in the world, ranking after
A. Wheat
B. Rice
C. Barley
D. Sorghum

2. The low average yields of pearl millet in India is primarily due to
A. Poor soil types and less soil moisture
B. Poor yielding capability of pearl millet
C. Pearl millet being grown in black soils
D. The crop being grown as an intercrop

3. One of the reasons for the decline in pearl millet area in India.

A. Poor farmers crop
B. Difficult to cook
C. No market for the produce
D. Change in the food habits for wheat and rice products

4. One of the ways to increase demand for pearl millet.

A. Growing pearl millet hybrids
B. Using pearl millet for value added products like poultry feeds
C. Growing tannin-free pearl millets
D. I am not sure

5. How many days does pearl millet seeds take to germinate at optimum temperature and moisture?

A. 2 weeks
B. 8 to 10 days
C. 5 to 7 days
D. 2 to 4 days

6. The type of roots in pearl millet in the picture (see figure alongside).

A. Buttress roots
B. Adventitious roots
C. Primary roots
D. I am not sure

7. Which picture shows flowering in pearl millet?

Module 2: Area and Distribution of Pearl Millet

After completing this Module, you will learn to:

- Locate the origin of pearl millet.
- Illustrate where pearl millet crop is important in the world.
- List and describe the features of pearl millet cultivating states in India.
- Recognize the reason for the decline in pearl millet area in India.

Origin of pearl millet

Pearl millet originated in tropical western Africa some 4000 years ago (Fig. 2.1). The greatest numbers of both wild and cultivated forms of this species occur in this region. From there, it differentiated into *globosum* race and moved to the western side, and it also differentiated into the *typhoides* race that reached eastern Africa and spread to India and southern Africa some 2000–3000 years ago.

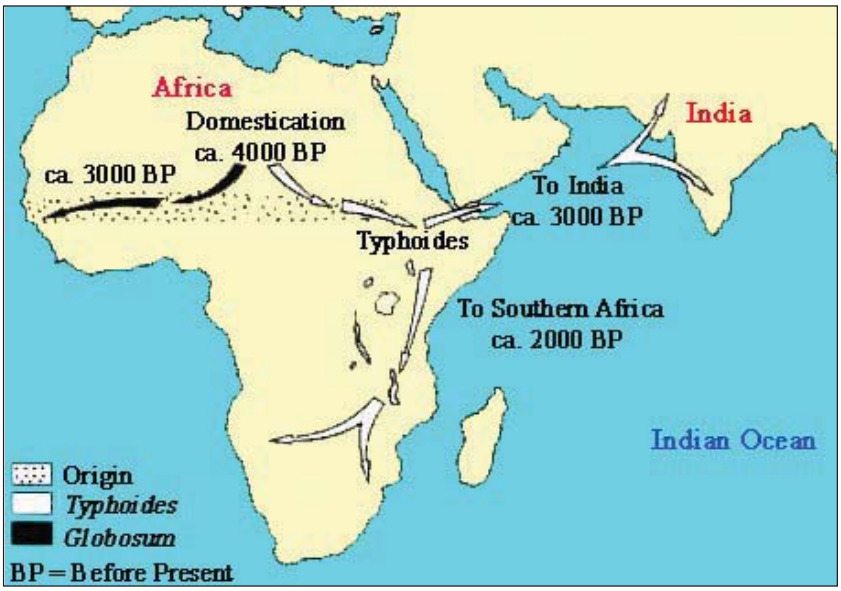


Figure 2.1. Origin of pearl millet.

Distribution of pearl millet

Area and production of pearl millet in the world is combined with other millet crops like finger millet, foxtail millet, etc. So, separate data are not available for pearl millet. However, pearl millet is cultivated mostly in Africa (about 14 million ha) and Asia (about 12 million ha). In Asia, India has the largest area of 10 million ha. Pearl millet accounts for about 50% of the total area under all millets in the world.

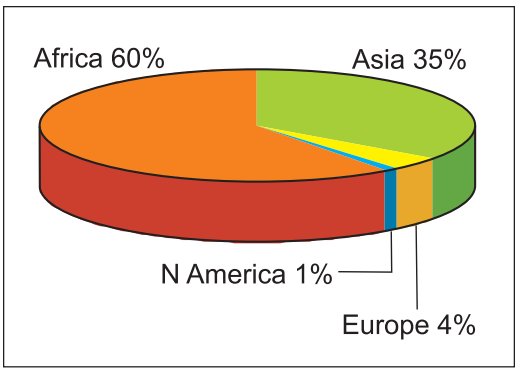


Figure 2.2. World millet area in 2004.

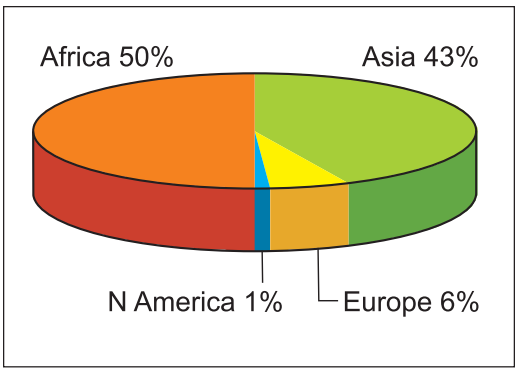


Figure 2.3. World millet production in 2004.

Sixty percent of world millet area is in Africa. Asian countries occupy 35% of world millet area (Fig. 2.2). European countries cover 4% of millet area and 1% is in North America. The developing countries in Asia and Africa contribute about 93% of total millet production in the world (Fig. 2.3). Asia alone contributes 43% of world millet production; European countries produce 6% and North America produces approximately 1%.

Pearl millet area in India

India is the largest producer of this crop, both in terms of area (9–10 million ha) and production (7.0–7.5 million t), with an average productivity of 780 kg ha^{-1} during 2000–04 (Fig. 2.4). As compared to the early 1980s, pearl millet area in India declined by 26% during 2000–04, but production increased by 19% owing to 44% increase in productivity. The major pearl millet growing states in India are given in Table 2.1.

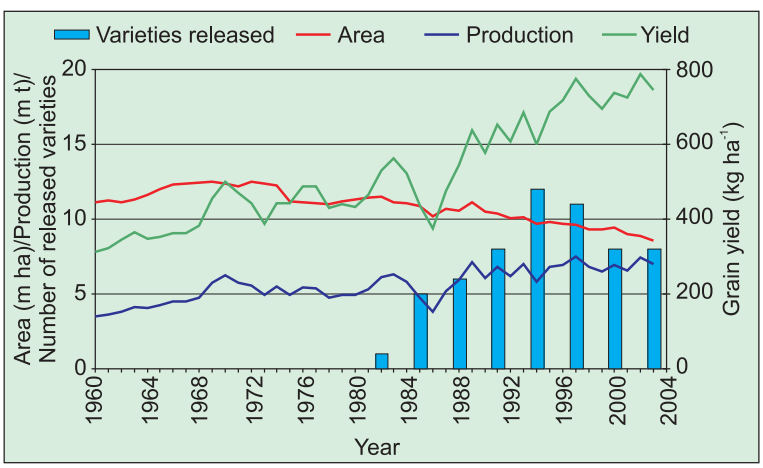


Figure 2.4. Pearl millet area, production and yield trends in India.

Table 2.1. Area, production and yield of pearl millet in different states of India during 2003–04.

State	Area (million ha)	Area share (%)	Production (million t)	Production share (%)	Yield (kg ha^{-1})	Irrigated area (%)
Maharashtra	1.32	12.50	0.90	7.42	676	5
Gujarat	1.07	10.11	1.60	13.20	1494	18
Uttar Pradesh	0.88	8.32	1.12	9.24	1277	5
Rajasthan	5.85	55.29	6.65	54.87	1137	5
Haryana	0.62	5.86	1.00	8.25	1606	24
Tamil Nadu	0.16	1.51	0.20	1.65	1259	12
Karnataka	0.32	3.02	0.21	1.73	660	9
Madhya Pradesh	0.19	1.79	0.26	2.14	1402	0.1
Andhra Pradesh	0.14	1.32	0.15	1.24	1072	22
Jammu & Kashmir	0.20	0.19	0.01	0.08	597	0.8
India	10.58	100	12.12	–	1145	8

Pearl millet cultivation is mainly during rainy season (*kharif*) across the country. It is also grown to a lesser extent during the summer season in Gujarat, Maharashtra, Andhra Pradesh, Karnataka and Tamil Nadu. Summer pearl millet is popular in Gujarat with very high yield exceeding 4–5 t ha^{-1} with excellent grain quality. In parts of Gujarat, pearl millet has also recently emerged as a winter season (*rabi)* crop. It is also grown during the summer season in Punjab, Rajasthan and Uttar Pradesh states predominantly for fodder purposes.

In India, the yield of pearl millet varies from state to state with varying rainfall and soil type, and also between seasons. The productivity imbalance in pearl millet is due to less rains/erratic rains/shifting of pearl millet cultivation to marginal soils due to diversification of traditional area with high value crops across the country. Only about 8% of pearl millet area is irrigated.

Production constraints

Cultivation of pearl millet on marginal lands, and unreliable rainfall tend to keep the use of inputs such as fertilizers to a minimum. Crop losses also occur due to occurrence of downy mildew and bird damage.

With this, Module 2 concludes. To check your understanding of the subject in this Module, please answer the following questions:

1. The origin of pearl millet is

A. Southern parts of Africa
B. Western parts of India
C. Western parts of Africa
D. South American region

2. In which region is pearl millet cultivated to a large extent?

A. South America B. North and Central America

C. Africa D. Asia

3. Why is the average yield of pearl millet in India low?

A. Poor soils B. Illiterate farmers

C. Fertilizers are not applied D. Mostly grown as rainfed crop in poor soils

4. Which state stands first in pearl millet area in India?

A. Andhra Pradesh B. Karnataka

C. Rajasthan D. I am not sure

5. Pearl millet is a popular crop grown during the summer season in

A. Rajasthan B. Haryana

C. Gujarat D. I am not sure

Module 3: Soils and Climatic Requirements

There are two Lessons in Module 3: (1) Pearl millet soils; and (2) Climatic requirements.

After completing two Lessons in this Module, you will learn to:

- Identify soils best suited for pearl millet cultivation.
- Know why problem soils are not suitable for pearl millet cultivation.
- Understand soil fertility conditions in the choice of soils for pearl millet cultivation.
- Explain the climatic requirements for pearl millet crop.
- Recognize the critical stages of pearl millet plant growth when rainfall is important.

Lesson 1: Pearl millet soils

After completing Lesson 1, you will learn to answer:

- What types of soils are best suited for pearl millet cultivation?
- What soil aspects are considered in the choice of a soil type for pearl millet?
- Does pearl millet tolerate soil salinity and alkalinity?

Pearl millet can be grown in different soils. It yields best on fertile, well-drained loamy soils (Fig. 3.1). However, it can also grow in shallow soils and in soils with clay, clay loam and sandy loam texture. Pearl millet does not grow well in soils prone to waterlogged conditions.

Pearl millet grown on deep, well-drained permeable soils usually develops extensive root systems. Mature plant roots may penetrate to a depth of 4 to 6 feet in an ideal soil. Root development can be severely restricted in soils having excessively high or low soil moisture levels, and hard pan and compacted layers. Soils seriously infected with witch weed or *Striga* must be avoided (Fig. 3.2).

Figure 3.1. Loamy soil.

Figure 3.2. Striga*-infested pearl millet field.*

In semi-arid and arid conditions of India, pearl millet is extensively grown in light-textured red sandy, red loamy, alluvial and coastal alluvial soils as well as on mixed black and red and medium black soils. It is also grown on medium black soils, deep alluvial loams and on sandy and gravelly soils of poor fertility with low organic matter content, but the yield is low.

With this, Lesson 1 in this Module concludes. The second lesson in this Module provides information on the climatic requirements for pearl millet cultivation.

Lesson 2: Climatic requirements for pearl millet

After completing Lesson 2, you will learn to answer:

- What are the ecological conditions required for pearl millet cultivation?
- What is the optimum temperature required for germination of pearl millet?
- How does cool temperature affect pearl millet germination?
- How much of rainfall is required for good pearl millet yields?
- What features of pearl millet help in its ability to withstand drought?

Pearl millet can grow in a wide range of ecological conditions and yield reasonably well even under unfavorable conditions of drought stress and high temperatures. It is mostly grown in countries with hot and dry weather, quite characteristic of the arid and semi-arid environments.

Pearl millet is a warm-weather crop and grows best at 30–34°C air temperature. It is more tolerant to higher temperatures than probably any other major cultivated cereal. Pearl millet hybrids having good seed set at air temperatures as high as 46°C are cultivated during the summer in parts of India. These useful characteristics mean that pearl millet is finding a new niche in some unexpected places. The best temperature for the germination of pearl millet seed is 23 to 32°C. Poor emergence and seedling growth may result, if planted before soil temperatures reach 23°C.

The optimum rainfall requirement of pearl millet ranges between 600 and 800 mm. But, pearl millet can be grown in areas which receive even less than 350 mm of seasonal rainfall. Prolonged spells of warm and dry weather is detrimental to the crop, leading to reduced crop yields. At harvest time, dry and warm weather is most suitable. Although pearl millet can respond to good moisture during its growth, it is nevertheless one of the toughest, drought-tolerant crops. It maintains its popularity in the regions where the weather is very unpredictable. The ability of pearl millet to grow in drier environments is due to a number of physiological and morphological characteristics:

- Rapid and deep root penetration (root depths of 3.6 m have been recorded).
- Root system has well-developed and specialized cell walls that prevent desiccation.

- Tillering capacity of pearl millet compensates for any reduction in yield-contributing components such as length of the head, grain weight, etc.

With this, Module 3 concludes. To test your understanding about soils and climatic requirements for pearl millet cultivation, please answer the questions that follow:

1. What type of soils is best suited for pearl millet cultivation?
A. Alfisols B. Fine textured soils
C. Vertisols D. Any fertile and well-drained soil

2. Pearl millet is highly tolerant to saline soils.
A. False statement B. True statement
C. Depends on soil texture D. I am not sure

3. Pearl millet grows well under drought stress and also low temperatures.
A. True statement B. False statement
C. Depends on the country D. I am not sure

4. Pearl millet is sensitive to high soil temperatures at germination stage.
A. True statement B. False statement
C. Depends on soil type D. I am not sure

5. The ability of pearl millet to grow in drier environments is due to
A. Large leaf area B. Less tillering
C. Deep root system D. Leaves with thick midrib

6. Prolonged spells of rains are not good for pearl millet at
A. Germination stage B. Flowering stage
C. Tillering stage D. I am not sure

Module 4: Field Preparation

After completing this Module, you will learn to answer:

- What are the objectives of field preparation?
- How does timely field preparation help?
- What is the advantage of summer plowing?
- What conditions decide the number and depth of plowings?
- What are the pearl millet sowing systems that govern the field preparation?
- What type of implement is used to make ridges and furrows?
- What are the advantages of broad-bed and furrow system?

The objectives of field preparation are based on the following principles:

1. Elimination and control of undesirable plants like crop volunteers and weeds to reduce competition with the established main crop.
2. Provide favorable conditions for sowing, allowing germination, emergence and good plant development.
3. Maintenance of fertility and productivity over a long term by preserving the soil organic matter and avoiding erosion.
4. Breaking of hard pan or compacted layers to increase water infiltration through the soil whilst avoiding erosion.
5. Facilitating mixing of fertilizers, lime or agro-chemical products into the soil.
6. Incorporation of organic matter and agricultural residues.

Timely field preparation facilitates timely sowing, which ensures higher yield. Land preparation should ensure that all crop residues, crop volunteers and weeds are completely buried in the soil.

Summer plowing is advantageous to kill the weed seeds and hibernating insects and pathogens by exposing them to the heat. Initial plowing should be carried out at optimum moisture range to get good tilth and should be avoided when moisture is in excess. Number and depth of plowings depends on weed intensity. For rainy season crop, with onset of rains in May–June, the field is plowed once or twice to obtain a good tilth.

Harrowing of soil should invariably follow after each plowing to reduce the clod size. After the initial plowing, the subsequent plowings and harrowings are carried out when the moisture content of the clods are reduced. The number of plowings should be minimized to reduce the cost of cultivation. Tillage operations should be repeated when the fields are heavily infested with perennial weeds like *Cynodon dactylon* (*dhub* grass) and *Cyperus rotundus* (nut grass) (Figs. 4.1 and 4.2). In that case, deep plowing is needed.

Figure 4.1. Cynodon dactylon (dhub *grass*).

Figure 4.2. Cyperus rotundus (*nut grass*).

Moisture is a critical element in good seedbed preparation and is essential for the successful establishment of the crop. Field preparation depends on the system of pearl millet sowing. Three systems of pearl millet sowing are followed: (1) on a flat surface, or (2) using ridge and furrow system, or (3) on a broad-bed and furrow system.

If sowing is done on a flat surface, the land should be leveled after final plowing using bullock-drawn or tractor-drawn levelers (Fig. 4.3). In ridge and furrow system, ridges are made using either tractor-drawn or animal-drawn ridge plows (Figs. 4.4–4.7).

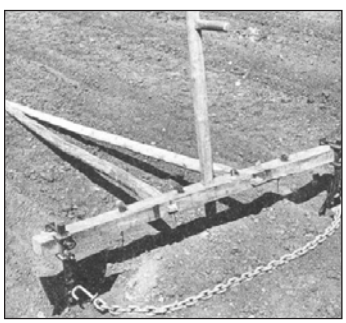


Figure 4.3. Chain attached to a wooden frame of a plow to level the land.

Figure 4.4. A tractor-drawn ridger.

Figure 4.5. Ridges and furrows.

Broad-beds and furrows are prepared by an animal-drawn ridger (Fig. 4.8), mounted on a tool carrier (eg, Tropicultor or Agribar), or by tractor-drawn implements with ridgers. Two ridgers may be fastened on a tool bar so that the top of the bed is 1.2 m wide and the distance from the center of one furrow to the center of the next furrow is 1.5 m. The depth of furrows should be 15 cm or more.

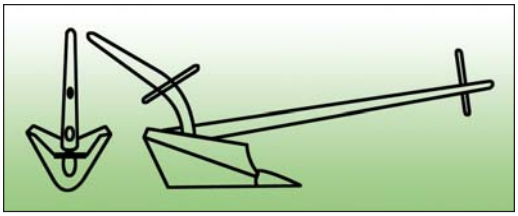


Figure 4.6. Animal-drawn wooden ridge plow.

Figure 4.7. Animal-drawn iron ridge plow.

Figure 4.8. Making broad-beds and furrows with Agribar.

Figure 4.9. Wooden frame leveler.

After forming broad-beds and furrows, the top of the beds are smoothened and leveled using a chain attached to a wooden frame of a plow (Figs. 4.3 and 4.8) or wooden-frame leveler mounted onto a tool bar (Fig. 4.9).

The broad-bed and furrow system has many advantages over flat sowing. These are:

- Helps in draining off excess water from the field.
- Provides more soil aeration for plant growth.
- Greater in-situ moisture conservation.
- Easier for weeding and mechanical harvesting.

With this, Module 4 concludes. To test your understanding of the subject in this Module, please answer the following questions:

1. One of the important objectives of field preparation is

A. To increase the fertility of the soil.
B. To remove weeds and improve soil texture.
C. To improve water-holding capacity.
D. To increase the depth of soil.

2. What conditions decide the number and depth of plowings?

A. Texture of the soil
B. Fertility of the soil
C. Weed intensity
D. Rainfall

3. One of the pearl millet sowing systems that govern the field preparation.

A. Intercropping
B. Ridge and furrow system
C. Crop rotation
D. Variety grown

4. One of the advantages of broad-bed and furrow system.

A. Improves soil fertility
B. Reduces germination of weeds
C. Helps in draining excess water
D. I do not know

Module 5: Pearl Millet Plant Nutrition

There are four Lessons in this Module: (1) Importance of pearl millet nutrition; (2) Importance of primary nutrients – nitrogen, phosphorus and potassium; (3) Importance of other nutrients; and (4) Application of manures and fertilizers.

After completing four Lessons in this Module, you will learn to:

- Discuss about pearl millet plant nutrition.
- Explain the role and need of plant nutrients for proper growth and development of pearl millet crop.
- Choose and efficiently apply manures and fertilizers to meet the plant nutrient needs of pearl millet crop.

Lesson 1: Importance of pearl millet nutrition

After completing this Lesson, you will be able to answer:

- Why is application of manures and fertilizers important in pearl millet cultivation?
- How can the gap between actual and potential pearl millet yields be reduced?
- What is the misnomer regarding fertilizer application to pearl millet crop?
- What is the usual notion (thinking) about potassium application to pearl millet crop?

The low yields in pearl millet are generally due to the crop being grown under less favorable conditions like poor soils, erratic rainfall conditions, etc (Fig. 5.1). Additionally, pearl millet is grown by many farmers in a traditional form of agriculture, ie, without any fertilizer application and with little or no use of manures, etc (Fig. 5.2).

Figure 5.1. Poor pearl millet crop under less favorable conditions.

Figure 5.2. Pearl millet crop grown without fertilizer application.

There is a wide gap between the national average yield (less than 800 kg ha^{-1}) and the potential achievable yield (more than 3,000 kg ha^{-1}). Inadequate availability of essential nutrients is one of the reasons for such a wide gap in pearl millet yields (Table 5.1).

Table 5.1. Grain yield of pearl millet and nutrient removal from the soils.

