

# Management Procedures for Pearl Millet Improvement

Compiled by

T. Nagur, B. Diwakar, and D.L. Oswalt



**Skill Development Series no. 5**



ICRISAT

**Human Resource Development Program**

**International Crops Research Institute for the Semi-Arid Tropics  
Patancheru, Andhra Pradesh 502 324, India**

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## **Human Resource Development Program**

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## Introduction

Pearl millet (*Pennisetum glaucum*) is one of the cereals being improved at ICRISAT. The improvement work involves collection and conservation of genetic material, evaluation of high-yielding genotypes with good quality grain and resistance to abiotic and biotic stresses, developing agronomic and management practices to increase its grain yield. An applied skill development program for pearl millet is offered by the Human Resource Development Program to in-service participants to help improve their field and laboratory techniques. The practical skills are improved by organizing individualized field and laboratory practicals. A multiple-choice set of questions is provided for self evaluation.

This manual helps the participants to improve their skills and techniques in pearl millet improvement. The management procedure 1 (MP 1) outlines a uniformity trial for identifying the variability in the soil to determine the feasibility and arrangements of experimental materials. The soil-sampling procedures for testing the soil are given in MP 2. The seed calibration and the determination of the seed density are described in MP 3 and MP 4. Nutrients, their sources, role, and requirements are explained in MP 5. The fertilizer calibration using straight and double fertilizers are given in MP 6. Agronomic aspects related to the importance and time of thinning, and weeding are included in MP 7 and MP 8. The GS<sub>1</sub>, GS<sub>2</sub>, and GS<sub>3</sub> growth stages and their interactions with the varieties and environment are explained in MP 9. The descriptors and descriptor characters for evaluating pearl millet genotypes along with the stage at which the characters are to be recorded are given in MP 10. Monitoring the shoot fly with fish meal traps and screening for shoot fly resistance are described in MP 11. The life cycles of different stem borers occurring on pearl millet, methods for rearing stem borer larva, and screening techniques for resistance are provided in MP 12. Techniques for screening for midge (MP 13) and descriptions of other pests (MP 14) are incorporated. Techniques for inoculation with downy mildew and methods for screening for resistance are provided in MP 15. Inoculation and screening techniques for ergot and smut are given in MP 16 and 17. The fungal, bacterial and viral diseases are described in MP 18. The *Striga* species occurring in India and Africa are described and the screening techniques of laboratory and field are given in MP 19 and MP 20.



## MP 1. Uniformity Trial

This is considered a preliminary trial to determine the variability in the field. One variety should be sown and treated uniformly over the entire area (statistically there would be no treatments *per se*). Crop growth and yield data are used to map the areas differing in fertility, drainage, water-holding capacity, and variations due to previous cropping systems and management practices (Oswalt 1975).

The area is divided into small plots to record germination, date of 50% flowering, height, yield, and other characters of interest. The smaller the plots, the more detailed the information obtainable and the more accurate the possibility of mapping the differences, but greater the labor requirement. The smallest plot should not be larger than the anticipated experimental plot size. Dividing the area into one-, two-, or three-row plots, 2-4 m in length permitted mapping of differences, when subsequent plot size was similar. This would allow trials to be arranged to make maximum use of uniform areas. It is recommended that experimental plots be uniform, narrow, relatively long, and placed across soil fertility gradients (Oswalt 1980).

A pearl millet uniformity trial (Fig. 1) was divided into 10 blocks having 80 rows of 3-m length with 75 cm between rows. The 80 rows in each block were individually harvested for grain yield.

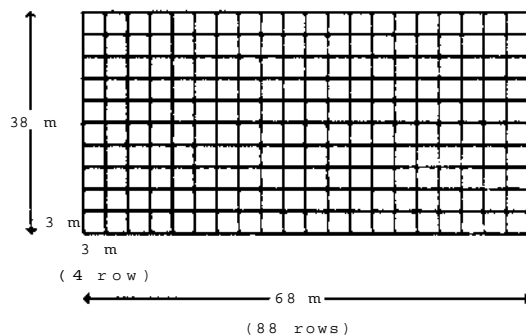


Figure 1. Field plan.

The row yields (3 x 0.75 m) were combined to obtain plots with combinations of lengths x widths; 3 x 3 m, 3 x 6 m, 3 x 9 m, 3 x 12 m, 6 x 3 m, 6 x 6 m, 6 x 9 m, 6 x 12 m, 9 x 3 m, 9 x 6 m, 9 x 9 m, 9 x 12 m, 12 x 3 m, 12 x 6 m, 12 x 9 m, and 12 x 12 m. Analyses were completed for the 16 plot sizes and the significance of treatments and replications, and coefficients of variation were calculated (Table 1). The grain yields  $\text{ha}^{-1}$  were categorized into five levels; 0.5-1.5  $\text{t ha}^{-1}$ , 1.6-2.5  $\text{t ha}^{-1}$ , 2.6-3.5  $\text{t ha}^{-1}$ , 3.6-4.5  $\text{t ha}^{-1}$ , and 4.6-5.5  $\text{t ha}^{-1}$ . The categorized grain yields for 3 x 3 m blocks were grouped and a response map was prepared to show yield variations (Fig. 2).



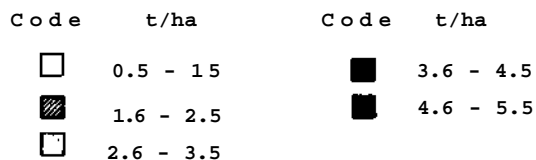
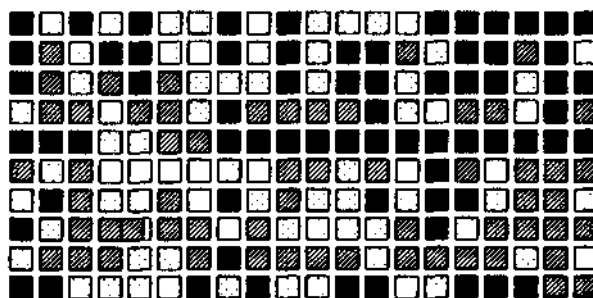


Figure 2. Map of responses.

The variations in the yield did not follow a systematic pattern. However, small uniform areas could be identified for experimentation. These differences in the soil variations may be reduced by growing a cereal crop and a legume crop in rotation for two or more seasons.

Table 1. Significance of treatments/replications and coefficient of variation for different plot sizes.

Length		Width			
		3 m	6 m	9 m	12 m
3 m	a) <sup>1</sup>	Sig	NS	NS	Sig
	b)	Sig	Sig	Sig	Sig
	c)	14	9	10	4
6 m	a)	Sig	NS	Sig	Sig
	b)	Sig	Sig	Sig	Sig
	c)	11	7	5	3
9 m	a)	Sig	NS	Sig	Sig
	b)	Sig	Sig	Sig	Sig
	c)	9	4	4	3
12 m	a)	Sig	NS	sig	Sig
	b)	Sig	Sig	sig	Sig
	c)	9	4	3	3

a) Significance between treatments at P = 0.05

b) Significance between replications at P = 0.05

c) Coefficient of variation (%)

The results indicated that plots 9 x 6 m and 12 x 6 m were the best sizes with no significant differences for treatments and had the smallest coefficients of variation.



## MP 2. Sampling for Soil Testing

It is very important to correctly sample the soils of a field as the data obtained from a sample cannot be better than the sample taken.

Suggested procedure:

Obtain sampling tube, auger or spade, and clean containers.  
Draw a sketch of the field and identify previous pattern of cropping, fertilizer, and treatments.  
Sketch areas having similar soil color, soil texture, cropping history, and fertilizer treatments.  
Sample by collecting equal amounts of soil to cultivation depth at 10 or more places from each uniform 0.5 ha in a zig-zag pattern (Do not mix light and dark soils together).  
Place the samples from an auger or spade (thin slice to maximum depth of sample) in a clean container for each different area. Then thoroughly mix separately each sample.  
Allow sample to air-dry on clean paper in a clean area.  
Send about 0.5 kg from each different area to a soil testing laboratory. Discard the remainder.