Grain yield (kg ha^{-1})	Nutrients removed from the soil (kg ha^{-1})		
	Nitrogen	Phosphorus	Potassium
500	13.3	4.7	16.3
1000	26.6	9.4	32.6
1500	39.9	14.1	48.9
2000	53.2	18.8	65.2
2500	66.5	23.5	81.5
3000	79.8	28.2	97.8

Pearl millet, because of its extended root system, extracts soil nutrients from the soil very efficiently. Pearl millet production without fertilizer application is obtained only at the expense of soil-stored nutrients. So, in poor soils the crop eventually gives low yield. Pearl millet responds profitably to a balanced application of plant nutrients.

Generally people opine that most of the Indian soils are rich in potassium and there is no need to apply potassium to pearl millet. The correctness of this statement has to be verified by soil testing. If a soil contains less than 150 kg ha^{-1} of available potassium, recommended dose of potassium application results in higher pearl millet yields.

With this, Lesson 1 on the importance of pearl millet nutrition in this Module concludes. The next Lesson in this Module is about the importance of primary plant nutrients: nitrogen, phosphorus and potassium in pearl millet nutrition.

Lesson 2: Importance of primary nutrients – nitrogen, phosphorus and potassium

There are three Units in Lesson 2 of Module 5:

Unit 1: Nitrogen nutrition; Unit 2: Phosphorus nutrition; and Unit 3: Potassium nutrition.

After completing the three Units in this Lesson, you will be able to answer:

- What is the role of nitrogen, phosphorus and potassium in plant nutrition in general, and in pearl millet crop in particular?
- What is the recommended rate and method of nitrogen application to pearl millet?
- What is the recommended rate and method of phosphorus application to pearl millet?
- How do you decide whether to apply potassium or not?
- What is the recommended rate and method of application of potassium to pearl millet?

Unit 1: Nitrogen nutrition

After completing Unit 1, you will learn to answer:

- What is the role of nitrogen in the growth and development of pearl millet plants?
- Does pearl millet crop require high dose of applied nitrogen?
- Why is a starter dose of nitrogen application important for pearl millet crop?
- What should be the basis to top dress pearl millet crop with nitrogen?

As with other crop plants, nitrogen plays an important role for good growth and development of pearl millet. Nitrogen is to a plant what petrol is to a car. It promotes plant growth which stops when plants run out of nitrogen. Nitrogen, to some extent, enhances the efficient utilization of phosphorus and potassium.

Nitrogen availability to plants is reflected in dark green color of stems and leaves, and vigorous growth (Fig. 5.3). Application of nitrogen is essential for acceptable yields. About 60–80 kg ha^{-1} is the optimum dose. In light soils (sandy loams) the applied nitrogen may be lost due to leaching with heavy rains (Fig. 5.4). So, only about half of the recommended nitrogen dose should be applied at seedbed preparation. The remaining half of nitrogen dose is side-dressed when the crop is 25 days old. On soils which do not leach easily like black soils, all of the nitrogen may be applied during seedbed preparation.

Figure 5.3. Pearl millet crop well supplied with nitrogen.

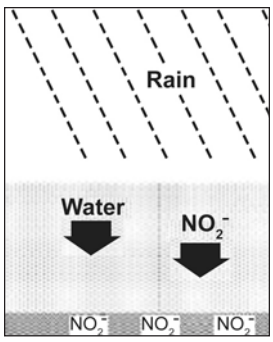


Figure 5.4. Loss of nitrogen due to leaching.

With this, Unit 1 in this Lesson concludes. The next Unit in this Lesson is about phosphorus nutrition.

Unit 2: Phosphorus nutrition

After completing this Unit, you will be able to answer:

- What is the role of phosphorus in plants?
- How is phosphorus application important for pearl millet crop?

- Why is entire phosphorus applied as basal dose?
- What is the method of phosphorus application to pearl millet?

Phosphorus is essential to provide energy for the growth and development of pearl millet plants. Phosphorus is to a plant what wheels are for a car. As a car cannot run on flat tyre even if the petrol tank is full, without phosphorus plants cannot grow even when nitrogen supply is in plenty.

Phosphorus availability helps in increased efficiency of nitrogen use by plants. Pearl millet plants take phosphorus from seedling stage up to grain-filling stage. So, phosphorus should be available to plants throughout their growth. Also, phosphorus uptake has been found to increase with increased availability of nitrogen.

Pearl millet seeds are sensitive to fertilizer burn. Do not apply fertilizer in the furrow with the seed or very near the seed in the row after sowing. It should be applied as side dressing (Fig. 5.5). Single super phosphate is a good source of phosphorus as it also contains calcium (19.5%) and sulfur (12.5%) in addition to phosphorus (16%). Super phosphate also contains zinc and magnesium in traces.

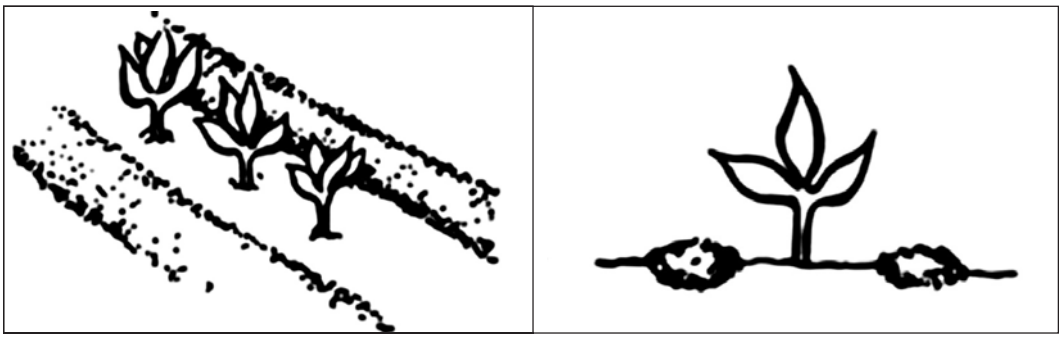


Figure 5.5. Side dressing of phosphorus/potassium fertilizer.

With this, Unit 2 on phosphorus nutrition in this Lesson concludes. The next Unit in this Lesson is about potassium nutrition in pearl millet.

Unit 3: Potassium nutrition

After completing Unit 3, you will be able to answer:

- What is the role of potassium in plants?
- How do you decide whether to apply potassium or not?
- What is the method of potassium application to pearl millet?
- Under what conditions is potassium applied as top dressing?

Though potassium application is not regularly practiced, it plays an equally important role as nitrogen and phosphorus in plants for their growth and development.

Potassium is important because it:

1. Provides resistance to insect pests, diseases and water stress.
2. Makes plants use the water economically.
3. Improves the quality of the crop produce.

Potassium is to a plant what brakes are to a car. Good brakes are a must for safe journey to reach the destination and so is potassium for good quality crop produce. Usually it is considered that most of the Indian soils are rich in potassium.

Make sure that the soil will meet the potassium needs of the pearl millet crop in your field through soil testing. If the soil test reveals that the available potassium is less than 150 kg of K_2O ha^{-1}, then there is a need to apply potassium in that field.

Uptake of potassium is greater in the early part of pearl millet growth than that of nitrogen and phosphorus. So, potassium fertilizers are usually applied in one dose at the time of sowing. However, in light soils, to minimize the loss of potassium due to leaching under heavy rainfall conditions, apply potassium in two split doses. In such cases, the top dressing should be done within 30 to 40 days of sowing.

Potassium fertilizers are placed along with nitrogen and phosphorus either in the furrows or side-dressed before sowing (Fig. 5.5). Potassium, if needed, is top dressed along with nitrogen application. The fertilizers are applied near the rows of the pearl millet plants and incorporated either by intercultivation or by manual weeding. There should be sufficient moisture in the soil at the time of top dressing of fertilizers.

With this, Unit 3 in Lesson 2 concludes. The next lesson is about the importance of other nutrients for pearl millet.

Lesson 3: Importance of other nutrients

After completing this Lesson, you will be able to answer:

- What are secondary nutrients?
- What are micronutrients?
- Why and where calcium and sulfur become deficient in pearl millet?
- How do you identify the need for the application of these plant nutrients to pearl millet?
- How do you decide whether to apply zinc or not?
- What is the recommended method of application of iron and zinc to pearl millet?
- How can iron deficiency be rectified?

Plants need certain other nutrients in addition to the nutrients which were discussed in Lesson 2. These nutrients are secondary nutrients and micronutrients. The secondary nutrients are calcium, magnesium and sulfur. The important micronutrients are iron, zinc, boron, molybdenum, manganese, copper, chlorine and cobalt.

These nutrients are equally essential for pearl millet plants for proper growth, development and disease resistance. Continued use of only common fertilizers, which do not supply these nutrients, is leading to their deficiencies, resulting in reduced pearl millet yields. Testing the soil will help in identifying the need for the application of these plant nutrients.

Application of organic manures like well-decomposed farmyard manure (FYM) and compost, green manuring and green-leaf manuring practices provide most of these plant nutrients. Also, using fertilizers containing one or more of these nutrients could help in supplying such nutrients. For example, applying super phosphate will not only supply phosphorus but also provide calcium and sulfur. Calcium and sulfur deficiencies may occur in problem soils. In acid soils, calcium application may be required. Similarly, sulfur deficiency may occur in alkaline soils. However, we very rarely come across the deficiency of these secondary nutrients in pearl millet growing areas.

Among the micronutrients, zinc and iron are most commonly deficient in pearl millet growing areas. Zinc deficiency can be corrected by applying zinc sulfate to the soil before the final plowing. Zinc application to soils lasts for several years. So, zinc should be applied once in 3 to 5 years.

Soil application of ferrous sulfate at the final plowing is recommended in soils low in available iron. Iron deficiency, if noticed in a standing crop, can be corrected by foliar application of 0.5–1.0% ferrous sulfate solution. Effect of soil application of iron will be long lasting than foliar application.

With this, Lesson 3 in this Module concludes. The last Lesson in this Module is about application of manures and fertilizers to pearl millet crop.

Lesson 4: Application of manures and fertilizers

After completing this Lesson, you will be able to answer:

- What should be the basis for deciding the amount of manures and fertilizers required for pearl millet?
- What is the recommended rate of organic manures for pearl millet?
- What is the nitrogen, phosphorus and potassium recommendation for pearl millet?
- When do you apply nitrogen in two doses?
- When do you apply phosphatic fertilizers?
- When and how will you apply recommended dose of potassium?

Prior to the availability of improved varieties and hybrids, very little fertilizers were used and consequently yields were low. With the cultivation of pearl millet hybrids, fertilizer application is essential to harness the yield potential of these cultivars.

Soil testing to know about the nutrient availability is the first step towards balanced fertilizer application program. In this approach fertilizers are not wasted as only the required amounts are applied for an anticipated level of production. Balanced fertility program improves water use efficiency, drought tolerance and grain yield at the lowest possible cost. Under dryland conditions with low rainfall, 30 to 40 kg of nitrogen ha^{-1} may be adequate for varieties of low yield potential. High/assured rainfall regions or irrigated areas may require 80 to 100 kg nitrogen ha^{-1} to get higher yields.

Recommended rate of nitrogen is applied in two equal split doses in light soils. The first application is done at sowing and the second 3–4 weeks after sowing coinciding with the availability of sufficient soil moisture.

Soil tests showing low and very low phosphorus indicate an expected response to phosphorus application, unless yield potential is restricted by insufficient moisture. Response has been erratic in soils with medium phosphorus levels, and is unlikely when the soil phosphorus levels are high or very high (Fig. 5.6).

The recommended rate of phosphorus application is 25 kg P_2O_5 ha^{-1} for rainfed pearl millet and 45 to 60 kg P_2O_5 ha^{-1} for irrigated pearl millet. The recommended rate of phosphorus is applied in one dose and along with the nitrogen fertilizer at the time of sowing. Phosphorus has to be applied as side dressing or by placement below the seed for its efficient utilization by the plants.

Soils with medium or high potassium levels will not show a yield response to added potassium fertilizer. For soils low in potassium (less than 150 kg ha^{-1}), the recommended rates are 25 kg ha^{-1} of K_2O for rainfed pearl millet and 50 kg ha^{-1} of K_2O for irrigated pearl millet. The recommended rate of nitrogen, phosphorus and potassium is given in Table 5.2. Like phosphorus, potassium is also applied in one dose at the time of sowing along with nitrogen fertilizer.

For rainfed crop, 6–7.5 t of FYM should be applied before last plowing and then properly incorporated in the soil. For hybrids and high-yielding varieties cultivated under irrigated conditions, the dose of FYM or compost should be doubled, ie, 12–15 t ha^{-1}.

Azospirillum, a biofertilizer, is recommended at the rate of 2 kg ha^{-1} mixed with each of 25 kg FYM and soil, and applied at the final plowing or at sowing. This will not only help to reduce the rate of nitrogen fertilizer application, but also enhance better utilization of applied nitrogen by the plants. Pearl millet hybrid cultivars respond profitably to a balanced fertilizer application.

Table 5.2. Fertilizer recommendations.

Conditions	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})
Very dry, low yield	0–20	0–20	0–20
Wet, medium yield	20–60	20–40	20–50
Irrigated, high yield	50–100	40–60	40–100

Figure 5.6. Response to phosphorus (P).

With this, Module 5 concludes. To test your understanding of the subject in this Module, please answer the questions that follow:

1. Low pearl millet yield in India is mostly because

A. It is a rainfed crop
B. It is a legume crop
C. It is mostly grown in black soils
D. It is traditionally cultivated under unfavorable conditions

2. Application of manures and fertilizers is important in pearl millet because

A. It is a rainfed crop
B. Its tillering habit
C. Its short duration
D. Improved varieties and hybrids are cultivated on low fertility soils

3. What is the recommended rate of nitrogen for irrigated pearl millet?

A. 10 kg N ha^{-1}
B. 25 kg N ha^{-1}
C. 50 kg N ha^{-1}
D. 100 kg N ha^{-1}

4. Why is ammonium sulfate better than urea application to pearl millet?

A. Ammonium sulfate contains more nitrogen.
B. Ammonium sulfate is cheaper.
C. Ammonium sulfate is easily available.
D. Ammonium sulfate contains sulfur which is beneficial to pearl millet crop.

5. Most of the Indian soils are rich in potassium. So, there is no need to apply potassium to pearl millet crop.

A. I agree with this statement.
B. I do not agree.
C. I need more information to decide on potassium application.
D. I am not sure.

6. What should be the basis for deciding the amount of manures and fertilizers required for pearl millet?

A. Plant uptake
B. Variety grown
C. Soil test report
D. Amount of rainfall

Module 6: Plant Nutrient Deficiency Symptoms

As you have learned from the earlier modules, pearl millet is a very hardy crop. The evolution of pearl millet under harsh environment and poor soil conditions imparted the ability for plants to grow under adverse conditions. Pearl millet plants do not readily show hunger signs even under low plant nutrient supply, more so to secondary and micronutrients.

In this Module, the nutrient deficiency symptoms of primary nutrients are described.

The nutrient deficiency symptoms due to nitrogen, phosphorus and potassium in pearl millet are mostly similar to those in sorghum. Hence, the images of nutrient deficiency symptoms in sorghum are shown in this Module. Images of deficiency symptoms in pearl millet crop are not easily available.

There are two Lessons in Module 6: (1) Understanding plant growth problems; and (2) Deficiency symptoms of primary nutrients.

After completing two Lessons in this Module, you will learn to answer:

- What are the reasons for plants to show abnormal growth symptoms in a standing crop of pearl millet?
- What are the likely causes for plants to show abnormal growth symptoms?
- Under what soil conditions do the nutrient deficiencies of primary/secondary/micronutrients occur?
- Describe the plant symptoms due to nutrient deficiencies of primary nutrients in pearl millet crop.

Lesson 1: Understanding plant growth problems

After completing this Lesson, you will be able to answer:

- What are the reasons for plants to show abnormal growth symptoms?
- What tools would you use to diagnose plant problems in a standing crop?
- What points do you need to consider in preparing the checklist to diagnose plant problems in a standing crop?
- What are the most likely causes for poor germination of pearl millet in a field?
- What are the most likely causes for irregular soil patterns in a pearl millet field?
- What are the most likely causes for irregular patterns not related to soil in a pearl millet field?
- What are the most likely causes for poor growth with distinct leaf pattern in a pearl millet field?
- What are the most likely causes for a distinct leaf or stem chlorosis in a pearl millet field?
- What are the most likely causes for discoloration, galls, over-growth and surface injury to roots?

From the Lessons in Module 5 you have learned that all nutrients must be present in optimum quantities for proper growth and development of pearl millet. When the soil does not provide the needed quantities of nutrient(s), the crop plants may reveal their hunger for the nutrient(s) through certain symptoms. These symptoms differ depending on the non-availability of a particular nutrient. First, you should understand that the symptoms you observe in the crop is a secondary effect and may be the result of more than one cause. Some symptoms are clear-cut while others are not. So, the symptoms observed have to be carefully identified and confirmed for their actual cause. One has to use systematic visual inspection to find the primary cause or at least narrow down to one or two of the most likely causes.

The diagnosis for these plant symptoms can best be made on individual plants in the field. Some of the most useful tools needed for diagnosing the plant problems are: (1) Spade, (2) Pocket knife, (3) Hand lens (if you have one), and (4) An open mind (most important).

Step 1

- Start your diagnosis by eliminating most obvious problems first.
- Make thorough field observations in a systematic manner.
- Make a checklist of crop production practices adopted, and note the possible unusual practices or conditions.
- Check for any varietal differences.

Step 2

- Check the field pattern of the affected plants and use the following "Key" as a guide.

Field pattern	Most likely causes
Poor germination and emergence	Uneven depth of sowing, uneven moisture availability, salinity, soil crusting, soil insects, herbicide injury and damping-off disease
Scattered individual plants	All the above, mechanical or animal injury, seed or insect-borne diseases
Irregular patterns related to soil differences	Nutrient deficiencies, salinity or alkalinity, soil compaction and moisture deficiencies or excesses
Irregular patterns not related to soil differences	Soil-inhabiting nematodes, soil-inhabiting fungi, insects or insect-borne diseases and uneven irrigation
Edge or corner of fields	Poor leveling, damage by animals, spray injury and soil compaction

Step 3

- Check the plant pattern.
- Move in the field and observe gradation in symptoms from the mildest to the most severe effects.
- Check also for secondary or associated symptoms; for example, leaf symptoms and the plant growth, etc.
- Check the roots.
- Choose at least three plant specimens – a normal plant, one showing mild symptoms, and one showing severe symptoms. Check the following points.

Plant symptoms	Most likely causes
Poor growth with no distinct leaf pattern	Excess or low moisture, soil compaction, salinity or alkalinity, nematodes, soil insects and diseases
A distinct leaf or stem chlorosis	Nutrient deficiencies, nutrient toxicities, viral or fungal diseases, insect damage and chemical injury
Discoloration, abnormal texture of internal tissue	Nematodes, insects, diseases, excess of chemicals
Discoloration, galls, over-growth, surface injury of roots	Plant pathogens, nematodes, insects, soil aeration, mechanical and chemical or rodent injury

One should decide the cause for the observed visual plant symptoms after ruling out other possible effects.

Even mechanical damage to the leaf at the first look may resemble phosphorus deficiency symptom (see Figure 6.1). By closer examination like whether the symptoms are seen in the initial stage of plant growth (could be phosphorus deficiency), or on a grownup plant clarifies whether the symptoms are that of phosphorus deficiency or not.

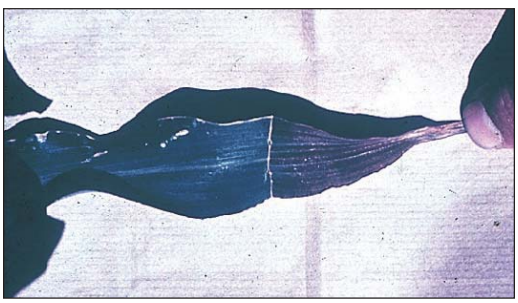


Figure 6.1. Damaged leaf.

Also, relate one symptom with other symptoms observed on the plants. In case of nutrient deficiency symptoms, fortunately, more than one symptom appears. For example, nitrogen deficiency symptom is yellowing of leaves but these leaves are young or lower leaves of the plants. If yellowing of leaves is observed on older leaves, we can rule out nitrogen deficiency.

With this, Lesson 1 on understanding plant growth problems in a standing crop in this Module concludes.

The next Lesson is about deficiency symptoms of primary nutrients in pearl millet.

Lesson 2: Deficiency symptoms of primary nutrients

There are three Units in Lesson 2:

Unit 1: Nitrogen deficiency symptoms; Unit 2: Phosphorus deficiency symptoms; and Unit 3: Potassium deficiency symptoms.

Unit 1: Nitrogen deficiency symptoms

After completing this Unit, you will be able to answer:

- Under what conditions does nitrogen deficiency result in pearl millet?
- Describe the leaf symptoms due to nitrogen deficiency in pearl millet.
- Why are nitrogen deficiency symptoms prominent only in older leaves?
- How do pearl millet plants look in a nitrogen-deficient field?

Nitrogen deficiency generally results from inadequate fertilizer application, or leaching loss due to excessive rainfall. Leaching occurs most commonly in sandy-textured soils during periods of excessive rainfall. Nitrogen is also lost through volatilization from surface applications during periods of hot and dry weather.

Nitrogen-deficient plants are stunted, pale green to pale yellow, and grow more slowly (Fig. 6.2). Eventually, the affected leaves become brownish, wither, die and hang down around the lower stem. Yellowing or chlorosis appears first on the lower leaves and the upper leaves remain green. The tendency of the young upper leaves remaining green is due to nitrogen moving towards the newly growing leaves (Fig. 6.3). The nitrogen-deficient plants are stunted and have thinner stems. Greater red streaking can be seen on the lower leaf sheaths of the nitrogen-deficient plants (Fig. 6.4).

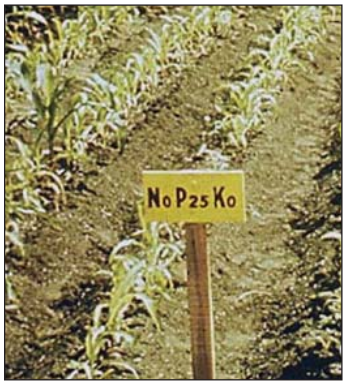


Figure 6.2. Nitrogen-deficient plants of sorghum.

Figure 6.3. Pale green, yellow, and brown lower leaves of sorghum.

Figure 6.4. Nitrogen-deficient (right) and normal (left) plants of pearl millet.

With this, Unit 1 on nitrogen deficiency symptoms in this Lesson concludes. The next Unit in this Lesson is about phosphorus deficiency symptoms in pearl millet.

Unit 2: Phosphorus deficiency symptoms

After completing this Unit, you will be able to answer:

- Why are phosphorus deficiency symptoms observed only in the very early stages of pearl millet crop?
- Under what conditions does phosphorus deficiency occur in pearl millet?
- Describe the leaf symptoms due to phosphorus deficiency in pearl millet.
- How do pearl millet plants look in phosphorus-deficient field?

There is greater demand for phosphorus during the very early stages of crop growth as the energy needed by young seedlings is high. Hence, phosphorus deficiency symptoms are more pronounced in young plants. Therefore, the plants should be examined for phosphorus deficiency during the early stages of crop growth.

Severe deficiencies of phosphorus are usually characterized by stunted growth of plants and dark red or purple coloration develops on the sheaths and blades of older leaves in the same way as in sorghum (Figs. 6.5 and 6.6). Severe deficiencies of phosphorus also delays flowering in pearl millet (Fig. 6.7).

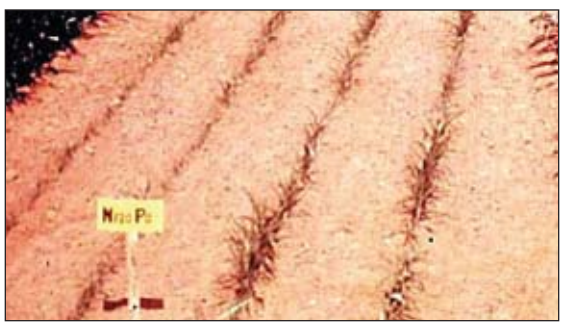


Figure 6.5. Stunted growth and purple pigmentation on leaves in sorghum.

Figure 6.6. Stunted sorghum plant with purple leaves.

Figure 6.7. Response to flowering with increased rates of phosphorus in pearl millet.

With this, Unit 2 on phosphorus deficiency symptoms in this Lesson concludes. The last Unit in this Lesson is about potassium deficiency symptoms in pearl millet.

Unit 3: Potassium deficiency symptoms

After completing this Unit, you will be able to answer:

- Describe the leaf symptoms due to potassium deficiency on pearl millet plants.
- How do you distinguish between yellowing of leaves due to potassium and nitrogen deficiencies in pearl millet crop?
- How do the pearl millet plants look in a potassium-deficient field?

Potassium-deficient plants exhibit chlorosis (loss of green color) or yellowing along the leaf margins or tips starting with the bottom leaves and progressing up the plant (Fig. 6.8). In severe cases, the leaves appear dry and scorched at the edges and the surfaces are irregularly chlorotic. The difference between yellowing of leaves due to nitrogen and potassium deficiencies is that the yellowing of leaf starts from midrib and spreads towards the edges of leaf in case of nitrogen deficiency. In potassium-deficient plants, yellowing starts from edges of leaf and spreads inwards (Fig. 6.9).

Figure 6.8. Yellowing at the leaf margin in sorghum.

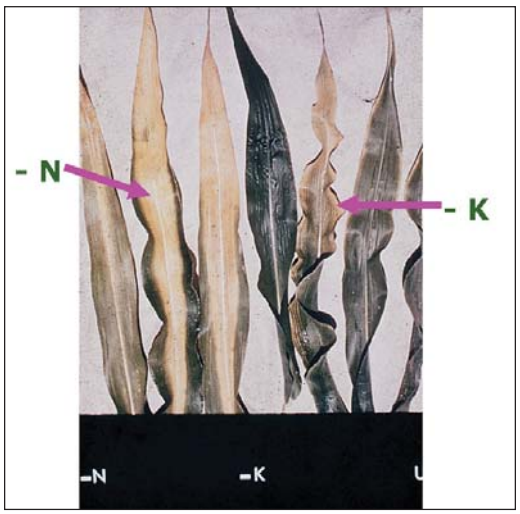


Figure 6.9. Yellowing of sorghum leaves due to nitrogen (N) and potassium (K) deficiencies.

With this, Module 6 concludes. To check your understanding of the subject in this Module, please answer the questions that follow.

1. One of the most likely causes for irregular patterns related to soil in a pearl millet field.

A. Organic matter content
B. Soil crusting
C. Soil salinity
D. Nutrient deficiencies

2. One of the most likely causes for irregular patterns not related to soil in a pearl millet field.

A. Salinity
B. Fertility of the soil
C. Nematodes
D. Moisture deficiencies

3. One of the most likely causes for poor growth with no distinct leaf pattern in a pearl millet field.

A. Nutrient deficiencies
B. Nutrient toxicities
C. Soil salinity
D. Variety grown

4. Nitrogen deficiency due to leaching occurs more in

A. Black soils
B. Fine textured soils
C. Coarse textured soils
D. I do not know

5. Sorghum plant in the figure reveals deficiency of

A. Potassium
B. Nitrogen
C. Iron
D. I do not know

6. Response of pearl millet to phosphorus in the figure reveals

A. Better growth
B. Early flowering
C. More leaves
D. I do not know

Module 7: Cropping Systems

There are two Lessons in Module 7: (1) Crop rotation practices; and (2) Intercropping and mixed cropping practices.

After completing two Lessons in this Module, you will learn to:

- Define crop rotation, monocropping, intercropping and mixed cropping.
- List the features of ideal crop rotation practice and intercropping system.
- Identify suitable crops for crop rotation with pearl millet.
- Recognize the importance of adopting intercropping practices in pearl millet cultivation.
- List the recommended crop combination for intercropping in pearl millet.

Lesson 1: Crop rotation practices

After completing this Lesson, you will learn to answer:

- Define cropping systems?
- List the features of an ideal cropping system.
- List the generally practiced cropping systems.
- What is monocropping?
- Define crop rotation practice?
- What types of crop rotation practices exist?
- What are the advantages of practicing crop rotation?
- What should be the criteria for selecting a good crop rotation practice?
- What crops are useful for crop rotation with pearl millet?
- Define intercropping system?
- How is intercropping system advantageous over monocropping of pearl millet?

A cropping system refers to growing a combination of crops in space and time. An ideal cropping system should use natural resources efficiently, provide stable and high returns, and should not damage the environment. Commonly practiced cropping systems are: crop rotation practices, intercropping systems, mixed cropping systems and ratoon cropping.

Growing the same crop year after year in the same field is called monocropping, while in crop rotation practice, crops are grown in a planned sequence from season to season within a year or from year to year. This planned crop rotation sequence could be: (1) Two crops in two different seasons within a year (double cropping) such as pearl millet followed by chickpea; (2) Two-year crop rotation (Year 1: pearl millet; Year 2: groundnut; Year 3: pearl millet); (3) Three-year crop rotation (Year 1: pearl millet; Year 2: groundnut; Year 3: sorghum/finger millet; Year 4: pearl millet again).

Some of the general advantages of crop rotations are: improve or maintain soil fertility; check soil erosion; reduce the buildup of pests; distribute appropriately the work load on family labor, use of bullocks, farm equipment, hired labor, etc; mitigate risk of weather changes; less reliance on agricultural chemicals and increase net profits.

When selecting a crop rotation, the long-term viability of that rotation to reduce weed, insect and disease pressure, as well as its economic viability must be considered. A well-developed plan, which can be altered when necessary, should always be followed. Otherwise, the desired crop sequence may be interrupted and the maximum benefits of the rotational effect will not be obtained.

The following are important points to be considered when designing a crop rotation, regardless of location:

- How will the previous crop affect subsequent crop production?
- Will the previous crop increase or decrease concerns in the following years?
- Disease, insect, weed control and residue management.
- Soil moisture and fertility utilization.
- Seedbed preparation.
- Planting and harvesting schedule.
- Gross economic returns.

Pearl millet crop is mostly grown as a rainfed monsoon crop during rainy season (June–July to October–November) and also, to a limited extent, as an irrigated summer season crop (January–May) in India. Pearl millet is often grown in rotation with sorghum, groundnut, cotton, foxtail millet, finger millet, castor, and sometimes, in southern India, with rice. If the pearl millet crop is sown early in May, it can be followed in the same year by horsegram. In areas where cotton and sorghum are grown, the rotations followed may be pearl millet-cotton-sorghum or pearl millet-sorghum-cotton (a 3-year rotation). In sandy soils, pearl millet is normally grown continuously year after year, which deteriorates soil health.

In some regions of Tamil Nadu, the rotation may be more complex: pearl millet-finger millet-groundnut-rice-sugarcane in a 3–year rotation, with irrigation. In red soils of Karnataka, pearl millet and finger millet rotation is practiced though pearl millet might not be grown every year. In coarse gravelly soils, castor may follow pearl millet. Cluster bean (*guar*)-pearl millet crop sequence with crop residue incorporation has significantly increased the productivity in arid zone of western Rajasthan where fallow-pearl millet/pearl millet after pearl millet crop sequence is practiced.

In Punjab, the dryland rotation may be small grain-millet-fallow. In irrigated lands, pearl millet is rotated with chickpea, fodder sorghum and wheat. In dry and light soils of Rajasthan, southern Punjab, Haryana and northern Gujarat, pearl millet is often rotated with a pulse like moth bean or green gram, or is followed by fallow, sesame,

potato, mustard and *guar*. Sesame crop may be low-yielding and may be replaced by castor or groundnut. Rotation of cultivars also should be adopted to avoid downy mildew disease problem. Pearl millet hybrids and open-pollinated varieties should be used in alternate years/seasons. It is advised not to grow the same hybrid or open-pollinated variety continuously on the same piece of land.

With this, Lesson 1 on crop rotation practices in Module 7 concludes. The next Lesson in this Module is about intercropping and mixed cropping practices in pearl millet.

Lesson 2: Intercropping and mixed cropping practices

After completing Lesson 2, you will learn to answer:

- Define intercropping system.
- What are the features of an ideal intercropping system?
- List useful intercropping systems for pearl millet cultivation.
- What is mixed cropping?
- Why do farmers practice mixed cropping?
- Why is intercropping a better system than mixed cropping?

Adverse weather conditions like delay in the onset of rains and/or failure of rains for few days to weeks some time during the crop period is very common in the rainfed pearl millet growing areas. Such a situation results in economic losses to the farmers due to partial or total failure of pearl millet crop. To overcome this situation there is a need to adopt or follow pearl millet-based cropping systems like intercropping or mixed cropping in rainfed pearl millet growing areas. Intercropping refers to growing more than one crop in the same land area in rows of definite proportion and pattern.

Pearl millet and groundnut intercropping system is recommended to farmers to meet the fodder needs of cattle and milch animals (Fig. 7.1). With particular reference to dryland agriculture, an intercropping system needs to be designed in such a way that in the case of unfavorable weather, at least one crop will survive to give economic yields. Thus, intercropping system should provide for the necessary insurance against unpredictable weather. In case the year happens to be normal with respect to rainfall, the intercropping system, as a whole, should prove to be more profitable than growing either of the crops alone.

Figure 7.1. Pearl millet-groundnut intercropping.

An ideal intercropping system should aim to: (i) Produce higher yields per unit area through better use of natural resources; (ii) Offer greater stability in production under adverse weather conditions and disease and insect infestation; (iii) Meet the domestic needs of the farmer; and (iv) Provide an equitable distribution of farm resources.

The following intercropping practices have been found to be remunerative than sole crop of pearl millet even under drought or more than normal rainfall in Andhra Pradesh.

- Pearl millet + Pigeonpea (2:1)
  (2:1 ratio indicates two rows of pearl millet and one row of pigeonpea)
- Pearl millet + Groundnut (2:4)
- Pearl millet + Soybean (4:2)
- Pearl millet + Sunflower (4:2)

While maintaining the yield levels of the sole crop of pearl millet, additional yields with the intercropping component have been realized under various systems. Since a food legume is involved in most of the systems, it will not only enhance the income of the farmer, but also provide the much-needed protein to supplement the predominantly cereal diet of farmers and help improve soil fertility. The suggested state-wise pearl millet-based intercropping for India is given in Table 7.1.

Table 7.1 Suggested intercropping practices in pearl millet.

State	Suggested intercropping	State	Suggested intercropping
Eastern Rajasthan	Pearl millet + Cluster bean	Uttar Pradesh	Pearl millet + Green gram
	Pearl millet + Cowpea		Pearl millet + Cowpea
	Pearl millet + Green gram		Pearl millet + Sesame
Western Rajasthan	Pearl millet + Moth bean	Madhya Pradesh	Pearl millet + Pigeonpea
	Pearl millet + Cluster bean		Pearl millet + Cowpea
Maharashtra	Pearl millet + Pigeonpea/Soybean		Pearl millet + Soybean
	Pearl millet + Black gram	Karnataka	Pearl millet + Pigeonpea/Soybean
	Pearl millet + Green gram		Pearl millet + Green gram
	Pearl millet + Cowpea		Pearl millet + Sunflower
	Pearl millet + Moth bean	Andhra Pradesh	Pearl millet + Pigeonpea/Soybean
	Pearl millet + Sunflower		Pearl millet + Green gram
			Pearl millet + Sunflower
			Pearl millet + Groundnut
Gujarat	Pearl millet + Green gram	Tamil Nadu	Pearl millet + Pigeonpea/Soybean
	Pearl millet + Cowpea		Pearl millet + Green gram
	Pearl millet + Sesame		Pearl millet + Cowpea
Haryana	Pearl millet + Cluster bean		Pearl millet + Sunflower
	Pearl millet + Green gram		
	Pearl millet + Cowpea		

Mixed cropping refers to simultaneously growing more than one crop in the same land area as a mixture (Fig. 7.2). Unlike in intercropping system, in mixed cropping the crops are grown without any definite pattern (Fig. 7.3.)

Figure 7.2. Pearl millet mixed with other crops.

Figure 7.3. Pearl millet in mixed cropping.

Mixed cropping of pearl millet-pigeonpea or cluster bean is most common. Mixtures with green gram, black gram, cowpea and even with sorghum and other cereals, vegetables, etc during rainy season are practiced under different situations. Mixed cropping is practiced in traditional subsistence farming to meet the domestic needs of the farmer's family. Thus, the number of crops mixed varies depending on the family needs. Even though crops in the mixed cropping meet the farmer's family needs, the yield of crops will be low due to the competition between the crops for water, light, nutrients, etc.

A better cropping system will be an intercropping system involving the major crops. However, the crop plants required to meet the family needs could still be grown on the field bunds, on the field borders, and in the backyards.

With this, Module 7 concludes. To check your understanding of the subject in this Module, please answer the questions that follow:

1. An ideal cropping system should
A. Fix atmospheric nitrogen
B. Not damage the environment
C. Have a crop that can be grown in all types of soils
D. Have a legume crop

2. Double cropping refers to
A. Monocropping
B. Intercropping
C. Two-crops sequentially in a year
D. Two crops in the field during rainy season

3. A good crop rotation system for rainfed red soil areas
A. Pearl millet-Groundnut
B. Pearl millet-Tobacco
C. Pearl millet-Chickpea
D. Pearl millet-Cotton

4. An important reason to follow pearl millet-based intercropping in rainfed areas.
A. Frequent droughts
B. Pearl millet being a fodder crop
C. Pearl millet being a poor man's crop
D. I do not know

5. An ideal intercropping should aim to

A. Use all soil nutrients
B. Offer greater stability in crop production
C. Better utilization of applied nitrogen
D. Include a pest resistant crop variety

6. A popular intercropping system in rainfed black soil areas

A. Pearl millet and cowpea
B. Pearl millet and pigeonpea
C. Pearl millet and sunflower
D. Pearl millet and groundnut

7. In mixed cropping, the number of crops grown varies depending on

A. Soil type
B. Rainfall
C. Farmer's family needs
D. Availability of land

Module 8: Seeds and Sowing

There are three Lessons in Module 8: (1) Seeds and seed preparation; (2) Pearl millet cultivars; and (3) Sowing of pearl millet.

After completing three Lessons in this Module, you will be able to:

- Select pearl millet seeds for establishing a good crop stand in the field.
- Describe the procedure for seed treatment in pearl millet.
- Recognize the importance of growing improved varieties in pearl millet and identify a high-yielding variety/hybrid for your location.
- List available improved varieties/hybrids of pearl millet and their important characteristics.
- Describe different systems of pearl millet sowing.
- Understand the procedures for determining the seed rate.
- Identify suitable conditions for sowing pearl millet.
- Know about suitable sowing periods in important pearl millet growing areas in the country.

Lesson 1: Seeds and seed preparation

After completing this Lesson, you will learn to answer:

- What is the foremost prerequisite for a healthy pearl millet crop?
- What seed treatments are practiced in pearl millet before the seeds are sown?
- What for is seed hardening recommended?
- What is the procedure for seed hardening?
- What seed treatment is done to prevent downy mildew?
- What seed treatment is done to prevent ergot?

The seed should be treated with appropriate chemicals prior to planting to prevent seedborne diseases as well as soil pests, which are common in the field. The seeds are also treated with some biofertilizers for easy and enhanced availability of important nutrients like nitrogen and phosphorus.

Seed hardening is practiced for better germination. Pearl millet seeds should be treated with recommended agro-chemicals following the given directions for use. This seed treatment prior to sowing will help in preventing soil-inhabiting insects and soilborne diseases. Seed treatment is particularly important where dry sowing prior to rains is practiced. The following are the seed treatment practices:

Soak the seeds in 2% (20 g in one liter of water) potassium dihydrogen phosphate solution for 6 hours. Use 350 ml of solution for soaking one kg of seed. Dry the seed in shade to original moisture level.

Soaking seeds in 1% calcium chloride or in plain water for 6 hours before sowing results in increased yield under drought conditions.

Seed treatment with biopesticides such as *Trichoderma harzianum* or *T. viride* using 4 g kg^{-1} or with thiram 75% WP at 0.75 g kg^{-1} seed or with thiram 75% dust/captan 75% at 3 g kg^{-1} of seed will help against soilborne diseases.

The seeds of pearl millet are treated with 300-mesh sulfur powder at 4 g of sulfur kg^{-1} of seeds for controlling the smut disease.

Soak seeds in 10% salt solution (one kg of common salt in 10 liters of water). Remove ergot-affected seeds which float to reduce the incidence of ergot disease.

Seed treatment with metalaxyl (Apron 35 SD) at 6 g kg^{-1} seed controls downy mildew.

Treating the seeds with three packets each of *Azospirillum* (600 g) and *Phosphobacterium* will enhance the availability of nitrogen and phosphorus.

Soaking the seed for one hour in 1% of 2-chloroethanol plus 0.5% sodium hypochlorite solution is effective in increasing germination rate.

Seed treatment is done manually for small amount of seeds. Large amount of seeds can be treated using a seed-treating drum (Fig. 8.1).

Figure 8.1. Seed treating drum.

With this, Lesson 1 on seeds and seed preparation concludes. The next Lesson is about pearl millet cultivars.

Lesson 2: Pearl millet cultivars

After completing this Lesson, you will learn to answer:

- How do you select a pearl millet hybrid or variety for your locality?
- Why are pearl millet hybrids advantageous?
- List pearl millet hybrids and/or improved varieties that are recommended for your area.
- Describe the good features of the above hybrids/varieties of pearl millet.

Natural selection and domestication over thousands of years have resulted in the development of numerous pearl millet varieties highly local in their adaptation. Most of the improved varieties prior to 1960 were the result of selections in the principal local cultivars. Changes in yield levels with these improved varieties were not substantial. Notable among such improved cultivars developed during this early period were: The Co-series in Tamil Nadu; The Nandyal, Guntur and

Anakapalle series of Andhra Pradesh; Bijapur selections of Karnataka; Bajri series of Maharashtra; and the RSJ and RSK series of Rajasthan.

Systematic research efforts began from 1965 for the development of open-pollinated varieties (OPVs) and hybrids of pearl millet. A choice of hybrids as well as of OPVs is now available for different pearl millet growing states and situations. Recently released pearl millet hybrids are becoming more popular than the OPVs. Pearl millet hybrids offer several advantages over OPVs besides 25–30% higher grain yields. These include more uniform growth and generally better fodder quality (foliage is leafy and remains green after grain harvest; profuse tillering; stems are succulent and sweet). Hybrid seed production is not difficult and so seed is readily available in markets. Recommended hybrids and OPVs for cultivation in various states are summarized in Tables 8.1 and 8.2.

Characteristics of some of the high-yielding, popular hybrids and varieties

HHB 67 Improved (Fig. 8.2)

- Downy mildew resistant improved version of the hybrid HHB 67.
- Released for cultivation in Haryana and Zone A1.
- High-tillering, extra-early maturity (62–65 days) and medium height (165–170 cm).
- Medium panicles (20 cm) of lanceo-conical shape with very small bristles and medium, slate gray-colored seeds.