Label the sample as follows (One on the outside and one on the inside of the container):

- a. Date of sampling
- b. Soil type and field number, sampled area
- c. Depth of the soil sample
- d. Cropping history
- e. Name and address of the sender

The containers should be packed in waterproof containers and labeled with a wax pencil or water proof pen (Oswalt 1975).

### MP 3. Seed Calibration

The amount of seed required for sowing is determined from the required population, germination of the seed lot, amount of seed to be over sown, and the 1000-seed mass.

Given: 1 hectare = 10 000 m<sup>2</sup>  
 Plot size = 15 m<sup>2</sup>  
 Area row<sup>-1</sup> = 3.75 m<sup>2</sup> (length 5 m, width 0.75 m)  
 Required population = 100 000 plants ha<sup>-1</sup>  
 Over sowing = 25%  
 1000-seed mass of pearl millet = 12 g  
 Germination = 90%

Determine: Seed required ha<sup>-1</sup>, seed plot<sup>-1</sup>, and seed row<sup>-1</sup>

Calculations:

a. How many seeds are required to have 100 germinable seeds?

$$100 \text{ germinable seeds} = \frac{100 \text{ seeds} \times 100}{90} = 111.1 \text{ seeds}$$

b. How many seeds of this sample are required for 100 000 plants ha<sup>-1</sup>?

$$100 \text{ 000 germinable seeds ha}^{-1} = \frac{111.1 \times 100 \text{ 000 ha}^{-1}}{100} = 111 \text{ 100 seeds ha}^{-1}$$

c. What is the mass of sample required ha<sup>-1</sup>?

$$\frac{12 \text{ g } 1000^{-1} \text{ seeds} \times 111 \text{ 100 seeds ha}^{-1}}{1000 \text{ g kg}^{-1} \text{ seed}} = 1.333 \text{ kg seed ha}^{-1}$$

d. How much seed of this sample is required for 25% over Bowing?

$$1.25 \times 1.333 \text{ kg seed ha}^{-1} = 1.666 \text{ kg seed ha}^{-1}$$

e. How much seed is required m<sup>-2</sup>?

$$\frac{1.66 \text{ kg ha}^{-1} \times 1 \text{ 000 g kg}^{-1}}{10 \text{ 000 m}^2 \text{ ha}^{-1}} = 0.16 \text{ or } 0.2 \text{ g m}^{-2}$$

f. How much seed is required plot<sup>-1</sup> (15 m<sup>2</sup>)?

$$0.2 \text{ g m}^{-2} \times 15 \text{ m}^2 \text{ plot}^{-1} = 3.0 \text{ g plot}^{-1}$$

g. How much seed is required row<sup>-1</sup> (3.75 m<sup>2</sup>)?

$$0.2 \text{ g m}^{-2} \times 3.75 \text{ m}^2 \text{ row}^{-1} = 0.75 \text{ or } 0.8 \text{ g row}^{-1}$$

## MP 4. Density of Seed

Seed density is calculated by dividing the mass of 1000 randomly selected seeds of pearl millet by its volume. The mass is obtained with a sensitive balance to the nearest 0.1 g. The volume is found by immersing 1000 seeds in alcohol in a graduated cylinder fitted to a conical flask (Fig. 3). The difference in the level of alcohol in the graduated cylinder after adding the 1000 seeds is the volume (cm<sup>3</sup>) of the seed (Oswalt 1980).

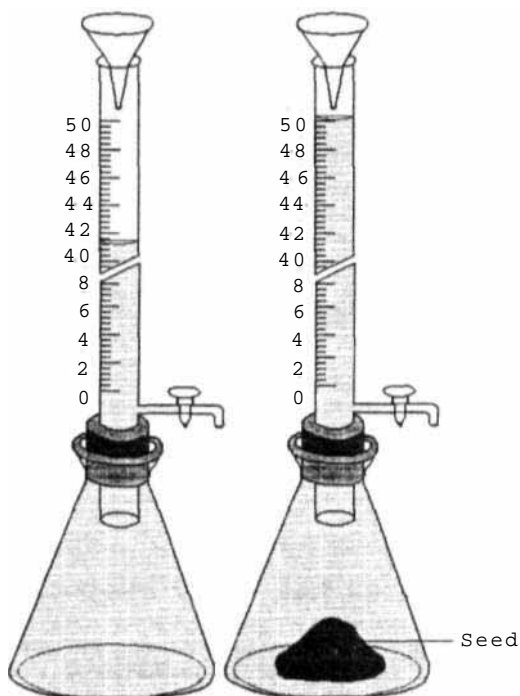


Figure 3. Estimation of seed volume.