Figure 8.2. HHB 67 Improved.

GHB 538 (Fig. 8.3)

- Released for cultivation in rainy season under rainfed condition in Zone A1.
- Early in maturity (70–75 days) with medium plant height (155–165 cm).
- Compact, medium-long (20–25 cm) panicles, non-bristled with medium, hexagonal gray seeds.
- Resistant to downy mildew and tolerant to moisture stress.

Figure 8.3. GHB 538.

Table 8.1. Recommended pearl millet hybrids for rainy *(kharif)* and postrainy *(rabi)* seasons for different states of India.

Cultivars	Season	Duration (days)	Remarks
Andhra Pradesh			
GHB 558	*Kharif*	75–80	Medium
ICMH 356	*Kharif*	75–80	Medium
GK 1004	*Kharif* and summer	82–85	Late
PAC 903	*Kharif*	84–86	Late
Gujarat			
GHB 558	*Kharif*	75–80	Medium (except scanty rainfall areas)
GHB 577	*Kharif*	80–85	Late
HHB 146	*Kharif*	75–80	Medium
PB 180	Summer	81–85	Late
GHB 526	Summer	80–85	Late
RHB 121	*Kharif*	78–80	Medium
Pusa 23	*Kharif*	80–82	Late
ICMH 356	*Kharif*	75–80	Mid-early
HHB 67	*Kharif*	62–65	Extra early (suitable for Kutch region)
HHB 67 Improved	*Kharif*	62–65	Extra early
JKBH 26	*Kharif*	83–85	Late
GHB 538	*Kharif*	70–75	Early
Haryana			
HHB 146	*Kharif*	75–80	Medium
GHB 577	*Kharif*	80–85	Late
GHB 558	*Kharif*	75–80	Medium (except scanty rainfall areas)
HHB 117	*Kharif*	74–78	Mid-early
RHB 121	*Kharif*	78–80	Medium
HHB 67, HHB 67 Improved	*Kharif*	62–65	Extra early
HHB 68	*Kharif*	60–62	Extra early
HHB 94	*Kharif*	73–76	Mid-early
ICMH 356	*Kharif*	75–80	Mid-early
HHB 50	*Kharif*	76–80	Medium
HHB 60	*Kharif*	74–76	Early
JKBH 26	*Kharif*	83–85	Late
Karnataka			
GHB 526	*Rabi*	80–85	Late
GHB 558	*Rabi*	75–80	Medium
ICMH 356	*Rabi*	75–80	Mid-early
MLBH 267	*Rabi*	75–80	Medium
GK 1004	*Kharif* and summer	82–85	Late
PAC 903	*Kharif*	84–86	Late

continued

Table 8.1. Continued.

Cultivars	Season	Duration (days)	Remarks
Madhya Pradesh			
HHB 146	*Kharif*	75–80	Medium
ICMH 356	*Kharif*	75–80	Mid-early
GHB 577	*Kharif*	80–85	Late
RHB 121	*Kharif*	78–80	Medium
MLBH 285	*Kharif*	83–85	Late
JKBH 26	*Kharif*	83–85	Late
JBH 1	*Kharif*	80–83	Late
Maharashtra			
GHB 558	*Kharif*	75-80	Medium
GHB 526	Summer	80–85	Late
PB 180	Summer	81–85	Late
Shraddha	Summer	78–80	Medium
AHB 251	Summer	82–85	Late (assured rainfall areas in light to medium soils of Marathwada region)
Pusa 23	*Kharif*	80–82	Late
Saburi	*Kharif* and summer	78–80	Medium
GK 1004	*Kharif* and summer	82–85	Late
PAC 903	*Kharif*	84–86	Late
Rajasthan			
RHB 121	*Kharif*	78–80	Medium
GHB 538	Kharif	70–75	Mid-early
RHB 90	*Kharif*	82–85	Late
RHB 58	*Kharif*	81–85	Late
RHB 30	*Kharif*	72–75	Early
Pusa 23	*Kharif*	80–82	Late
HHB 67, HHB 67 Improved	*Kharif*	60–62	Extra early (suitable for Barmer, Jodhpur, Jalore, Bikaner, Jaisalmer and Pali districts)
ICMH 356	*Kharif*	75–80	Mid-early
JKBH 26	*Kharif*	83–85	Late
PB 180	Summer	81–85	Late
Tamil Nadu			
CoH (Cu) 8	All seasons	80–85	Late
GHB 526	*Rabi*	80–85	Late
GHB 558	*Kharif*	75–80	Medium
ICMH 356	*Kharif*	75–80	Mid-early
MLBH 267	*Kharif*	75–80	Medium
GK 1004	*Kharif* and summer	82–85	Late
PB 180	Summer	81–85	Late
PAC 903	*Kharif*	84–86	Late

continued

Table 8.1. Continued.

Cultivars	Season	Duration (days)	Remarks
Uttar Pradesh			
HHB 146	*Kharif*	75–80	Medium
GHB 558	*Kharif*	75–80	Medium
JBH 1	*Kharif*	80–83	Late
ICMH 356	*Kharif*	75–80	Mid-early

Table 8.2. Recommended open-pollinated pearl millet varieties for different states of India.

State	Cultivars	Season	Duration (days)	Remarks
Rajasthan, Haryana, Gujarat, Uttar Pradesh, Maharashtra, Jammu Division and Punjab	Raj 171	*Kharif*	80–85	Late and dual-purpose
Rajasthan, Gujarat, Haryana, Uttar Pradesh, Delhi, part of Madhya Pradesh and Punjab	GICKV 96752	*Kharif*	80–82	Rainfed/irrigated/low or high fertility conditions
	Pusa Composite 334 (MP 334)	*Kharif*	75–80	Rainfed/irrigated/low or high fertility conditions
	Pusa Composite 383 (MP 383)	*Kharif*	80–82	Rainfed/irrigated/low or high fertility conditions
	JBV 2 (MP 309)	*Kharif*	75–80	Above 400 mm rainfall areas
Andhra Pradesh	ICMV 221	*Kharif*	75–80	Medium
	Ananta (APS 1)	*Kharif* and *rabi*	83–85	Late
Gujarat	CZP 9802 (MP 406)	*Kharif*	70–75	Early
Haryana	HC 20	*Kharif*	80–83	Late
	CZP 9802 (MP 406)	*Kharif*	70–75	Early
	HC 10	*Kharif*	75–80	Rainfed/irrigated conditions
Punjab	PCB 164	*Kharif*	85–88	Late
Rajasthan	CZP 9802 (MP 406)	*Kharif*	70–75	Early
Maharashtra	Samrudhi (MP 282)	*Kharif*	78–80	Shallow to medium soils with 400–700 mm rainfall areas
	Parbhani Sampada (PPC 6)	*Kharif*	75–80	–
Maharashtra, Karnataka (except Bellary), Tamil Nadu (except Coimbatore) and Pondichery	ICMV 221, ICTP 8203	*Kharif*	75–80	Mid-early

HHB 117 (Fig. 8.4)

- Released for cultivation in Haryana and Zone A.
- Mid-early in maturity (74–78 days) and medium in height (175 cm).
- Medium thick panicle of candle shape with obovate gray grains.
- Possesses stay green character.
- Resistant to downy mildew and tolerant to drought.

Figure 8.4. HHB 117.

HHB 146 (Fig. 8.5)

- Released for cultivation in Zone A.
- Medium maturity (75–80 days).
- Medium tall (187 cm), and long, well filled, compact panicles with obovate, gray grains.

Figure 8.5. HHB 146.

GHB 558 (Fig. 8.6)

- Released for cultivation in all pearl millet growing zones of India.
- Medium maturity of 75–80 days.
- Plants are of medium height (170–175 cm) with long thick compact panicles.
- Broad obovate leaves, and bold seeds of dark gray color.

Figure 8.6. GHB 558.

RHB 121 (Fig. 8.7)

- Released for cultivation in Rajasthan and Zone A (Table 8.3).
- Medium maturing (78–80 days) and medium in height (163–175 cm).
- Compact, thick, conical panicles with long purple bristles.
- Globular gray-brown grains.
- Resistance to downy mildew and tolerant to drought.

Figure 8.7. RHB 121.

HHB 94 (Fig. 8.8)

- Released for cultivation in Haryana.
- Medium tall (180–220 cm) and high tillering.
- Mid-early maturity of 73–76 days.
- Cylindrical panicles with medium size seeds of gray color.

Figure 8.8. HHB 94.

ICMH 356 (Fig. 8.9)

- Released for cultivation in all pearl millet growing zones of India.
- Mid-early in maturity (75–80 days) and medium in height (170–175 cm).
- Semi-compact, medium, candle-shaped panicles (15–20 cm) and medium size seeds of gray color.
- Possesses stay green character and yields 2.5 t ha^{-1}.

Figure 8.9. ICMH 356.

CZP 9802 (Fig. 8.10)

- Dual-purpose variety.
- Grain yield potential of 2.0–2.2 t ha^{-1}.
- Produces high quantity of dry stover (average 3.3 t ha^{-1}).
- Tall (180 to 200 cm), good tillering (2 to 4 per plant) and compact panicles.
- Flowers within 45 days and matures in 70 to 75 days.
- Released for cultivation in the scanty rainfall and drought-prone areas of Rajasthan, Haryana and Gujarat.

Figure 8.10. CZP 9802.

JBV 2 (Fig. 8.11)

- Released for cultivation in Zone A.
- Medium maturity of 75–80 days.
- Tall (203 cm), compact, cylindrical panicles with obovate light gray grains.

Figure 8.11. JBV 2.

ICMV 221 (Fig. 8.12)

- Released for cultivation in all pearl millet producing regions of India except central and western Rajasthan and northern Gujarat that receive <400 mm mean annual precipitation.
- Mid-early in maturity (75–80 days) with medium height (160–180 cm).
- Compact, medium-long panicles (18–25 cm) with large globular seeds of gray color.

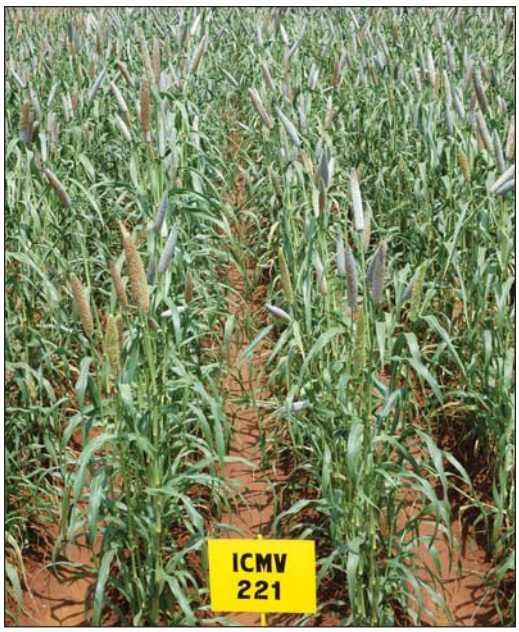


Figure 8.12. ICMV 221.

Raj 171 (Fig. 8.13)

- Released for cultivation in all pearl millet growing areas.
- Late maturing (80–85 days), medium tall (180–200 cm) with long cylindrical semi-compact to compact panicles with obovate gray-brown grains.
- Resistant to downy mildew.

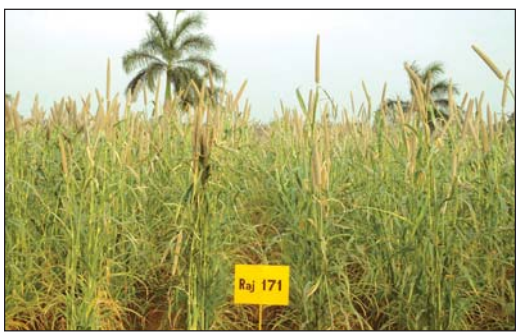


Figure 8.13. Raj 171.

ICTP 8203 (Fig. 8.14)

- Released for cultivation in Andhra Pradesh and Maharashtra.
- Plants are of medium height (150 cm) with compact panicles of 16 to 18 cm.
- Mid-early maturity of 75 to 80 days.
- Large globular seeds of dark gray color with shiny outer surface.
- Good resistance to downy mildew and tolerance to drought.

Figure 8.14. ICTP 8203.

Table 8.3. Recommended drought-tolerant/drought-avoiding hybrids/varieties of pearl millet in India.

State	Hybrids	Varieties
Maharashtra	Nandi 35, Saburi, PAC 903	PPC 6, HC 20, JBV 2, ICTP 8203, ICMV 221, AIMP 92901
Tamil Nadu	GHB 558, CoH (Cu) 8, X 7	Co7, ICMV 221, ICMV 155
Andhra Pradesh	PB 106, GHB 558	AIMP 92901, ASP-1, ICTP 8203
Karnataka	PB 106, GHB 558	ICMV 221, ICTP 8203
Rajasthan	HHB 67, RHB 121, GHB 538, PB 180	CZP 9802, Raj 171
Gujarat	GHB 577, GHB 526, PB 172, PB 112, ICMH 356	JBV 2, HC 20
Haryana	HHB 67, GHB 538, HHB 117, ICMH 356	CZP 9802

With this, Lesson 2 on pearl millet cultivars in this Module concludes. The last lesson in this Module is about sowing techniques in pearl millet cultivation.

Lesson 3: Sowing of pearl millet

After completing this Lesson, you will learn to answer:

- Describe the systems of pearl millet sowing.
- Which system of pearl millet sowing do you recommend and why?
- What are the different methods followed in pearl millet sowing?
- What implements are used in pearl millet sowing?
- What criteria should be followed in determining the amount of seed required for sowing?
- What plant populations are recommended for pearl millet cultivation?
- What are the steps involved in estimating the required seed to establish a given plant stand?
- How do you determine the spacing to be followed in pearl millet cultivation?
- How do you determine the suitable conditions for carrying out pearl millet sowing in your field?

Three systems of sowing are followed in pearl millet: sowing on a flat surface (Fig. 8.15), sowing on a ridge and furrow system (Fig. 8.16) and sowing on a broad-bed and furrow system.

Figure 8.15. Sowing on flat surface.

Figure 8.16. Ridge and furrow system.

When seeds are sown using ridge and furrow system, the seeds are either sown at the bottom of the furrow or in the side or top of the ridge (Fig. 8.17). Planting in the side or top of the ridge is practiced in heavy rainfall areas and under irrigated conditions.

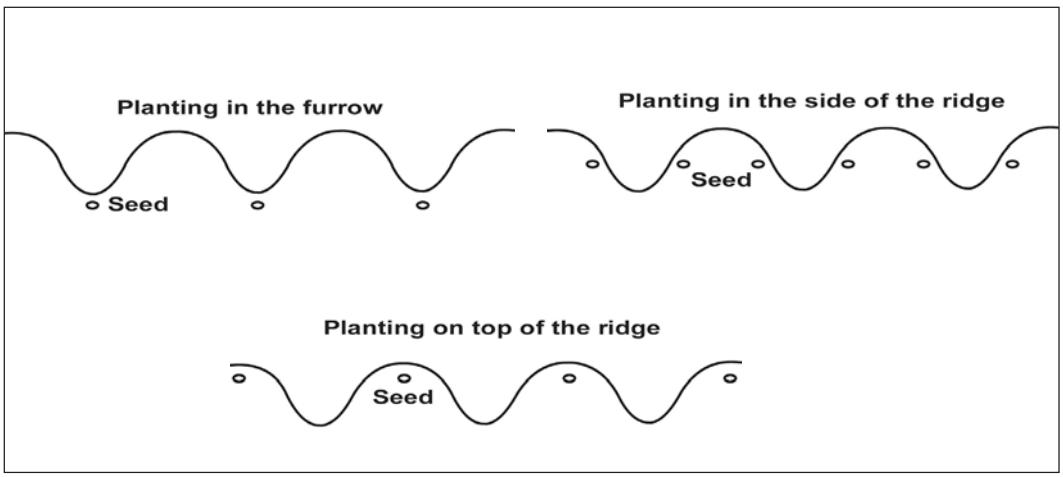


Figure 8.17. Pattern of sowing of seeds using ridge and furrow.

The broad-bed and furrow system (Fig. 8.18) has an advantage over flat sowing in draining off excess water, providing more soil aeration for plant growth, greater in-situ moisture conservation and is easier for weeding and mechanical harvesting.

Figure 8.18. Broad-bed and furrow.

The seeds are sown either by broadcasting seed manually or sowing behind country plow using *pora* (country seed drill), or an improved seed drill which may or may not be fitted with hoppers for fertilizer application, or mechanical seed drills attached to a tractor. Manual sowing by broadcasting the seed is practiced when the area to be sown is small. After broadcasting, the seeds are covered by running a brush harrow. The germination may not be uniform in hand sowing, so one has to use a higher seed rate to get the optimum plant stand in the field.

A country seed drill called *pora*, ie, a wooden hopper attached to a hollow bamboo (Fig. 8.19) is used to sow the seeds in the shallow furrows opened by the tines of a country plow. A larger area can be covered with this method of sowing. The best method is to sow the hardened seeds of pearl millet at 5 cm depth with seed-cum-fertilizer drill (Fig. 8.20) to ensure uniform depth of sowing and fertilizer application before the onset of monsoon.

Figure 8.19. Country seed drill.

Figure 8.20. Seed-cum-fertilizer drill.

Seed rate

The amount of seed required per unit area depends on: optimum plant stand required per unit area, plant type, ie, tall or short plants, seed mass and quality of seed in terms of germination. Seed rate should be determined based on the optimum number of plants required per unit area (acre or ha or sq ft or sq m) for good yields.

The optimum plant population for pearl millet can vary between 150,000 and 250,000 plants ha^{-1}. If the plant population is on the higher side of 150,000 plants, the reduced panicle is compensated by the higher number of panicles per unit area. The recommended plant stand for pearl millet under normal conditions is 180,000 plants ha^{-1} or 18 plants m^{-2} or 72,000 plants $acre^{-1}$. Under irrigation or high levels of management on highly productive soils, a population of 225,000 plants ha^{-1} (100,000 plants $acre^{-1}$) is recommended. On extremely sandy, droughty soils, a population of about 90,000 plants ha^{-1} (40,000 plants $acre^{-1}$) is desirable.

Estimation of seed quantity

Example 1

Given: Pearl millet seed with 75% germination, 1000-seed mass of 12 g and the required plant population is 180,000 plants ha^{-1}.

Step 1

Since the germination percentage is 75, we need to adjust for this deficiency. Number of seeds needed to get 100 seedlings:

$$\frac{100 \times 100}{75} = 134$$

Step 2

To get 100 seedlings, 134 seeds are required; then, the number of seeds required for 180,000 plants for grain crop is:

$$\frac{180000 \times 134}{100} = 241200$$

Thus, 241,200 seeds are needed to establish 180,000 plants ha^{-1}.

Step 3

The quantity of seeds (seed rate) required for 241,200 seeds, based on 1000-seed mass of 12 g is:

$$\frac{241200 \times 12}{1000} = 2894 \text{ g or } 3 \text{ kg } ha^{-1}$$

Thus, 3 kg of seeds are needed per ha to establish 180,000 plants ha^{-1}.

Example 2

Given: Assuming pearl millet seeds with 100% germination, 1000-seed mass of 12 g, and the required plant population is 180,000 plants ha^{-1}.

Step 1

Based on 1000-seed mass of 12 g, the required quantity is:

$$\frac{12 \times 180000}{1000} = 2160 \text{ g or } 2.2 \text{ kg } ha^{-1}$$

If germination percentage of seeds is not known, then the seed rate is determined by adding additional 20% of seeds.

Step 2

Based on 20% more seed requirement for any seed germination problem, ie, 120% required, the estimated quantity is:

$$\frac{120 \times 2.2}{100} = 2.64 \text{ kg } ha^{-1}$$

Thus, 2.64 kg of seeds are needed per ha to take care of any seed problem and to establish 180,000 plants ha^{-1}.

The seed rate for grain crop varies from 2 to 6 kg ha^{-1} depending upon soil types, expected soil moisture during crop period, and methods of sowing.

If seeds are carefully drilled, only 2 to 2.5 kg ha^{-1} will be sufficient. For raising a fodder crop, the seed rate will be three times more. Also note that seed mass is an important consideration in determining the seed rate for grain crop or fodder crop.

Sowing distance

Figure 8.21. Thinning in pearl millet.

Plant spacing between rows and within a row can vary depending on the method of sowing. However, it should be remembered that the sowing distance determines the optimum plant stand requirement. In general, if ridges are formed 45 cm apart, then the plants should be 12 to 15 cm apart within a row. If broad-bed and furrow method is adopted, then the rows will be 60 cm apart on the bed and the distance between plants should be 10 cm to get the optimum population. If there are excess plants than the optimum plants (18 plants m^{-2}), the excess seedlings are thinned out when the plants are 12 to 15 cm in height (Fig. 8.21). Transplanting the plants available from the thinning operation could fill any gaps found in the row.

Sowing time

The sowing time of pearl millet is an important aspect in increasing the crop yield. The sowing time is also related to soil moisture and soil temperature, as well as the distribution of rainfall. In general, the rainy season crop should be sown immediately after commencement of monsoon and/or when soil has adequate moisture. The seeds should be sown when there is moisture in the soil up to a depth of 15–18 cm. If irrigation facility is available, irrigating the field for sowing just before the onset of rainy season and thus advancing the sowing substantially increases pearl millet yield.

Dry seeding of pearl millet one week in advance of monsoon (firm forecast) is recommended in Marathwada region of Maharashtra. As heavy and prolonged rains are generally harmful to flowering and grain ripening, delayed sowing (July to mid-August) may be practiced in areas where the monsoon is prolonged. In north and central part of India, pearl millet sowing is done with the onset of monsoon and no later than 15 July. The *rabi* crop is sown between 25 September and 15 October. Late sowing beyond October may result in poor germination and plant stand due to low soil temperatures. Soil temperatures should be at least 18°C or warmer before pearl millet is sown. It germinates well at soil temperatures of 20 to 30°C.

In Tamil Nadu, the crop is sown in October with the onset of North-East monsoon. Sowing in summer is done from second week of January to first week of March in Andhra Pradesh, Maharashtra, Karnataka, Gujarat and Tamil Nadu. This summer crop is grown under irrigation only.

Transplanting of pearl millet

Pearl millet is also transplanted in some parts of Tamil Nadu, Andhra Pradesh, Karnataka and Gujarat. This practice is common under irrigated conditions.

Pearl millet nurseries are raised in well-fertilized raised seedbeds. Healthy seedlings (15 to 20 days old) are transplanted in the water-soaked fields. A nursery of 0.03 ha is sufficient to supply seedlings to plant one ha main field.

With this, Module 8 concludes. To check your understanding of the subject in this Module, please answer the following questions:

1. The foremost prerequisite for healthy pearl millet crop
A. Soil fertility
B. Good market
C. Learned farmers
D. Quality seeds

2. To induce drought tolerance pearl millet seeds are treated with
A. Captan
B. Thiram
C. Potassium dihydrogen phosphate
D. Carbofuran

3. The seeds of pearl millet are treated with 300-mesh sulfur powder at 4 g of sulfur per kg of seeds for controlling
A. Shoot fly
B. Stem borer
C. Smut disease
D. I am not sure

4. Which pearl millet variety will you select for resistance to downy mildew?
A. ICTP 8203
B. HB 1
C. HB 3
D. I am not sure

5. If rains coincide with grain-filling stage, which pearl millet variety is preferred?
A. Bold-seeded type
B. Dwarf variety
C. Ergot resistant
D. I am not sure

6. Drilling pearl millet seeds will be better than manual sowing.
A. I agree
B. I do not agree
C. Depends on soil type
D. Depends on farmer's family

7. What is the recommended plant population for rainfed pearl millet?
A. 90,000 plants ha^{-1}
B. 180,000 plants ha^{-1}
C. 333,000 plants ha^{-1}
D. I do not know

8. Transplanting of pearl millet is practiced in
A. Rajasthan
B. Haryana
C. Tamil Nadu
D. I do not know

Module 9: Weeds and Weed Control

There are two Lessons in Module 9: (1) Weeds and weed competition in pearl millet; and (2) Weed control strategies.

After completing two Lessons in this Module, you will learn to:

- Recognize the importance of weed control in pearl millet crop.
- Identify different weeds that compete with pearl millet crop.
- Practice different strategies for controlling weeds in pearl millet crop.
- Describe cultural and physical methods of weed control.
- Choose and apply proper herbicides to control weeds in pearl millet crop.

Lesson 1: Weeds and weed competition

There are two Units in Lesson 1:

Unit 1: Weed competition in pearl millet; and Unit 2: Weeds in pearl millet.

After completing the two Units in this Lesson, you will learn to answer:

- Why is weed control important in pearl millet crop?
- When is the critical period for weed competition in pearl millet crop?
- Name few important broad-leaved weeds in pearl millet crop.
- Name few important grass weeds in pearl millet crop.
- Name few important sedges that compete with pearl millet crop.

Unit 1: Weed competition in pearl millet

Pearl millet being mainly grown during the rainy season encounters several weeds which grow luxuriantly and dominate during this season more as compared to *rabi*/summer season. Weeds in pearl millet crop compete with the crop for nutrients, water and light as with other crops. Weeds are more competitive when moisture is limiting and especially under drought situation (Fig. 9.1) when young, grain pearl millet does not compete well with weeds.

Figure 9.1. Weeds dominating pearl millet crop.

Unless good weed control is achieved, substantial yield losses will occur. Yield losses of more than 70% due to weeds compared to the weed-free crop (Fig. 9.2) have been reported from weed control experiments.

It is necessary to keep the crop weed-free during the first 30 days after sowing. Weed competition is critical during this period. Early planting of pearl millet avoids competition from the flush of weeds that come up with continuous rains during the early monsoon period.

With this, Unit 1 on weed competition concludes. Unit 2 gives the list of major weeds in pearl millet crop.

Figure 9.2. Weed-free pearl millet crop.

Unit 2: Weeds in pearl millet

Several weeds are associated with pearl millet crop. The type of weeds varies from place to place depending on soil type, season and environment where pearl millet is grown. These weeds comprise diverse plant species of annual grasses, seasonal broad-leaved weeds and sedges (Table 9.1). Weed problems in pearl millet include perennial grasses such as johnson grass and bermuda grass, annual grasses such as crabgrass and goose grass, and many broad-leaved weeds.

Table 9.1. Some common weeds encountered in pearl millet fields.

Botanical name	Common name	Botanical name	Common name
Common broad-leaved weeds			
Abutilon indicum	Indian mallow	*Alysicarpus* sp	One-leaf clover
Argemone mexicana	Mexican poppy	*Celosia argentina*	White cock's comb
Borreria articularis	Button plant	*Gynondropsis* spp	Wild spider flower
Digera arvensis	*Kundra*	*Corchorus olitorius*	Jew's mallow
Anagallis arvensis	Scarlet pimpernel	*Bidense pilosa*	Spanish needle
Eclipta spp	False daisy	*Ipomoea* spp	Morning glory
Portulaca spp	Common purslane	*Vernonia cinerea*	Little iron weed
Leucas aspera	*Dronapushpi*	*Xanthium strumarium*	Cocklebur
Tridax procumbence	Tridax daisy, wild daisy	*Euphorbia* spp	Spurge
Amaranthus spp	Pigweed	*Mollugo verticillata*	Carpet-weed
Common grass (monocots) weeds			
Chloris spp	Finger grass	*Digetaria sanguinalis*	Crabgrass
Dactyloctenium aegyptium	Crowfoot grass	*Echinocloa* spp	Barnyard grass
Commelina spp	Benghal dayflower	*Paspalum distichum*	Water couch
Eleusine indica	Goose grass	*Eragrostis* spp	Love grass
Setaria spp	Foxtail	*Cynodon dactylon*	Bermuda grass
Common sedges			
Cyperus rotundus	Purple nut sedge	*Cyperus esculentus*	Yellow nut sedge
Cyperus defformis	Nut sedge	*Cyperus compressus*	Nut sedge

With this, Unit 2 and also Lesson 1 on weeds and weed competition in this Module concludes. The last Lesson in this Module is about strategies for controlling weeds in pearl millet cultivation.

Lesson 2: Weed control strategies

After completing Lesson 2, you will learn to answer:

- When should the first schedule for weed control activity in pearl millet start?
- How does pre-sowing rainfall or irrigation help in better weed control in pearl millet?
- What methods of weed control are practiced in pearl millet cultivation?
- List the cultural practices that help in reducing the weeds in pearl millet crop.
- What is the correct schedule for manual weeding in pearl millet crop?
- What is the correct schedule for intercultivation to control weeds in pearl millet crop?
- What are the precautions to be taken to use herbicides for weed control in pearl millet crop?
- List the herbicides based on their time of application.
- Give an example of pre-planting herbicide for pearl millet weed control.
- Describe your recommendation for one pre-emergence herbicide for pearl millet weed control.

Weed control needs to be practiced in pearl millet crop even before sowing so that the plants grow without any weed competition from germination onwards. That means the first weed control activity starts before sowing (Fig. 9.3).

Figure 9.3. Weed-free field for sowing.

The weed seeds in the soil are allowed to germinate with the first rainfall and then the final harrowing or plowing is carried out. This practice will provide a weed-free environment for vigorous and robust growth to pearl millet seedlings (Figs. 9.4 and 9.5).

Figure 9.4. Weed-free environment in the early stages.

Weeds are not allowed to grow during the first 30 days after sowing pearl millet as this is the most critical weed competition period.

Late weeding by farmers is due to many factors: unavailability of labor at peak

periods, cost of labor and erratic rainfall. Some farmers even wait for weeds to grow to use as fodder for cattle. However, it should be remembered that delay in weeding would lower the yield proportionate to the delay.

There are three methods of weed control: control through cultural practices, manual or mechanical control, and chemical control. Efficient and effective weed control can be achieved by wisely combining the above methods of weed control.

Figure 9.5. Weed-free crop.

Cultural practices

A good crop cover by adopting right spacing between rows and within the row will smother the weed growth. For this, adopt the recommended spacing of 45 cm between rows and 10 cm between plants within the row. Mulching the soil surface in between rows with crop residue like straw, etc may prevent the germination of weed seeds and at the same time smothers the established young weeds. This mulching practice also helps in conserving the soil moisture (Fig. 9.6).

Figure 9.6. Mulching with straw.

Growing pearl millet crop every year in the same field (monocropping) encourages injurious weeds like nut sedge, bermuda grass (*dhub*), *Striga*, etc to multiply and dominate the field. Such weeds will reduce pearl millet crop yields much more than the competition from a wide spectrum of weeds. So, adopting proper crop rotation practices will help in overcoming the domination of certain weeds and reducing the weed competition in pearl millet crop.

Intercropping in pearl millet crop not only provides the monetary and land utilization advantages, but also helps in smothering the weeds with good crop cover over the land surface.

Manual weeding

Manual weeding is a very common practice to control weeds in pearl millet crop. Timely weeding is important than the frequency of weeding. It is necessary to keep the crop free during the first month of its growth through manual weeding. Hand hoeing is an effective method adopted widely to control weeds in the inter-row spaces of line-sown crop. This method provides excellent physical condition to the crop growth by way of soil aeration through stirring of the soil (Figs. 9.7 and 9.8). First hand weeding is done about 15 days after sowing and should be repeated after a fortnight. Manually operated implements like wheel push hoe are also used to control weeds in pearl millet.

Figure 9.7. Manual weeding.

Figure 9.8. Hand hoeing to control weeds.

Mechanical weeding

Blade harrowing in relatively dry and loose soil between the rows of pearl millet is a widely followed method for effective weed control as this operation cuts the root system of weeds resulting in desiccation of weeds (Fig. 9.9). Duck-foot harrows are also used for intercultivation in pearl millet. The first intercultivation is done about two weeks after sowing and the second and the third about a fortnight and a week later. No inter-culture would be possible when the plants have grown more than 125 cm.

Figure 9.9. Intercultivation using blade harrow.

Chemical control

The delay in manual weeding and intercultivation could be due to uncertain weather conditions. Therefore, chemical weed control has a place in pearl millet weed

control strategy. Chemical control or herbicide application is advantageous in case of non-availability of labor and/or very high cost of labor for manual weeding. Use of correct herbicides will provide completely weed-free situation to the crop whereas manual or mechanical weeding can be practiced only after the emergence of weeds. Use of chemicals (herbicides) to control weeds should be based on their cost effectiveness compared to manual and mechanical control measures. Herbicide application requires some knowledge about the use of such chemicals. Improper use of herbicides may lead to complete loss of the crop. The farmers need to understand the proper use and application of herbicides before applying them to control weeds in pearl millet crop.

Satisfactory control can be obtained by combining timely cultivation, crop rotation and herbicide applications. However, efficient and cost-effective weed control can be achieved by using combination of herbicides or combining manual and herbicide control methods. Depending on the time of application, herbicides are grouped as: (i) Pre-planting herbicides (incorporated into the soil before sowing of the crop) (Fig. 9.10); (ii) Pre-emergence herbicides (after sowing but before emergence of seedling) (Fig. 9.11); and (iii) Post-emergence herbicides (after emergence of weeds and the crop) (Fig. 9.12).

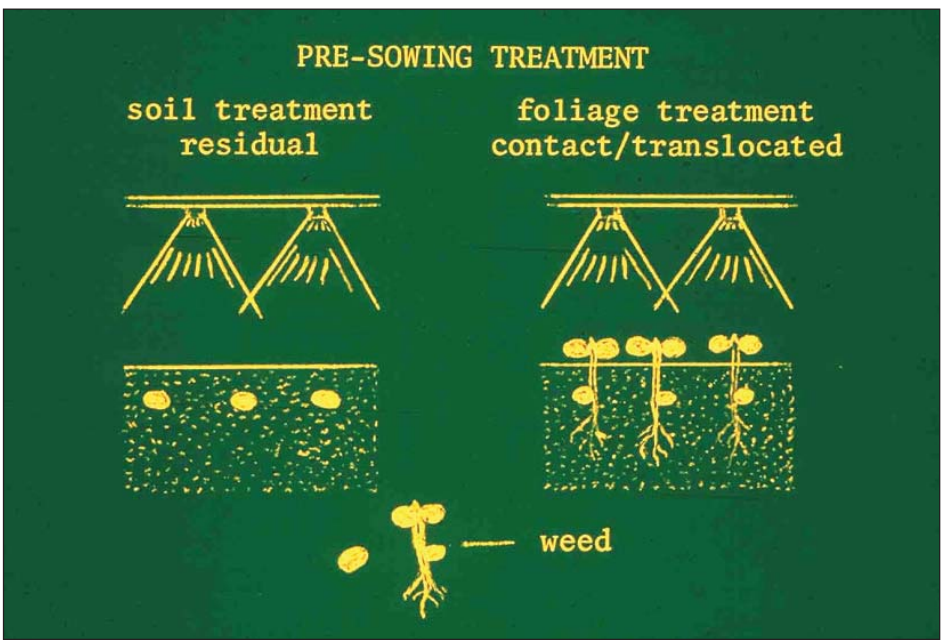


Figure 9.10. Pre-sowing/planting application of herbicides (incorporated into the soil before sowing of the crop).

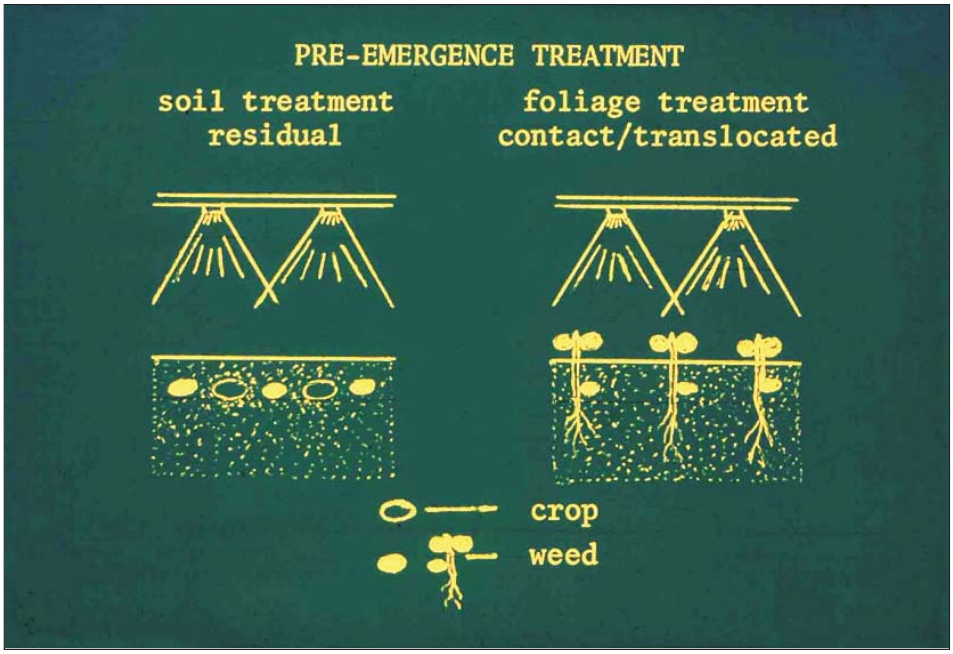


Figure 9.11. Pre-emergence application of herbicides (after sowing but before emergence of seedling).

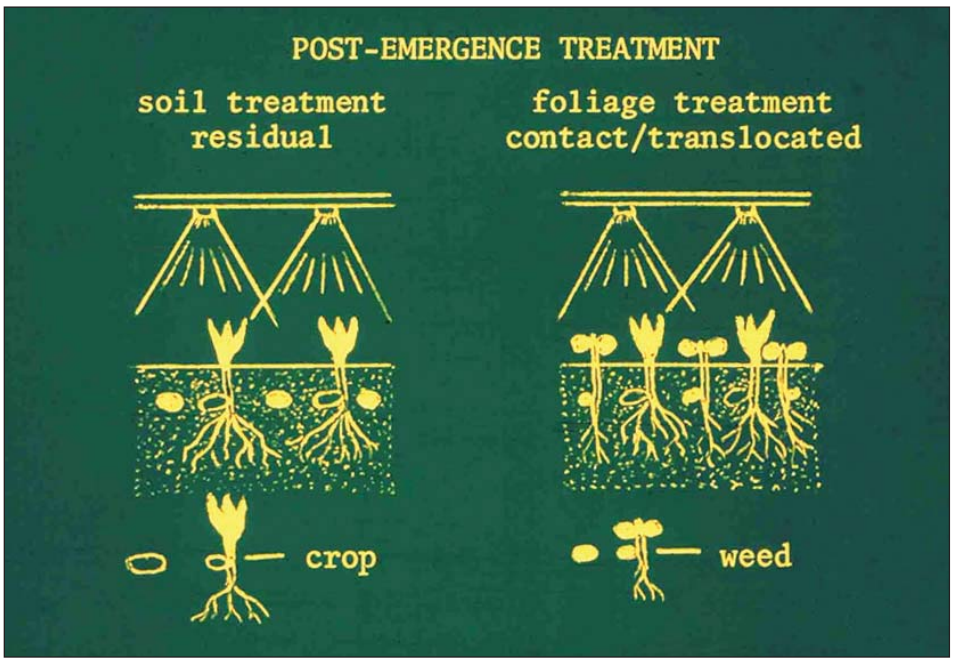


Figure 9.12. Post-emergence application of herbicides (after emergence of weeds and the crop).

Herbicides should be selected based on specific type of weeds (broad-leaved or grass or sedge) encountered in a field, and also keeping in view the rotational crops followed after pearl millet harvest. It is very difficult to control grassy weeds with post-emergence herbicides as pearl millet crop itself may be affected. So a pre-emergence herbicide should be used if grassy weeds are expected. In general, herbicides like atrazine, propazine, prometryne and simazine are recommended for weed control in pearl millet. Atrazine usually gives better control of weeds than propazine but propazine has been found to be safest.

If the field is weedy with annual grasses and broad-leaved weeds before sowing pearl millet, spray praquat (Gramoxone) on the weeds at 0.5 to 1.5 L ha^{-1} depending on the weed density. Consult the product label prior to use. If sedges like *Cyperus* spp, bermuda grass, johnson grass and field bind weed dominate the field, spray glyphosate (Roundup) at 0.5 to 1 L ha^{-1}. Spray directly on the weeds as glyphosate becomes inactive in the soil. Consult the product label prior to use.

Pre-emergence application

Atrazine or propazine or prometryne at 1.0 kg ai ha^{-1} is recommended to control emerging weeds after the sowing of pearl millet. There should be optimum soil moisture at the time of application of atrazine. Application of metalochlor at 1 kg ai ha^{-1} has been found to control the weeds effectively and increase the yield and net income of pearl millet intercropped with pulses like cowpea/black gram/green gram.

Post-emergence application

Low rates of 2,4-D at 0.5 to 1.0 kg ha^{-1} may be applied when the plants are about 10 to 30 cm tall. Spraying later affects yield by reducing seed set. Early treatment can also be injurious by damaging the root system.

With this, Module 9 concludes. If you want to test your understanding of the subject in this Module, then please answer the following questions:

1. Weed control is particularly important in rainfed pearl millet because

A. Of its long duration.
B. Of slow initial growth.
C. It is a shallow rooted crop.
D. Of severe competition from grassy weeds.

2. The critical period of weed competition in pearl millet crop.

A. Sowing time
B. Flowering stage
C. Grain-filling stage
D. 2 to 4 weeks after sowing

3. When should the first schedule for weed control activity in pearl millet start?

A. Before sowing
B. Immediately after germination
C. After the seedlings are established
D. At flowering

4. An important parasitic weed in pearl millet crop.

A. *Cynodon*
B. *Striga*
C. Dodder
D. Field bind weed

5. Efficient and effective weed control can be achieved by

A. Manual weeding
B. Cultural practices
C. Chemical control
D. Appropriately combining any 2 or all 3 practices

6. One of the cultural practices to minimize weed competition in pearl millet crop.

A. Use organic manures
B. Apply more phosphorus
C. Adopt good crop rotation
D. Use high-yielding variety

7. Use of chemicals (herbicides) to control weeds should be based on

A. Using right chemical
B. Correct usage of the chemical
C. Comparative advantage over manual weeding
D. All the 3 above

Module 10: Soil Moisture Relationships and Irrigation

There are two Lessons in Module 10: (1) Soil moisture relationships; and (2) Irrigation in pearl millet cultivation.

After completing two Lessons in this Module, you will learn to:

- Understand soil moisture relationships and growing of pearl millet crop.
- Identify critical periods of crop growth when soil moisture availability is important.
- Follow the practices that help in conserving soil moisture.
- Recognize the importance of irrigation in pearl millet cultivation.