Example:

- a. Find the mass of 1000 dry seeds.

$$1000\text{-seed mass} = 9.9 \text{ g}$$

- b. Find the volume of 1000 seeds.

- i) Initial level of liquid in cylinder = 41.2 cm<sup>3</sup>
- ii) Level of liquid after adding 1000 seeds = 50.0 cm<sup>3</sup>
- iii) Difference in levels = 50.0 cm<sup>3</sup> - 41.2 cm<sup>3</sup> = 8.8 cm<sup>3</sup>
- iv) Therefore: volume of 1000 seeds = 8.8 cm<sup>3</sup>

- c. Find the density.

$$\text{Density} = \frac{\text{Mass of 1000 seeds (g)}}{\text{Volume of 1000 seeds (cm}^3\text{)}} = \frac{9.9 \text{ g}}{8.8 \text{ cm}^3} = 1.125 \text{ g cm}^{-3}$$



## MP 5. Plant Nutrient Role and Requirement

Plants like other organisms, require "food" for their growth and development. From chemical elements drawn from soil, water, and air, plants build a vast array of plant products. These essential elements (Table 1) are plant nutrients. The elements carbon, hydrogen, and oxygen are derived from the air and water. Nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, zinc, manganese, copper, boron, molybdenum, cobalt, and chlorine are derived from the reserves in the soil or through applications of manures and fertilizers. The nutrients which are required in large quantities are major nutrients; those that are needed in smaller, but appreciable quantities are the secondary nutrients. The micronutrients or trace elements are those that are required in very small quantities (Roy et al. 1980).

**Table 1. Nutrients and their sources**

From air or water	From soil, fertilizers, or manures		
	Primary nutrients	Secondary nutrients	Micro/trace nutrients
Hydrogen	Nitrogen	Calcium	Iron Zinc
Carbon	Phosphorus	Magnesium	Manganese Copper
Oxygen	Potassium	Sulfur	Boron Molybdenum Chlorine Cobalt

A productive soil should contain all the essential plant nutrients in sufficient quantities (Table 2), in balanced proportions, and in available forms. The functions of nutrients are (Roy et al. 1980):

### Nitrogen (N)

- a. An important constituent of chlorophyll, protoplasm, protein, and nucleic acids.
- b. Increases growth and development of all living tissues.

### Phosphorus (P)

- a. Constituent of phosphatides such as nucleic acids, proteins, phospholipids, and coenzymes.
- b. Constituent of certain amino acids.
- c. Constituent of chromosomes.
- d. Stimulates root, flower, seed, and fruit development.

### Potassium (K)

- a. Activator of enzymes involved in protein and carbohydrate metabolism.
- b. Aids in carbohydrate translocation, synthesis of protein, stomatal opening, membrane permeability, and pH control.



- c. Aids in greater utilization of light during cool and cloudy weather.
- d. Enhances ability to resist plant diseases and lodging.
- e. Induces plumpness of seeds and improves the quality of fruits.
- f. Constituent of chlorophyll molecules.

Calcium (Ca)

- a. Constituent of cell walls in the form of calcium pectate (cell wall/division).
- b. Helps in membrane stability and maintenance of chromosome structure.
- c. Activator of enzymes (phospholipase), arginine, kinase, and adenosine triphosphatase.
- d. Acts as detoxifying agent.
- e. Helps in the translocation of carbohydrates.

Magnesium (Mg)

- a. Key element in chlorophyll molecule (photosynthesis).
- b. Activator of many enzyme systems involved in carbohydrate metabolism and synthesis of nucleic acids.
- c. Promotes uptake and translocation of phosphorus.
- d. Helps in the movement of sugars within the plants.

Sulfur (S)

- a. Constituent of sulfur-bearing amino acids.
- b. Involved in the metabolic activities of vitamins, biotin, thiamine, and coenzyme A.
- c. Helps stabilize protein structures.
- d. Aids in synthesis of oils and formation of chlorophyll.

Zinc (Zn)

- a. Involved in the biosynthesis of the hormone indole acetic acid (IAA).
- b. Essential component of metalloenzymes; carbonic anhydrase and alcohol dehydrogenase.
- c. Synthesis of nucleic acids and protein.
- d. Helps in the utilization of phosphorus and nitrogen in plants.

Copper (Cu)

- a. Constituent of cytochrome oxidase and component of the enzymes; ascorbic acid oxidase, phenolase, and lactase.
- b. Promotes the formation of Vitamin A in plants.

Iron (Fe)

- a. Synthesis and maintenance of chlorophyll in plants.
- b. Component of several enzymes.
- c. Involved in nucleic acid metabolism and RNA metabolism.

Manganese (Mn)

- a. Acts as catalyst in several enzymatic and physiological reactions.
- b. Oxidation of carbohydrate to CO<sub>2</sub> and H<sub>2</sub>O.
- c. Activates enzymes in the metabolism of nitrogen, and synthesis of chlorophyll.

Boron (Bo)

- a. Changes the activities of certain enzymes.
- b. Increases the permeability in membranes and facilitates carbohydrate transport.
- c. Involved in the synthesis of lignin.
- d. Affects cell division.
- e. Associated with the uptake of calcium and its utilization.
- f. Regulates potassium/calcium ratio.
- g. Essential for protein synthesis.

Molybdenum (Mo)

- a. Associated with nitrogen utilization and fixation.
- b. Constituent of nitrate reductase and nitrogenase.

Chlorine (Cl)

- a. Constituent of chlorine containing auxin-chloroindoly-3-acetic acid.
- b. Constituent of many compounds found in fungi and bacteria.
- c. Stimulates the activity of certain enzymes, influences carbohydrate metabolism, and water-holding capacity of plant tissues.

Deficiency symptoms of selected nutrients:

Nitrogen deficiency

- a. Stunted growth.
- b. Appearance of light-green to pale-yellow on the older leaves starting from the tips and progressing towards the base of the leaf blade. This is followed by drying and/or dropping of the older leaves.
- c. In acute deficiency, flowering is greatly reduced.
- d. Lowers the protein content.

Phosphorus deficiency

- a. Stunted growth, reduction in the internodal and leaf length.
- b. The mature leaves have characteristic dark to blue-green colorations. In acute deficiency, purpling of leaves and stems.
- c. Restricted root development.
- d. Delayed maturity, poor seed development.

Potassium deficiency

- a. Slow and stunted growth of plants.
- b. Interveinal chlorosis near the margins followed by scorching and browning of tips of older leaves; then symptoms gradually progress inwards.
- c. Weak stalk and plants lodge.
- d. Chaffy seed.



**Table 2. Nutrient reaoval by pearl millet grain production.**

Grain yield (kg ha <sup>-1</sup> )	Nutrients removed from the soil (kg ha <sup>-1</sup> )		
	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

Source: Roy et al. 1980.

## MP 6. Fertilizer Calibration

Fertilizer applications are based on the nutrient requirements of the crop and fertility of the soil. An application of 60-17-0, means 60 kg N, 17 kg P, and 0 kg K ha<sup>-1</sup>. To supply 60-17-0, nitrogenous and phosphatic fertilizers are required. There are fertilizers that carry only nitrogen, only phosphorus, or both of them. Those carrying a single nutrient are straight fertilizers and those carrying two nutrients are double fertilizers. Therefore, the nutrient requirements can be calculated using straight fertilizers or by combination of a double and straight fertilizers.