Lesson 1: Soil moisture relationships

After completing Lesson 1, you will learn to answer:

- What characteristics of pearl millet contribute to its adaptation to dry conditions?
- What is the amount of water required for good crop of pearl millet?
- List the important growth stages when soil moisture stress affects pearl millet crop.
- What practices help in conserving soil moisture in pearl millet cultivation?
- What will be the problem with continuous rains during grain-filling stage?

Much of pearl millet's success in surviving through the ages has been its ability to produce well in hot, arid and drought-prone areas where most crops fail. This adaptation reflects on pearl millet's origin in the Sahel-region of Africa, where growing conditions are hot and dry. Pearl millet is dubbed as a "Diamond in the Rough" because of its adaptation to very low rainfall areas.

Pearl millet is considered more efficient in utilization of soil moisture than sorghum and maize. It is a hardy crop that can grow in very hot and dry areas, and on soils too poor for sorghum. In general, pearl millet fits in the same areas of adaptation as sorghum, except that it is more drought tolerant, matures early and can produce grain in shallow and poor soils.

Pearl millet appears to have relatively faster root development, with extensive root growth both laterally and downward into the soil profile to take advantage of available moisture and nutrients. Its roots may penetrate up to 360 cm, although 80% of the root mass is in the top 10 cm. This deep root system and less defined "critical water use period" makes pearl millet tolerant to short-duration drought.

Annual rainfall in the areas where most of the pearl millet is grown ranges from 250 to 700 mm although it is also grown in areas receiving up to 1500 mm rainfall. It is sensitive to waterlogging. At harvest time, dry warm weather is most suitable. Water (soil moisture) is the most common limiting factor for better yields in pearl millet. Pearl millet crop needs 250–300 mm of water during the season for a high-yielding

crop. This can come from rain, irrigation or stored soil moisture. However, it is not the total amount of moisture the crop receives that is most important; timing of rainfall or irrigation can have a dramatic effect on both crop yield and quality. Rainfall during the pre-sowing period governs the time of sowing but does not affect yields. However, rainfall during germination period, particularly the first 3 to 4 days, results in poor germination and low yields. Heavy rain during flowering or ripening reduces seed set, and causes lodging, thus reducing grain yield and quality.

The water absorbed by pearl millet during the first month after sowing is relatively small. Hence the very early growth phase after seedling emergence is not highly sensitive to moisture stress. The period of 40 to 65 days after sowing (flowering and grain formation stages) are very sensitive to moisture stress. Often, rainfed pearl millet crop experiences soil moisture stress when rains fail during the monsoon season. Practices like contour cultivation in a sloping field, soil mulching, intercultivation and good weed control help in soil moisture conservation and drought management during the crop growth.

Spraying of 2% urea at the time of soil moisture stress experienced by the crop also helps overcome moisture stress. Continuous rains with cloudy weather leading to high humidity during grain-filling and hardening stages can result in sprouted and low-quality grain as well as excessive losses due to stalk lodging (Fig. 10.1), and incidence of ergot and smut diseases.

Figure 10.1. Stalk lodging.

Lesson 1 on soil moisture relationships in pearl millet cultivation in this Module concludes. The next Lesson in this Module is about irrigation practices in pearl millet cultivation.

Lesson 2: Irrigation in pearl millet cultivation

After completing Lesson 2, you will learn to answer:

- Why pearl millet yields are often low when grown under rainfed conditions?
- How does irrigation help pearl millet crop?
- What is the advantage of pre-sowing irrigation in pearl millet cultivation?
- Which are the critical stages for water requirement in pearl millet plant growth?
- What symptoms help you to decide the irrigation requirement for pearl millet crop?
- List the irrigation schedule for a ratoon pearl millet crop.
- What contingency plan will you follow in the event of drought during the pearl millet crop growth?

Pearl millet is mainly grown under rainfed situation. Only about 8% of pearl millet area is irrigated in India. The crop is exposed to drought conditions very often during its growth and consequently the yields are lower than the potential yield. So, if the farmers want higher pearl millet yields even during the rainy season, the crop should be irrigated, if water is available and if there is any dry spell.

Irrigation helps pearl millet crop to make efficient use of inputs, increases yield, improves quality of grain, improves reliability and reduces risk, and increases profitability. Adequate soil moisture at sowing helps assure uniform plant stand and contributes to early plant growth. Pre-planting irrigation can supply this moisture when early rains do not reach the root zone prior to planting. Allowing the seed to remain in dry soil for several days may result in poor germination and seedling vigor. So, irrigation prior to sowing is recommended if water is available. Whether irrigating before or after planting, apply no more water than required to reach the effective root zone. Encourage deep root system by maintaining only moderate soil moisture levels during early vegetative growth. Moderate plant moisture stress during early vegetative growth normally does not reduce grain yield significantly. There is little quantified information about pearl millet response to irrigation during its growth. It appears that pearl millet responds less to irrigation than other grain crops. Greatest water use occurs during the flowering and soft dough stages. Irrigation intervals and the amount of water to be applied is determined by rainfall, soil water-holding characteristics, plant rooting depth and other climatic conditions like air temperature, etc.

The visible signs for irrigating the crop or moisture requirement of the crop are drooping and withering of leaves in the morning, and cracking of the soil surface of the field. Plan the irrigation to provide adequate soil moisture during these periods of high water requirement.

Drought contingency plan for rainy season crop

To conserve in-situ rainwater, deep plow the field during summer on heavy soils as those in Maharashtra, Tamil Nadu, Andhra Pradesh, Karnataka and eastern Rajasthan. A wider row spacing of 60 cm is advocated where rainfall is less than 400 mm.

Adopt suitable intercropping system (review Module 7). Select early-maturing hybrids/varieties of pearl millet under late onset of monsoon (review Module 8). Keep the crop weed-free by timely weeding. If dry spell occurs immediately after sowing, replant pearl millet in between the existing rows or relay cropping may be practiced including short-duration oilseeds/pulse crops. Under normal onset of monsoon and occurrence of prolonged dry spell during grand-growth period of the crop, reduce the plant population to the extent of 25 to 40%. If drought prevails for 2–3 weeks during the pre-flowering to grain-setting stage, one life-saving irrigation may be given, if water is available.

With this, Module 10 concludes. To check your understanding of the subject in this Module, please answer the following questions:

1. Which one of the following is most important in relation to soil moisture or irrigation for pearl millet crop?

A. Quantity of water
B. Quality of water
C. Timing of availability of water
D. Depth of water

2. Pearl millet is sensitive to

A. Low soil moisture
B. Continuous rains
C. Waterlogging
D. Hot weather

3. Continuous drizzle during the flowering stage of pearl millet crop

A. Advances maturity
B. Favors ergot
C. Delays maturity
D. Reduces grain size

4. One way of preparing pearl millet to cope with moistures stress.

A. Have a high plant stand
B. Cultivate in sandy soils
C. Spraying 2% urea solution
D. Late sowing

5. Advantage of pre-planting irrigation for pearl millet cultivation.

A. Easy field preparation
B. Efficient application of fertilizers
C. Increased seedling vigor
D. Better herbicidal activity

6. Mid-season drought affecting the pearl millet crop can be corrected by

A. Application of zinc
B. Ratooning
C. Thinning the plants by 40%
D. I am not sure

7. Symptom to decide to irrigate pearl millet crop.

A. Shallow root system
B. Drooping leaves
C. Strong sun the previous day
D. I am not sure

8. One of the practices in pearl millet for drought contingency planning

A. Shallow plowing
B. Adopt intercropping
C. Replace with maize
D. Opt for local varieties

Module 11: Harvesting and Storage

After completing Module 11, you will learn to:

- Identify the right stage for harvesting pearl millet crop.
- Recognize the importance of proper drying of pearl millet after harvesting 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%.

Thin stems, heavy panicles and profuse tillering, which are inherent traits of varieties, may result in lodging of the plants. The seeds in the panicles of lodged plants germinate in the moist field and thus affect grain yield and quality. Hence, the plants are tied together to prevent lodging (Fig. 11.1).

Most standability concerns develop when growers leave pearl millet in the field until grain moisture is below 14%. Harvesting at about 20% moisture prevents a significant amount of standability problems (Fig. 11.2).

Figure 11.1. Tying of plants.

Figure 11.2. Pearl millet standability.

The best stage to harvest pearl millet is when the plants reach physiological maturity. Physiological maturity can be determined by the black (dark) spot at the bottom of the grain in the hilar region. When the crop matures, the leaves turn yellowish and present a nearly dried up appearance. The grains are hard and firm. The usual practice of harvesting pearl millet is cutting the earheads first and the stalks later. The stalks (straw) are cut after a week, allowed to dry and then stacked.

The harvested earheads are dried before threshing. The grain is separated from the earheads by using a mechanical thresher or by drawing a stone roller over the earheads

or trampling with cattle. The separated grain is then cleaned by winnowing (Fig. 11.3) and dried.

Conventional grain dryers or use of natural air drying are options for drying the grain. Grain at or below 14% moisture is considered dry. For long-term storage (more than 6 months), grain moisture content should be less than 12%.

Pearl millet grain is stored traditionally in mud bins or straw bins or bamboo bins or metal bins (Figs. 11.4–11.6).

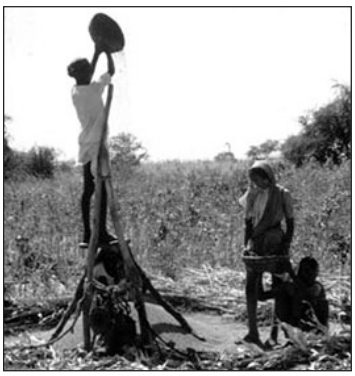


Figure 11.3. Winnowing of pearl millet.

Figure 11.4. Mud bin to store pearl millet.

Figure 11.5. Bamboo bin to store pearl millet.

Figure 11.6. Metal bin to store pearl millet.

The storage structures in rural areas are not ideal from scientific storage point of view, as substantial losses occur during storage of grain from insect pests, molds, rodents, etc. Keeping the requirements of the farmers in view, the Indian Grain Storage Institute (IGSI), Hapur, Uttar Pradesh, with its branches at Ludhiana and Hyderabad, have developed several metal bins of different capacities for scientific storage of grains in rural areas (Fig. 11.7).

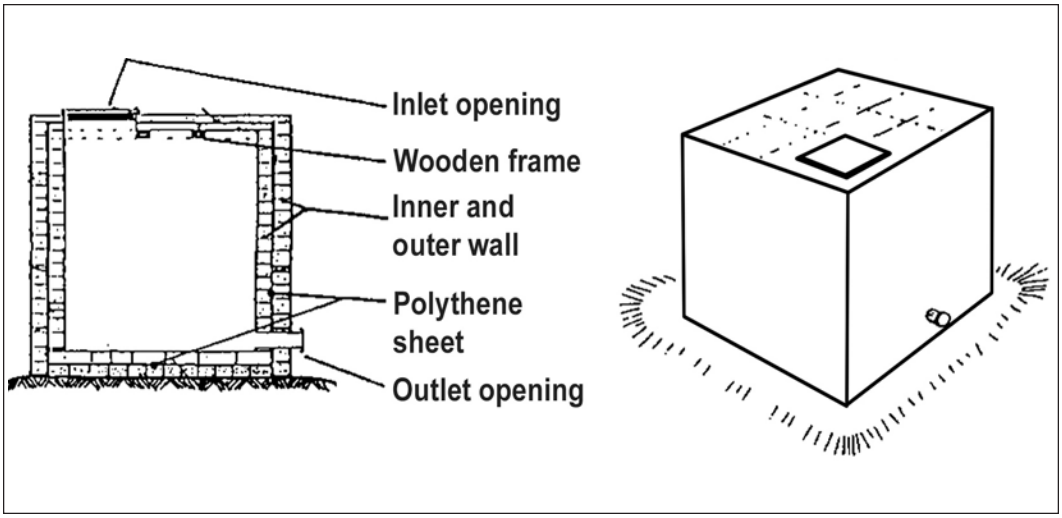


Figure 11.7. "Pusa" metal bin to store pearl millet.

With this, Module 11 concludes. To check your understanding of the subject in this Module, please answer the following questions:

1. The ideal moisture content for harvesting pearl millet grain.
A. 30% B. 26%
C. 20% D. 10%

2. Lodging of pearl millet at the time of harvest could be due to
A. Tall varieties B. Downy mildew infection
C. Stalk rots D. Inherent trait of the variety

3. The best stage to harvest pearl millet is when the plants reach the
A. Physiological maturity B. Hard dough stage
C. Soft dough stage D. I am not sure

4. Harvesting pearl millet at the proper time ensures
A. Easy harvesting B. Compact earheads
C. Less labor requirement D. Good grain quality

5. Physiological maturity can be identified by
A. Drying of upper leaves B. Hard grain
C. Black spot in hilar region of the grain D. Lodging of plants

Module 12: Diseases of Pearl Millet

There are five Lessons in this Module: (1) About pearl millet diseases; (2) Downy mildew disease; (3) Ergot; (4) Smut; and (5) Rust.

After completing five Lessons in this Module, you will learn to:

- List and identify diseases that affect pearl millet crop.
- Identify the damage symptoms from pearl millet diseases.
- Manage economically important diseases in pearl millet crop.

Lesson 1: About pearl millet diseases

After completing this Lesson, you will learn to answer:

- Why pearl millet crop is not much affected by many diseases?
- List the three major diseases of pearl millet.
- Explain three major disease-controlling strategies that farmers can practice.

Fortunately, pearl millet is not affected by many diseases. The main reasons for this are the relatively short duration of the crop, cultivation in dry regions, cultivation following a long, hot, dry summer season and its genetical composition. However, few diseases that oocur on pearl millet crop result in considerable economic losses because most of these diseases affect pearl millet panicles and the grains. These economically important diseases are downy mildew, ergot, smut and rust. Downy mildew also affects leaves as does the rust.

The three major disease control strategies available for farmers are disease resistant cultivars, cultural practices and use of chemicals. Advance planning is required to follow these practices. There are several downy mildew resistant hybrids and improved varieties and only a few smut resistant varieties. Growing such cultivars is the foremost control measure. Since not much targeted attention has been paid to the breeding of ergot and rust resistant cultivars, no cultivar is resistant to ergot and only few can tolerate rust.

Cultural control measures are many times under-recognized for their effectiveness in disease control. With proper crop management, the crop can escape most diseases or withstand them with negligible impact on yield.

Chemicals used for disease control are limited to seed treatments by fungicides.

With this, Lesson 1 about pearl millet diseases concludes.

Lesson 2: Downy mildew

After completing this Lesson, you will learn to:

- Recognize the importance of downy mildew disease in pearl millet.
- Describe the symptoms of downy mildew disease in pearl millet.
- Employ practices to manage downy mildew disease in pearl millet.

Distribution of downy mildew

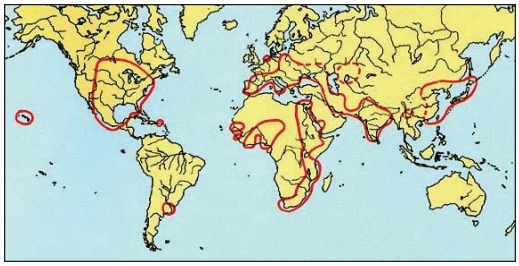


Figure 12.1. Distribution of downy mildew on pearl millet.

Downy mildew of pearl millet, caused by *Sclerospora graminicola*, sometimes referred to as 'green ear', is the most destructive disease of pearl millet. This disease is widely distributed in the tropical areas of the world (Fig. 12.1), and is of greatest importance in India, especially on single-cross hybrids. In India, the disease is present in all the states where pearl millet is cultivated. In India, downy mildew epidemics caused substantial yield losses during 1970s and 1980s with the first epidemics observed on hybrids HB 1 and HB 3. Grain yield losses of 10 to 60% caused by this disease have been reported.

Economic importance of downy mildew

The yield reducing potential of downy mildew is very high, and this was dramatically demonstrated in HB 3, a popular hybrid, when pearl millet grain production in India was reduced from 8 million t in 1970–71 to 5.3 million t in 1971–72. This reduction was, to a large extent, due to a downy mildew epidemic, in which yields in some fields were reduced by 60 to 70%.

Symptoms of downy mildew

There is considerable variation in the symptoms, which almost always develop as a result of systemic infection. Systemic symptoms generally appear on the second leaf. Once these symptoms appear, all the subsequent leaves and panicles also develop symptoms.

The disease can appear on the first leaf also under conditions of severe disease development (Fig. 12.2). Symptoms appear as chlorosis (yellowing) at the base of the leaf and successively higher leaves show severe chlorosis (Fig. 12.3) and powdery materials on the lower side of the leaf surfaces.

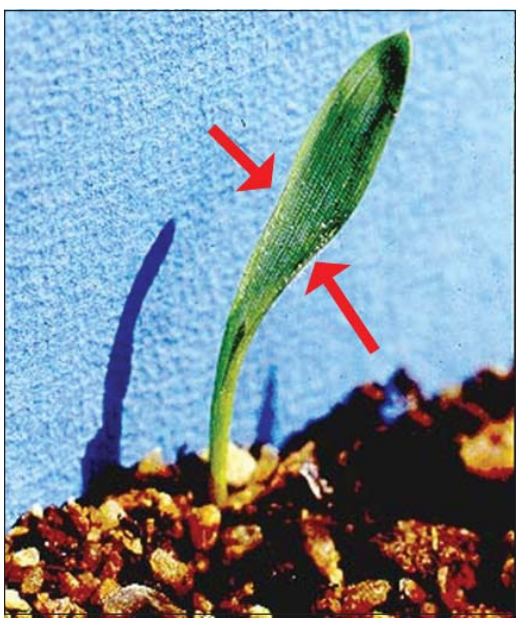


Figure 12.2. Partially unfolded first leaf showing downy mildew infection.

The 'half-leaf' symptoms (Fig. 12.4) characterized by a distinct margin between the diseased (basal) portion and no disease area towards the tip also occur in pearl millet cultivars.

Figure 12.3. Progression of downy mildew symptoms.

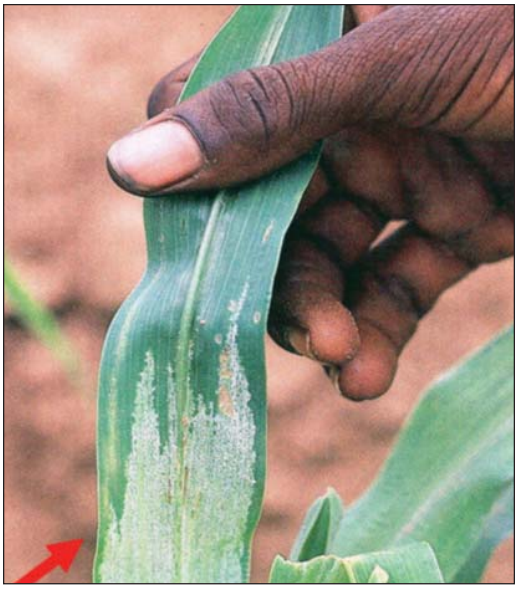


Figure 12.4. Typical 'half-leaf' symptoms.

Under conditions of high humidity and moderate temperature, the infection could be very severe. Severely infected plants are generally stunted and do not produce earheads (Fig. 12.5).

When earhead is infected, the floral parts are transformed into leaf-like structures, which can be partial (Fig. 12.6) or total (Fig. 12.7). Note the different types of malformation that can occur (Fig. 12.8).

Figure 12.5. Severely infected plant showing stunted growth.

Figure 12.6. Partially infected earhead.

Figure 12.7. Totally infected earhead.

Figure 12.8. Malformed earheads (normal earhead on the extreme left).

Management of downy mildew

Management practices should aim at reducing the movement of primary soil and seed-borne fungal inoculum, and the secondary spread of the fungus within and between pearl millet fields. This can be achieved by the combination of the three disease management practices – cultural, chemical and host plant resistance.

Cultural methods

All cultural methods are aimed at manipulating the environment to the advantage of the host and disadvantage of the disease causing fungus. Five such methods have been suggested to manage the pearl millet downy mildew.

1. Sanitation

Use of disease-free seed and effective removal of infested plant material from the field after the harvest of the crop is essential to reduce the primary inoculum in the soil. Downy mildew-infected plant material should be burned, or if feasible, the field should be plowed deeply to bury the plant material.

2. Early sowing

A pearl millet crop sown very early in the season generally has less downy mildew than that sown late in the season. This can be practiced only if sowing is possible with sufficient rains early in the season.

3. Transplanting of pearl millet

A transplanted crop of pearl millet suffers significantly less from downy mildew than a direct sown crop, both in the rainy and postrainy seasons. Hence, this method can be followed to reduce the downy mildew problem where transplanting can be practiced.

4. Roguing

Removal and destruction of infected plants reduces the spread of disease during the same season and also reduces the inoculum buildup, reducing the incidence of this disease during the following seasons. To practice this method farmers should be able to detect infected plants at an early stage. They would have to be convinced that the return from reducing the disease would be worth the extra effort.

5. Diversification of cultivars

Growing one hybrid for several years over a large area should be avoided. Instead, if hybrids are to be grown, several of them should be cultivated at the same time within a given area. Growing open-pollinated varieties (OPVs) provides another way to keep the disease under control. These improved varieties may not be disease-free, but it is likely that an unacceptable level of disease buildup will take much longer time to develop on such cultivars.

Chemical methods

The systemic fungicide metalaxyl has been used successfully to control downy mildew in pearl millet. Seed treatment with metalaxyl at 2 g ai kg^{-1} seed can control the disease for about the first 35 days after sowing (Fig. 12.9).

Foliar application of metalaxyl at 125 mg ai L^{-1} arrests further development of the disease in the systemically infected plants. If sprayed before floral initiation, disease-free heads are produced.