### a. Meeting requirements using single fertilizers.

Given: Ammonium sulfate (AS) = 20% N  
 Single super phosphate (SSP) = 7% P  
 Nutrient recommendation = 60-17-0

$$\text{Fertilizer kg ha}^{-1} = \frac{\text{kg nutrient required ha}^{-1}}{\% \text{ nutrient in fertilizer}}$$

$$60 \text{ kg N ha}^{-1} = \frac{100 \times 60 \text{ kg ha}^{-1}}{20} = 300 \text{ kg ha}^{-1} \text{ of AS}$$

$$17 \text{ kg P ha}^{-1} = \frac{100 \times 17 \text{ kg ha}^{-1}}{7} = 242.8 \text{ kg ha}^{-1} \text{ of SSP}$$

Thus 300 kg ammonium sulfate and 243 kg single super phosphate are required ha<sup>-1</sup> to supply the 60-17-0.

### b. Calculating requirements using double fertilizers.

Given: Diammonium phosphate (DAP) = 18% N and 20% P  
 Urea = 46% N  
 Nutrient recommendation = 60-17-0



Step 1: Calculate DAP to provide P required

$$17 \text{ kg P ha}^{-1} = \frac{100 \times 17 \text{ kg ha}^{-1}}{20} = 85 \text{ kg ha}^{-1} \text{ of DAP}$$

Step 2: DAP contains 18% N

$$\text{Therefore; } 85 \text{ kg DAP} = \frac{18 \times 85 \text{ kg}}{100} = 15.3 \text{ kg N}$$

Step 3: Required N = 60 kg ha<sup>-1</sup>.

Therefore, the additional N required is 60 kg - 15.3 kg or 44.7 kg N from urea.

$$44.7 \text{ kg N ha}^{-1} = \frac{100 \times 44.7 \text{ kg ha}^{-1}}{46} = 97.17 \text{ kg urea ha}^{-1}$$

Thus, to supply N and P at the rate of 60-17-0, 85 kg DAP ha<sup>-1</sup> and 97 kg urea ha<sup>-1</sup> are needed.

## MP 7. Thinning

Pearl millet tillering starts by the 15th day after emergence. It then becomes difficult to recognize the main seedlings, therefore, pearl millet should be thinned before the 6th day after emergence. Care should be taken while removing the excess seedlings to avoid disturbing the remaining plants.

Determine the plants m<sup>-2</sup> for a selected plant population to facilitate thinning plants to the desired plant density.

Given: Row width = 0.75 m  
Desired plants ha<sup>-1</sup> = 100 000

Calculate:

$$\text{Plants m}^{-2} = \frac{100 \ 000 \ \text{ha}^{-1}}{10,000 \ \text{m}^2 \ \text{ha}^{-1}} = 10 \ \text{plants m}^{-2}$$

$$\text{Area of 1 meter of row} = 0.75 \text{ m} \times 1 \text{ m} = 0.75 \text{ m}^2$$

$$\text{Plants m}^{-1} \text{ row} = 10 \ \text{m}^{-2} \times 0.75 \ \text{m}^2 = 7.5 \ \text{seedlings m}^{-1}$$

To establish 100 000 seedlings ha<sup>-1</sup> it is necessary to retain 7.5 plants m<sup>-1</sup> of row after thinning when rows are 0.75-m apart. Seedlings should be left as equally spaced as possible. A 2-m stick can be placed along the row and the seedlings in excess of 15 can be removed.

## MP 8. Weed Control

Weeds reduce grain and fodder yield of pearl millet. Weeds not controlled in the early stages can completely smother the crop and reduce the grain yields (Bourke 1963). Proper weeding not only increases the grain yield but improves the quality of produce (Kumar et al. 1973).

Usually the weeds are removed when they are 5-8 cm, but they have already competed with the crop for nutrients and water and it is difficult to destroy the weeds at that stage as some of the weeds will regrow. This damage at the seedling stage results in poor growth and low yield of the crop. To avoid such damage hand hoeing or cultivation with animal-drawn equipment or machines should be completed when the weeds germinate and remain just below the soil surface or have just emerged. It is easy and less time consuming to uproot, kill, or cover weeds with soil at this stage. Therefore, it is less expensive and any seedling damage by the weeds is avoided (Rachie and Majmudar 1980).

Weeds can be controlled by spraying herbicides (preemergence and postemergence). The preemergence herbicides (atrazine, propazine, or prometryne) are found to be effective in controlling weeds in pearl millet (Diwakar 1980).

A herbicide is usually expressed as active ingredient (a.i.) or acid equivalent (a.e.) in a commercial product to be applied  $\text{ha}^{-1}$  (Table 1).

Table 1. Rates of herbicides recommended for weed control.

Herbicide	Soils	
	Alfisols	Vertisols
	(kg a.i. $\text{ha}^{-1}$ )	
Atrazine	0.50	0.75
Propazine	0.75	1.00
Prometryne	1.00	1.00

The amount of a herbicide to be applied from an emulsifiable concentrate, a granular or wettable powder can be determined by:

$$\text{Herbicide kg ha}^{-1} \text{ or L ha}^{-1} = \frac{\text{Rate (a.i. or a.e. kg ha}^{-1}) \times \text{area (ha)} \times 100}{\% \text{ a.i. or a.e. in product}}$$

Problem: Atrataf (50% atrazine); rate =  $0.50 \text{ kg a.i. ha}^{-1}$   
Area =  $15 \text{ m}^2 \text{ plot}$

Calculations:

$$\text{Atrataf m}^{-2} = \frac{500 \text{ g a.i. ha}^{-1} \times 100}{50 \text{ a.i.} \times 10\,000 \text{ m}^2 \text{ ha}^{-1}} = 0.1 \text{ g m}^{-2}$$

Therefore, a  $15 \text{ m}^2 \text{ plot}$  would require:  $0.1 \text{ g m}^{-2} \times 15 \text{ m}^2 \text{ plot}^{-1}$  or  $1.5 \text{ g plot}^{-1}$  of Atrataf to provide  $0.5 \text{ kg a.i. of atrazine ha}^{-1}$ .

## MP 9. Growth and Development of Pearl Millet

The growth (Table 1) can be divided into three major stages (Fig. 4):

### a. Vegetative phase (GS<sub>1</sub>):

The seedling establishment with root, leaf, and tiller development takes place during this phase. The dry-matter accumulation is primarily in the roots and leaves. Internode elongation is limited. Leaf primordia is initiated in the tillers. The floral initiation is represented with the presence of an apical dome with a basal constriction. In late varieties, the floral initiation is considerably delayed. The size of the apex may range from 0.5 mm in early varieties to 1.0 mm in late varieties.

### b. Panicle development phase (GS<sub>2</sub>):

Expansion of all the leaves, emergence of all the tillers, floral initiation in the tillers, and stem elongation through elongation of internodes takes place during this phase. The dry-matter accumulation is in roots, leaves, stem, and panicle. The elongation of the panicle and the formation of rachillae, bristles, spikelets, florets, androecium, and gynaecium are found in this stage. The GS<sub>2</sub> phase comes to an end with the emergence of the stigmas on the panicle (flowering).

### c. Grain-filling stage (GS<sub>3</sub>):

This phase begins with the fertilization of florets and continues up to maturity of the plant. The dry-matter accumulation during this phase is mainly in the formation of grain and partly in the enlargement of the stem and leaves of the tillers. The tillers that arise from upper nodes (nodal tillers) are late and produce small panicles which are usually sterile. The end of this phase (physiological maturity) is indicated by the development of a small dark, layer of tissue in the hilar region of the grain that occurs 20-25 days after flowering.

**Table 1. The growth stage of RB 3 (India) and Mil zongo (Western Africa).**

Growth character	HB 3	Mil Zongo	
	Approximate days after emergence		
0	Coleoptile visible	0	0
1	Third-leaf stage	6	6
2	Fifth-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	53
7	Milk stage	49	61
8	Dough stage	58	69
9	Black layer formation (physiological maturity)	65	75