Figure 12.9. Plots grown without (left) and with (right) metalaxyl seed treatment. The untreated plot hardly produced any heads.

Host plant resistance

Use of resistant cultivars is the most cost-effective method for the control of downy mildew. The popular hybrids such as HHB 67 Improved, RHB 121, GHB 558, GHB 538, Pusa 23, ICMH 356, PB 106, 7688, and OPVs such as Raj 171, JBV 2, Pusa 383, CZP 9802, WC-C75, ICTP 8203, ICMV 221 and ICMV 155 released in India are resistant to downy mildew.

Lesson 2 on downy mildew of pearl millet concludes. The next lesson is about ergot disease of pearl millet.

Lesson 3: Ergot

After completing this Lesson, you will learn to:

- Recognize the importance of ergot disease of pearl millet.
- Describe the symptoms of ergot disease in pearl millet.
- Employ practices to manage ergot disease in pearl millet.

Distribution of ergot

Ergot of pearl millet, caused by C*laviceps fusiformis*, has been reported from India, Pakistan, and several countries in Africa (Fig. 12.10). In India, the disease is present in all the states where pearl millet is cultivated.

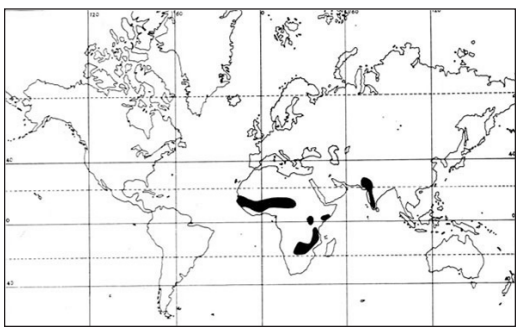


Figure 12.10. Distribution of ergot disease.

Economic importance of ergot

Ergot sometimes is a very destructive disease on pearl millet grain in India. Although the disease has been known for a long time, possibly over 100 years, the first large-scale spread of ergot was not reported until 1957.

The importance of ergot as a major threat to pearl millet production was recognized in late 1960s with the cultivation of commercial hybrids. Losses in grain yield due to ergot have been estimated to be as high as 58 to 70% in hybrids. This disease assumes special importance because grain is easily contaminated by fungal bodies (sclerotia) which affect the health of human beings and animals.

Normal grain contaminated with ergot-infected grain (Fig. 12.11) when consumed by human beings induces nausea, vomiting, and giddiness and in extreme cases may be fatal also. The feed contaminated with ergot-infected pearl millet grain when fed to sows (female pigs) prevents from raising litters. In chicken, this toxicity leads to dropping of feathers and weakening of legs.

Figure 12.11. Contamination of healthy pearl millet with ergot-infected seed.

Symptoms of ergot

The ergot-causing fungus infects the florets and develops in the ovaries, producing initially copious creamy, pink, or red-colored sweet sticky liquid called honeydew (Fig. 12.12). The honeydew can drip down onto the upper leaves making them sticky. Often pollen and anther sacs adhere to the honeydew. Subsequently, long, dark-colored, hard structures called sclerotia develop from infected florets, which at first appear dark at the tip and then turn completely black (Fig. 12.13).

Management of ergot

The major source of primary inoculum is sclerotia already present in the soil from the previous crop or added at sowing with the use of contaminated seed. Disease development and spread depends on prevailing weather conditions during flowering and the timely availability of pollen.

Figure 12.12. Ergot symptoms: Honeydew stage.

Figure 12.13. Honeydew stage (left) turning to sclerotial stage (right).

Cultural control

Deep plowing soon after harvest helps bury sclerotia in the soil at a depth which prevents their germination, thus reducing primary inoculum.

Separate infected seed from normal seed by soaking in 10% salt solution. Floating light weight infected seeds are separated from normal seeds which sink to the bottom.

In India, two perennial grass weeds, C*enchrus ciliaris* and *Panicum antidotale*, have been found to harbor the pearl millet ergot fungus (Fig. 12.14). Eradicating these two weeds from around pearl millet fields during early May/June helps reduce the inoculum.

Figure 12.14. Perennial grass weeds in pearl millet: (left) Cenchrus ciliaris*; and (right)* Panicum antidotale.

Chemical control

A practical and economical fungicide spray schedule for farmers is yet to be demonstrated.

Host plant resistance

Use of resistant cultivars is the most cost-effective method for the control of ergot disease. Open-pollinated varieties such as WC-C75, ICTP 8203 and ICMV 155 released in India are less vulnerable to ergot, not because they are resistant, but because they benefit from pollen-based escape mechanism (ie, pollination and rapid fertilization provides a competitive edge over the germinating propagules of ergot, preventing infection).

Lesson 3 on ergot disease of pearl millet concludes. The next lesson is about smut disease of pearl millet.

Lesson 4: Smut

After completing this Lesson, you will learn to:

- Recognize the importance of smut disease of pearl millet.
- Describe the symptoms of smut disease in pearl millet.
- Employ practices to manage smut disease in pearl millet.

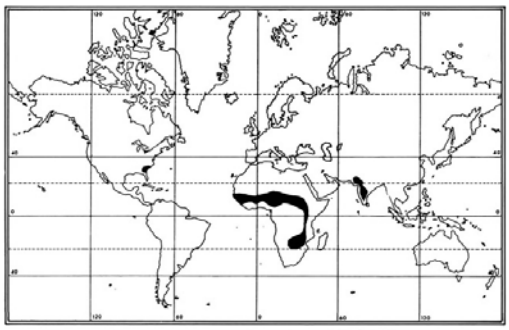


Figure 12.15. Distribution of smut disease.

Distribution of smut

Smut of pearl millet, caused by *Moesziomyces penicillariae*, has been reported from Pakistan, India, USA and several countries in Africa (Fig. 12.15). In India, the disease is present in most of the states, especially the northern states where pearl millet is cultivated.

Economic importance of smut

In India, a survey during the 1950s indicated that smut severity in farmers' fields ranged from 1 to 30% in parts of Tamil Nadu, Andhra Pradesh and Maharashtra. In recent years, the disease has become more important in northern India, particularly in the states of Haryana, Punjab, Gujarat and Rajasthan. The increased severity of this disease is mainly due to commercial cultivation of hybrids.

Symptoms of smut

In the infected florets, ovaries are converted into structures called sori. The sori are larger than grains and appear as enlarged, oval to conical bodies projecting somewhat beyond the glumes in place of grains. Initially, the sori are bright green but later turn brown to black (Fig. 12.16).

Figure 12.16. Smut of pearl millet.

Management of smut

Although no effective and practical cultural or chemical control measures are available, there are several reports of chemicals having varying successes. Chemical control measures are neither economical nor feasible at the farmers' level. The major limitations to chemical control of smut in pearl millet are low economic value of the crop, and scarcity of resources available to pearl millet growing farmers.

Use of resistant cultivars is the most cost-effective method for the control of smut. The OPVs, WC-C75, ICTP 8203 and ICMV 155, released in India are less vulnerable to smut due to the same pollen-based escape mechanism that reduces ergot infection.

Lesson 4 on smut disease of pearl millet concludes. The next lesson is about rust disease in pearl millet.

Lesson 5: Rust

After completing this Lesson, you will learn to:

- Recognize the importance of rust in pearl millet.
- Describe the symptoms of rust in pearl millet.
- Employ practices to manage rust disease in pearl millet.

Importance of rust

Pearl millet rust, caused by *Puccinia substriata* var *indica*, has been observed throughout India. In northern India, the disease does not frequently occur until flowering time in September when temperatures are somewhat moderate. In other regions of the country, rust may attack even the seedling stage, causing substantial reduction in yield.

Symptoms of rust

The distal half of the leaf is commonly infected first, then sori (fungal bodies) spread over both surfaces of leaves, as reddish pustules, but more occur on the upper surface (Fig. 12.17). Necrotic spots may develop around groups of pustules, and premature drying of the leaves may result.

Figure 12.17. Rust symptoms.

Management of rust

Rust-causing fungi develop on many grass weeds. These weeds help in spreading the disease to pearl millet crop. So, good weed control practice helps reduce rust in pearl millet. Growing of rust resistant cultivars is advised for rust endemic areas.

Dusting sulfur and similar inorganic chemicals, applied frequently enough, do control rust but this may not be economical to the farmers growing pearl millet for grain.

With this, Lesson 5 on rust disease in pearl millet concludes, and also Module 12 on diseases of pearl millet concludes. To check your understanding of the subject in this Module, please answer the following questions:

1. The first downy mildew epidemic occurred due to susceptibility of
A. NHB 3 B. HB 3
C. HB 1 D. WC-C75

2. Which fungal bodies of pearl millet disease affect the health of human beings and animals?
A. Downy mildew oospores B. Smut sori
C. Ergot sclerotia D. None of the above

3. Which is the most effective downy mildew disease management strategy?
A. Use of chemicals B. Cultural practice
C. Host plant resistance D. Biological control

4. The most widely distributed disease of pearl millet is
A. Rust B. Blast
C. Smut D. Downy mildew

5. Which of the following is collateral host for ergot disease of pearl millet?
A. *Cenchrus ciliaris* B. *Cynodon dactylon*
C. *Cyperus rotundus* D. *Digitaris sanguinalis*

Module 13: Seed Production, Processing and Marketing

In this Module, there are four Lessons: (1) Seed classes and production; (2) Seed production management; (3) Seed processing; and (4) Seed marketing.

Lesson 1: Seed classes and production

After completing this Lesson, you will learn about:

- Various seed classes.
- Linkage among various seed classes.
- Care to be taken during seed production.
- Seed production procedures.

Commercial end products in pearl millet are open-pollinated varieties (OPVs) and hybrids. Once the decision is taken to release a cultivar with specific characteristics, and an OPV or a hybrid is identified with a name, pearl millet seed production chain starts. Seed multiplication of any class depends upon the actual requirements and the buffer stock. In pearl millet, seed is multiplied in four stages (Nucleus, Breeder, Foundation and Certified) called seed classes.

Nucleus seed production

Nucleus seed refers to the seed produced by the breeder who developed the particular variety and the parental lines of hybrids, or by any other breeder of the institution where the variety was developed which is directly used for multiplication of breeder seed.

Nucleus seed is the first stage in the chain of seed multiplication of a released variety or hybrid parents and is the only seed that can be used to produce its own seed class. The highest degree of purity should be maintained for all the characters associated with the identity of a variety or line. The procedure for the production of Nucleus seed of OPVs (Fig. 13.1), male-sterile line, maintainer line (Fig. 13.2) and restorer line in pearl millet is described below.

Open-pollinated variety

Season I: Isolation Block

- Basic seed of OPV should be grown in an area of 0.1 ha maintaining strict isolation of at least 1000 m from any other plot of pearl millet or wild relatives.
- One-third of the normal plant population should be maintained keeping at least 3000–5000 plants.
- Carefully observe true-to-type plants at critical stages (tillering, preflowering, flowering, dough stage and maturity) and select 500 to 1000 plants with characters typical of the released variety.

- Harvest and keep seed of each selected plant separately and evaluate for seed characters.
- Keep one part of the seed from each plant progeny as remnant seed and use the other part for evaluation.

Season II: Progeny evaluation

- Plant unreplicated progeny rows along with check rows (grown from the basic bulk seed of OPV) after every 15–20 rows.
- Compare progeny rows at critical stages and select 30 to 50% progenies conforming to the varietal characters.
- Bulk the remnant seed corresponding to the selected progenies.

Season III: Nucleus seed nursery

- Use the bulked seed to grow Nucleus seed nursery in isolation (1000 m).
- The harvested seed is bulked and divided into five or six lots and kept under cold storage.
- One of these lots is kept as a backup stock for Nucleus seed production when required, and the other lots are used for Breeder seed production in subsequent years.

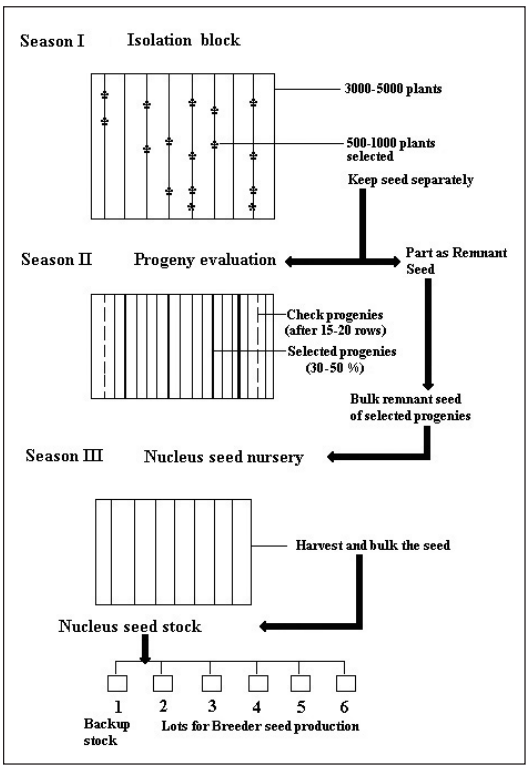


Figure 13.1. Nucleus seed production of open-pollinated variety.

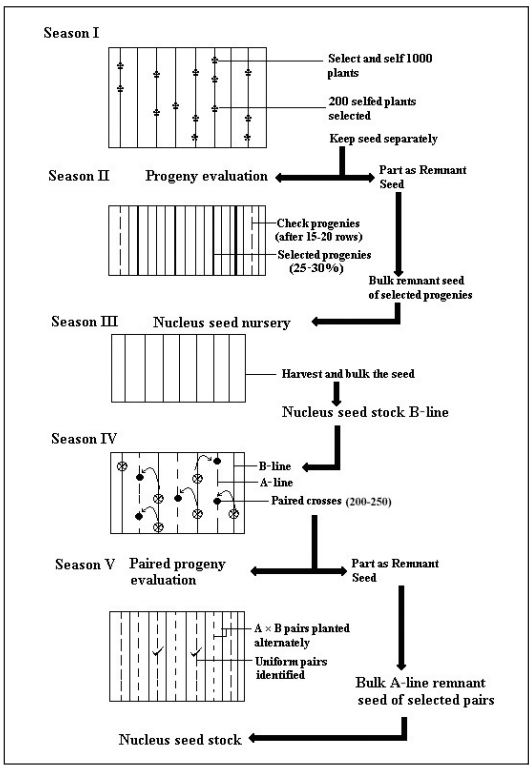


Figure 13.2. Nucleus seed production of maintainer (B) line and male-sterile (A) line.

Maintainer line (B-line)

Season I

- Grow the B-line in an isolation plot (0.05 ha) (if possible).
- Select and self about 1000 plants at the time of flowering.
- Finally select about 200 selfed plants conforming to the characters of the maintainer line and divide it into two lots.

Season II

- Grow plant-to-row using the seed from one lot.
- The progeny rows are studied for the diagnostic characters and rows not conforming to the characteristics of the line are rejected.
- Identify the best progeny rows (25–30%).
- Bulk the seed of the second lot for the progenies corresponding to those selected in the field test.

Season III

- Grow the bulk seed prepared above in isolation.
- Bulk the open-pollinated seed of the plants after harvest.
- This forms the Nucleus seed bulk of B-line.

Male-sterile line (A-line)

Season IV

- Grow A- and B-lines in alternate rows in isolation (if possible). Seeds of B-line to be used will be Nucleus seed bulk.
- Make 200–250 paired crosses between A- and B-line plants.
- Care must be taken to cross A- and B-line plants conforming to the line standards only. Care should also be taken to ensure that A-line plants involved in crossing are those that are fully male-sterile.
- Paired crosses among A- and B-lines should be labeled, viz, A1 × B1, A2 × B2, etc and harvested seed of each pair should be kept separately.

Season V

- Grow respective paired crosses involving A-line (crossed seed) and B-line (selfed seed) in alternate rows.
- Retain a portion of seed of all the A-line plants (crossed seed) and B-line plants (selfed seed) as remnant seed.
- Observe critically the pairs of A- and B-lines for all the characters including height, flowering and typical morphological characters conforming to the line standards.
- Observe for pollen shedders in A-lines. The A-line progenies showing pollen shedders and corresponding B-lines should also be rejected.

- Identify uniform pairs of A- and B-lines which conform to the standards of parental lines.
- Remnant seed of the A-lines of the selected pure pairs is bulked.
- This forms Nucleus seed bulk of A-line.

Restorer line (R-line)

Season I

- Grow the R-line in an isolation plot (0.05 ha) (if possible).
- Self about 1000 plants conforming to the standards of the line at the time of flowering.
- Finally select about 400 selfed plants based on field studies as well as observation in laboratory for seed color, shape, etc and divide it into two lots.

Season II

- Grow plant-to-row using one lot of the seeds.
- The progeny rows are studied for the diagnostic characters.
- The progenies not conforming to the characteristics of the line are rejected.
- Identify the best progeny rows (30 to 50%) based on all characteristics typical of the line. In the progeny row testing if adequate number of progeny rows conforming to the line standards are not obtained, selfing for one or more generations will be required. These selfed plants of R-line should also be tested for their restoration ability.
- Bulk the remnant seed of best lines.

Season III

- Grow the bulk seed of remnant seed in isolation.
- Bulk the seed of all the plants after harvest.
- This forms the Nucleus seed bulk of R-line.

Breeder/Foundation seed production

Breeder seed of a released OPV or hybrid parents is produced by or under the direct control of the sponsoring plant breeder. This class of seed is the base of the first and recurring increase of Foundation seed production plot of this class of seed is inspected by a monitoring team consisting of a breeder, seed certification officer, representatives of National Seed Corporation (NSC) and State Seed Corporation (SSC).

Foundation seed of a released OPV or hybrid parents is produced from Breeder seed, the production of which is carefully supervised or approved by the breeder and seed certification agency at the experimental station or recognized seed farms. It is used to produce Certified seed.

Male-sterile (A) line and maintainer (B) line

- Multiply A-line by planting A- and B-lines in alternate set, usually in the ratio of 4:2.
- Plant 4–8 border rows of the B-line around production block to ensure adequate pollen supply to the A-line.
- Careful and strict roguing is necessary in A- and B-lines. Rogue out pollen shedders in the A-line, if any.
- Harvest the B-line rows immediately after completion of flowering period.
- Carefully harvest the A-line rows and bulk the seed.
- For Breeder seed production of B-lines a separate production plot of 0.1 ha under isolation (1000 m) is planted using the Nucleus seed stock. Foundation seed is produced by planting Breeder seed.
- Follow roguing and other procedures as detailed in the Nucleus seed production method.

Restorer (R) line and OPV

- Breeder/Foundation seed production of R-lines and OPVs is done by bulk planting under isolation (1000 m). Nucleus seed stock is used to produce Breeder seed, and Breeder seed is used to produce Foundation seed.
- Seed plots should be 0.1–0.2 ha for R-lines/OPVs and at least 3000–5000 plants should be maintained.
- The crop is inspected at the following different stages of growth to identify deviants for different characters:

Stage of crop	Characters specifically observed
18 days after sowing	Identify deviants for early vigor
30–35 days after sowing	Identify deviants for tillering, plant height and other traits
Boot leaf stage	Identify deviants based on early flowering
50% flowering	Identify deviants for late flowering, panicle exertion and panicle type (and pollen shedders in A-line)
Maturity stage	Identify deviants for panicle and seed type and seed color

- Identified off-type plants should be removed by uprooting as cutting of plants may lead to ratoon tillers.
- Select 500–1000 panicles (depending on the requirement) from the bulk planting.
- Harvest and bulk the seed.
- After harvest, the seed should be dried, processed and stored in safe containers.

Certified seed production

The stipulated isolation distance for Certified seed production, both for hybrids and OPVs is 200 m. The pattern of planting and seed production of OPVs is the same as

for the Breeder and Foundation seed production. Production must be acceptable to seed certifying agency and fulfill all requirements of certification.

Certified seed is generally arranged through contract growers. Some private seed companies also undertake Certified seed production programs. The Certified seed of a hybrid is produced by growing A-line and R-line in 4:2 ratio in an isolated field (Fig. 13.3).

Synchronization of A- and R-lines is an important consideration for Certified hybrid seed production. This can be manipulated by (1) differential dates of sowing; (2) controlling water and fertilizer application to one of the hybrid parents; and (3) removal of extra-early tillers in A- or R-lines to synchronize the pollen shedding and stigma receptivity.

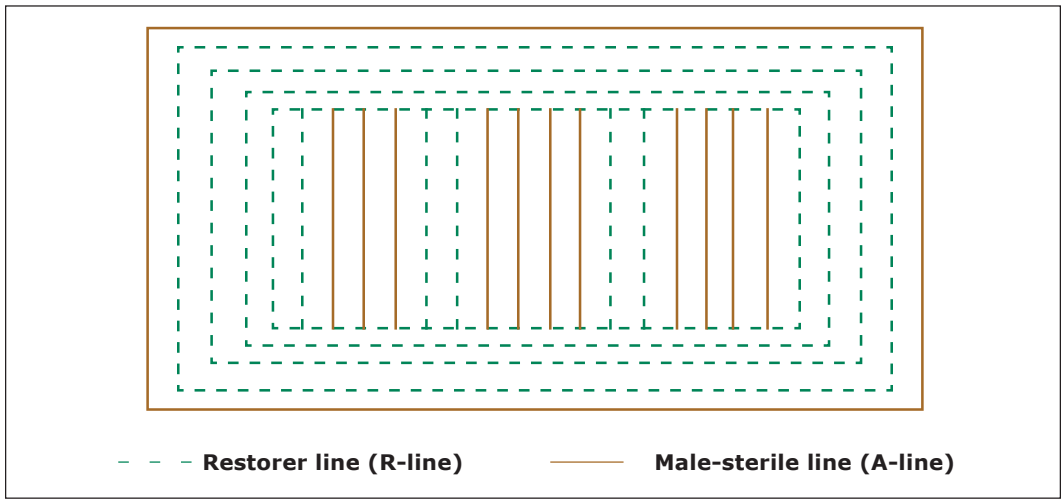


Figure 13.3. Pattern of A-line and R-line rows for Certified hybrid seed production in pearl millet.

Off-type plants in R-line and pollen shedders in A-line should be rogued out carefully to maintain genetic purity. A satisfactory Certified seed production can be achieved if seed village concept is followed. Maintenance of A-line and its use in hybrid seed production is given in Figure 13.4.

The seed production chain from Nucleus seed to Certified seed reaching the farmer is given in Figure 13.5.

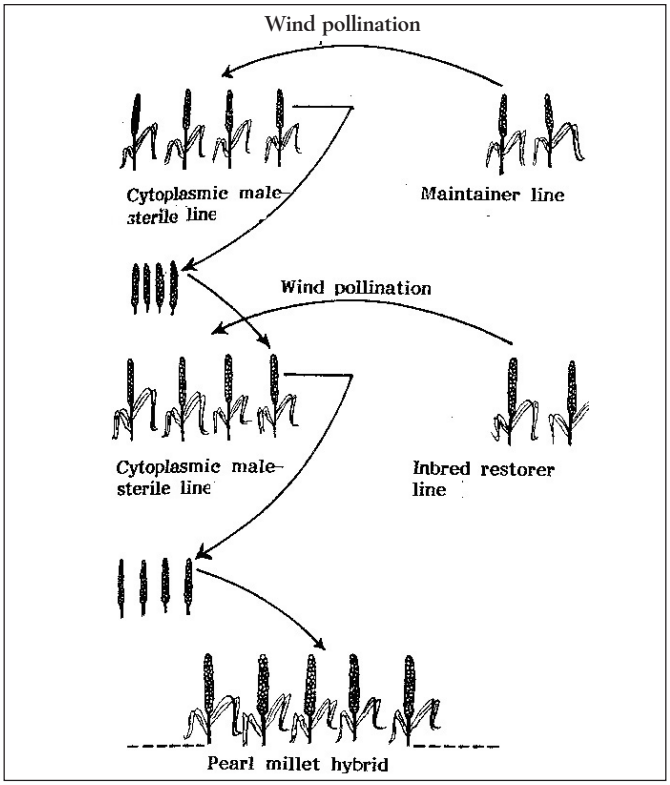


Figure 13.4. Scheme for pearl millet hybrid seed production in isolated fields.

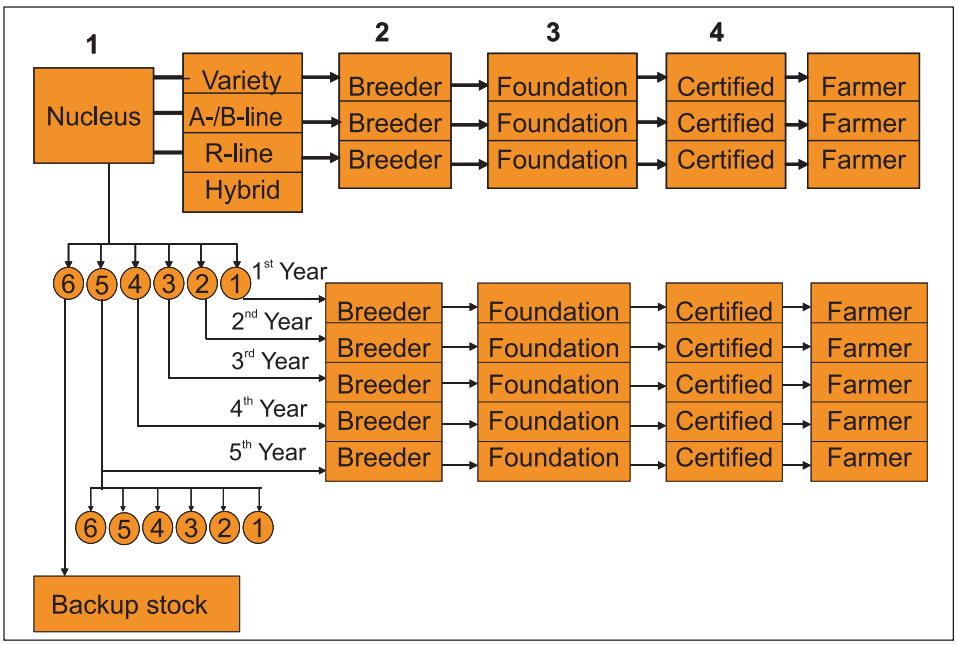


Figure 13.5. Linkages between seed classes.

Lesson 2: Seed production management

In this Lesson, you will learn about:

- Selection of seed production fields.
- Land preparation.
- Planting procedures.
- Fertilizer application.
- Weed control.
- Disease control.
- Harvesting.

To obtain high quality seed with good physical appearance, uniformity, large grain size and high germination percentage, proper agronomical practices should be adopted as detailed below.

Seed production plots require extra care. The area chosen should be uniform, well leveled, free from inoculum, weeds and cross-compatible wild species of pearl millet. Avoid areas where rain occurs during seed development stages. A few rains, or even continuous high humidity during seed ripening period may cause mold development, or even seed germination in panicles, discoloring them and substantially reducing germination and storage life. The land on which pearl millet crop was grown in the previous season should be avoided to minimize the problems of volunteers.

Land should be well prepared (15–20 cm deep) for seed production plots. It is advisable to plant seed on ridges at a distance of 45 to 60 cm. Planting is done by drilling, dibbling or transplanting. Drilling places the seed at a uniform distance and depth, enabling uniform plant stand. Further, large areas can be quickly planted by using a precision fertilizer-cum-seed drill mounted on a tractor or drawn by bullocks. Dibbling is a common practice where labor is cheap and fields are small. Transplanting is done practically in all the southern states to save valuable seed material. About 0.03 ha nursery is enough to provide seedlings for 1 ha. It reduces the life span of the crop in the main field by 18–21 days. Transplanting also enables easy adjustment of staggered plantings.

To ensure optimum plant population (120,000 plants) in 1 ha, with 45 cm between rows and 12 cm between plants, 4 kg seed is required for the multiplication of R-lines and OPVs while 3 kg of A-line and 1 kg of B-line or R-line are needed for the multiplication of A-line or hybrid, respectively.

Manure and fertilizer requirements include 8–10 t of farmyard manure (FYM) or compost, 100 kg nitrogen, 60 kg P_2O_5 and 40 kg K_2O ha^{-1}. Fertilizer doses may be split into two; a basal dose of 40 kg nitrogen and all P_2O_5 and K_2O at the time of planting, and top dressing of the remaining nitrogen in two equal splits at tillering and panicle emergence may be practiced.

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. Efficient drainage in seed field is also essential as pearl millet is susceptible to waterlogging, particularly in the early stages of crop growth.

Weeds claim major share of soil moisture and nutrients, and reduce yield of seed crop. They may act as alternate hosts for various diseases and pests, and also create problems during harvesting and threshing. These may be reduced through two inter-cultures at an interval of 20 days in the early stages of crop growth, or use of herbicides that greatly reduces the losses due to weed competition.

Pearl millet is a high-value seed crop. It is, therefore, essential to control diseases and insect pests which are likely to reduce the seed yield and quality. Cultural control methods like clean cultivation, planting date adjustment, and uprooting of disease-affected plants can substantially reduce the damage and minimize seed yield losses. Sometimes, disease and pest attacks may be controlled through chemicals.

In a seed crop, harvesting may influence the physical quality of the seed, processing requirements, storability and seedling vigor. If the panicles can be artificially dried and threshed mechanically, then harvesting can safely be done when the seed has attained physiological maturity (20% moisture content).

The panicles should be dried to 12% moisture content. Proper care must be taken in harvesting particularly of hybrids and A-/B-lines multiplication to avoid mechanical mixture with seeds from lodged plants. Care must also be taken during threshing operations. Proper handling of all classes of seed in postharvest operations should be of great help not only to maintain seed quality but also to prevent postharvest losses. Threshing of Nucleus/Breeder seed should be done by small size thresher. These threshers should be thoroughly cleaned. After threshing, seed should be dried and kept in sealed containers.

Lesson 3: Seed processing

In this Lesson, you will learn about various aspects of seed processing such as:

- Seed drying.
- Cleaning and upgrading.
- Seed treatment.
- Seed packing and labeling.
- Seed storage.

Seed lots received from the field often have high moisture content and contain trash and other inert material, weed seeds, deteriorated and damaged seeds, etc. Seed

processing is a vital part of upgrading the quality of the seed by removing foreign material and undesirable seeds.

Drying

Moisture content is an important factor of seed to be considered prior to processing. Seeds with moisture content above 15% are subjected to excessive damage in processing. Hence natural or artificial drying is necessary. Sun-drying is mostly practiced in pearl millet to bring down the moisture to the safe processing level of 12% or less. Solar-cum-Agriculture Waste Fire Dryers can be used for pearl millet during inclement weather. These dryers are available with a capacity of 800 kg seed. The cost of a dryer is approximately Rs 10,000 and drying cost of 1 t seed is about Rs 20 only.

Seed cleaning and upgrading

Seed cleaning and upgrading mainly depends on seed size (length, width, thickness), density, shape, surface texture, color, etc. If the differences between desirable and undesirable material with regard to any of these properties exist, separation of undesirable material should be done with the help of suitable machine.

Pearl millet seeds are either round or oblong. Screens for cleaning are selected according to the size and shape of the seed. A top screen with round holes or slotted screen may be used for round seeds, while for oblong seeds, top and bottom screen with oblong holes may be used. The suggested screens for seed cleaning in pearl millet are given in Table 13.1.

Table 13.1. Suggested screens for seed cleaning in pearl millet.

Cleaner	Place of screen	Number and size of screen
Four screen	Top screen upper shoe	9, 8
	Bottom screen upper shoe	14 × 14, 1/148
	Top screen lower shoe	1/12 × 1/2
	Bottom screen lower shoe	3 × 16 Sp, 3 × 14
Three screen	Top screen	9, 88
	Middle screen	1/12 × 1/2
	Bottom screen	3 × 16 Sp, 3 × 14

Source: A.T. Ferrel and Co.

In certain cases, it may be necessary and in others rather desirable to further upgrade the seed quality by removing either specific contaminants, or by very precise size upgrading operations. The choice of upgrading, however, shall depend upon type of contaminants. Various types of upgrading equipment are utilized for the purpose.

Seed treatment

Seed treatment refers to an application of fungicides, insecticides or a combination of both to seeds. The purpose of seed treatment is to disinfect and to protect the seed from seedborne and soilborne pathogenic organisms and storage insects. Pearl millet seed is also protected against downy mildew, ergot and smut.

Seed packing and labeling

Seeds are packed in containers of specified weight after processing and treatment. Cloth bags of 3.0 or 1.5 kg capacity are utilized in pearl millet. Cloth bags of 5.0 or 8.0 kg capacity are also used. A label must be placed in, or on the bags to maintain positive identity of the seed. The outer label or tag can be sewn to the bag when bags are sewed with a sewing machine. The label must carry the following information:

Crop ---------- Label no. ----------
Variety ---------- Pure seed* (%) ----------
Class of seed ---------- Inert matter* (%)----------
Production institutes ---------- Germination* (%)----------
(Name, address and seal) Genetic purity*----------
Date of test ----------
Net contents ----------
(When packed ----------% moisture)

* Based on actuals

Seed storage

Good seed storage is a basic requirement to maintain the quality of seed. Seeds remain in the head and stored in field after harvest, or taken to seed stores or remain in transit (carts, trucks, railway sheds, rail wagons, etc), and then finally reach retail stores, or the farmer's house. Germination and vigor may be considerably affected in the above storage situations. So, proper care should be taken while storing seed at different places. The basic steps in seed movement through a processing plant are divided into three phases as illustrated in Figures 13.6 and 13.7.

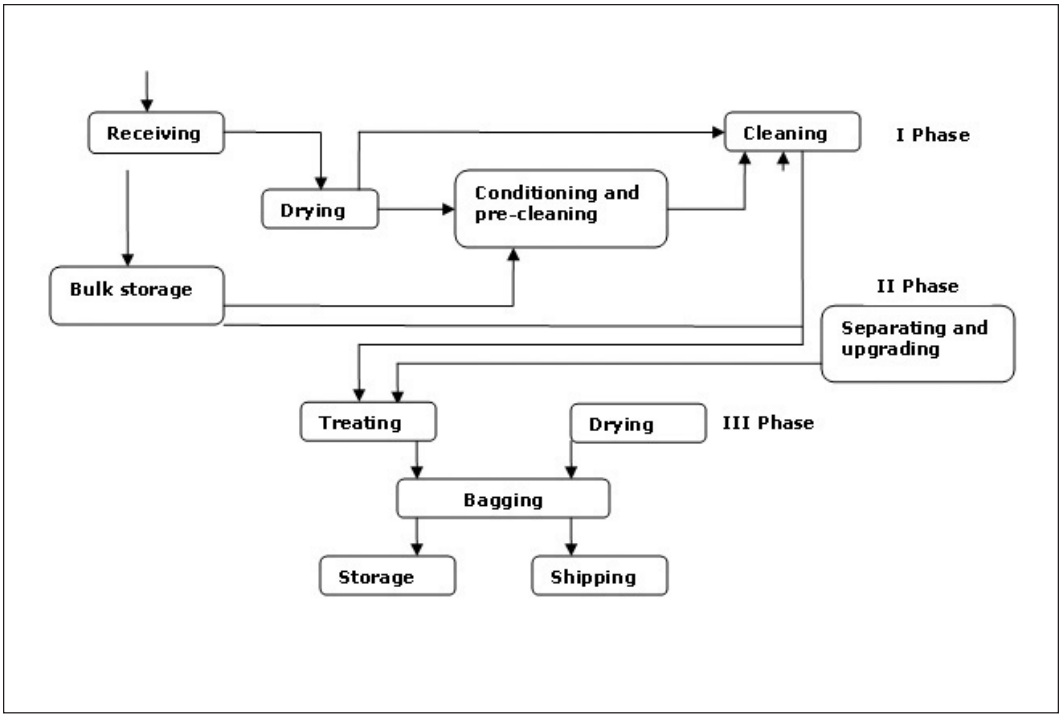


Figure 13.6. Basic steps in seed movement through a processing plant.

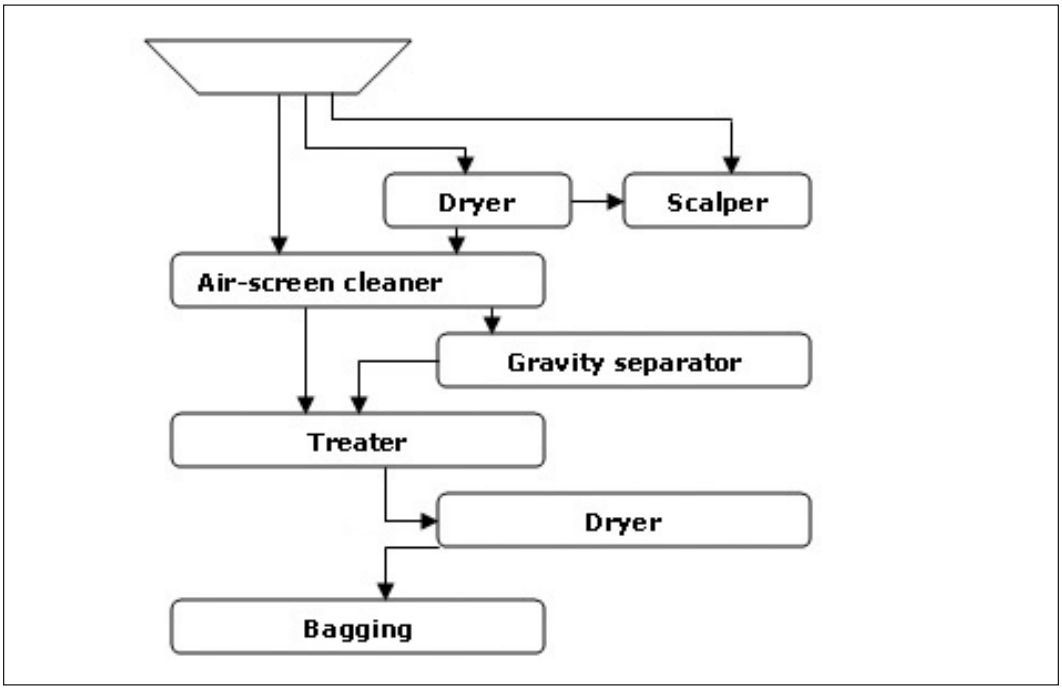


Figure 13.7. Seed processing operations in pearl millet.

Lesson 4: Seed marketing

The National Seed Corporation (NSC) and State Seed Corporations (SSCs) are the public sector organizations chiefly involved in the distribution and marketing of seeds. NSC seeds reach the farmers at the state, district, tehsil and village levels through distributors or through their sales counters at the tehsil level. This prevents the involvement of middle man and ensures check on prices and quality. The SSC seeds are supplied through appointed distributors, state agricultural department seed stores or through SSC sales counters. The NSC and SSCs also distribute seeds via agro-industries corporation and government godowns.

Private seed companies follow their own marketing and distribution channels. Their seeds reach farmers via one or more distributors at district or town level. Each distributor has a number of dealers at the village level, who sell seeds directly to farmers. In general, dealers are responsible to the company's distributor, and sell seed at prices fixed by the company. The distributors receive 12–15% discount or commission from the company, who passes on 10% to the dealer. In many areas, the company may often sell seed directly to the farmers through retail depots.

The seed pricing policy is the most effective but delicate issue for regulating the flow of seed according to the plans. The price fixed for sale should be such as to attract a large number of farmers to purchase the Certified seed. However, prices of Certified seed are rather high since they include the cost of production, processing, certification, storage, marketing, interest on capital, transportation and dealer's commission.

Prices of private seed companies are generally 50–100% higher than those of the public sector agencies because they also include the research costs. Generally differences between retail price of public and private seed of a hybrid is considerable. It indicates that pearl millet hybrid seed of private seed companies' hybrids on average is more expensive than public-bred hybrid. There is no standard formula for calculating the Certified, Foundation or Breeder seed costs. Foundation and Breeder seed prices are related to price of Certified seed. Seed production companies in the public and private sector are free to fix their own price for their seed. Normally, the cost of Certified seed produced by the public sector agencies is two to three times more than that of procurement/spot price of the grain. The price of the Breeder seed is normally 50% higher than the Foundation seed.

Generally, farmers purchase Certified seeds on cash basis. The NSC and SSCs do not directly give credit to farmers for purchase of seeds. However, credit can be obtained from the cooperative societies. Often, poor farmers fail to purchase the costly seeds in the absence of this facility. However, some private seed companies offer 10–45 days

credit through dealers depending on the credit worthiness of the buyer and the farmer's relationship with the trader.

With this, Module 13 concludes. To check your understanding about seed production, processing and marketing, please answer the questions that follow:

1. Which seed class is the first stage in the chain of seed multiplication of a released variety or hybrid parents?

A. Foundation seed
B. Certified seed
C. Nucleus seed
D. Breeder seed

2. Breeder seed of released OPV or hybrid parent is produced by or under the direct control of

A. Farmer
B. An extension specialist
C. Seed company
D. Plant breeder

3. The Certified seed of a hybrid is produced by growing

A. A- and R-lines
B. B- and R-lines
C. A- and B-lines
D. R- and R-lines

4. The isolation distance required to produce the Breeder seed of OPV is

A. 1000 m
B. 100 m
C. 500 m
D. 50 m

Answers to the Questions Given in the Modules

Module 1
1 (D), 2 (A), 3 (D), 4 (B), 5 (D), 6 (B), 7 (B).

Module 2
1 (C), 2 (C), 3 (D), 4 (C), 5 (C).

Module 3
1 (D), 2 (B), 3 (B), 4 (A), 5 (C), 6 (B).

Module 4
1 (B), 2 (C), 3 (B), 4 (C).

Module 5
1 (D), 2 (D), 3 (D), 4 (D), 5 (C), 6 (C).

Module 6
1 (D), 2 (C), 3 (C), 4 (C), 5 (B), 6 (B).

Module 7
1 (B), 2 (C), 3 (A), 4 (A), 5 (B), 6 (B), 7 (C).

Module 8
1 (D), 2 (C), 3 (C), 4 (A), 5 (C), 6 (A), 7 (A), 8 (C).

Module 9
1 (B), 2 (D), 3 (A), 4 (B), 5 (D), 6 (C), 7 (D).

Module 10
1 (C), 2 (C), 3 (B), 4 (C), 5 (C), 6 (C), 7 (B), 8 (B).

Module 11
1 (C), 2 (D), 3 (A), 4 (D), 5 (C).

Module 12
1 (B), 2 (C), 3 (C), 4 (D), 5 (A).

Module 13
1 (C), 2 (D), 3 (A), 4 (A).

About ICRISAT®

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is a non-profit, non-political organization that does innovative agricultural research and capacity building for sustainable development with a wide array of partners across the globe. ICRISAT's mission is to help empower 600 million poor people to overcome hunger, poverty and a degraded environment in the dry tropics through better agriculture. ICRISAT belongs to the Alliance of Centers of the Consultative Group on International Agricultural Research (CGIAR).

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