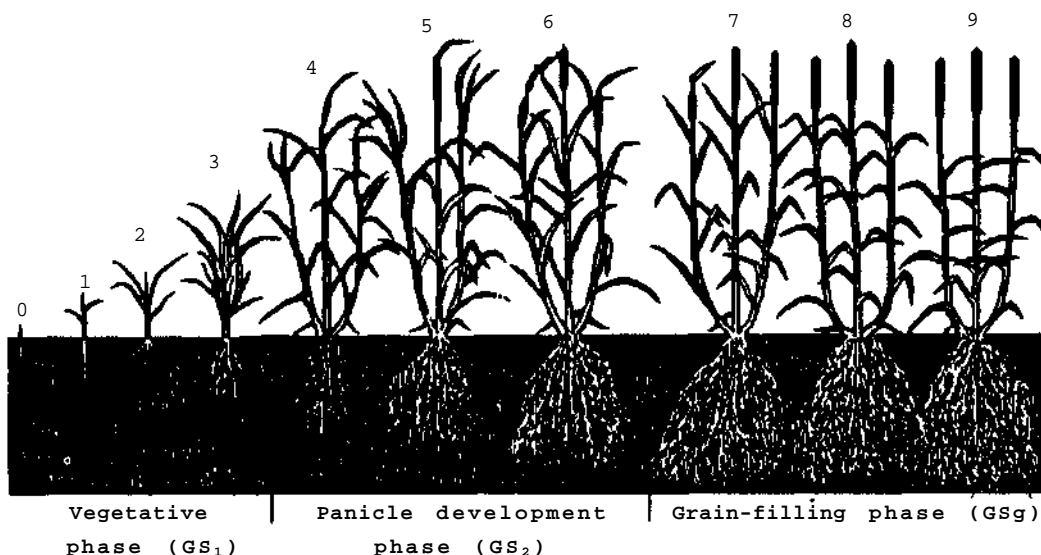


Figure 4. Growth stages.

Table 2. The approximate duration for the three Major growth phases (Fig. 4) for HB 3 (India) and Mil Zongo (Western Africa).

Major growth phase	HB 3	Mil Zongo
	Approximate duration (days)	
GS <sub>1</sub>	22	28
GS <sub>2</sub>	18	25
GS <sub>3</sub>	25	22

These growth stages (Table 2) are the averages for environmental conditions during June-September at Hyderabad, India (17°N latitude). Developmental rates are a function of the environmental conditions and the variety that is grown. The day-length affects the time for panicle initiation. The temperature affects the rates of leaf emergence and length of the grain-filling period. The duration of growth stages may vary considerably for other locations and varieties. Some landraces from Africa do not reach panicle initiation until 80-120 days after emergence when compared to 40-50 days for Indian varieties. As a consequence the western Africa types produce more leaves, stem internodes, and total dry matter than the Indian varieties when grown at Hyderabad (Maiti and Bidinger 1981).

## MP 10. Characters and Field Note Codes

### At head-emergence stage

Leaf angle  
3 = erect                      5 = intermediate                      7 = pendant

Leaf color  
3 = light-green    5 = green                      7 = dark-green

Leaf sheath pubescence  
3 = glabrous              5 = sparsely hairy              7 = densely hairy

Types of tillers  
3 = erect                      5 = intermediate                      7 = spreading

### At flowering stage

Internode pubescence  
1 = absent              2 = present

Node pubescence  
1 = absent              2 = present

50% flowering = number of days for 50% of the plants to reach 50% stigma emergence.

Rust: *Puccinia penniseti* (Zimm)

Assess the top four leaves at 50% flowering

1 = 5% infection    2 = 10% infection    3 = 25% infection  
4 = 40% infection    5 = 65% infection    6 = 100% infection

### At dough stage

Internode pigmentation  
3 = light              5 = intermediate                      7 = dark

Node pigmentation  
3 = light              5 = intermediate                      7 = dark

Juice type of the stem  
3 = insipid    5 = intermediate                      7 = sweet

Sheath pigmentation  
3 = green              5 = red                      7 = purple

Color of bristles  
3 = green              5 = brown                      7 = red

Bristle length  
3 = bristles below the level of seed apex  
5 = bristle length above the seed <2 cm  
7 = bristles >2 cm above the seed

Height (Main plant/tiller)  
Average height (cm) of the plants in the center of the plot measured from the soil to the tip of the ear head and corrected to 10 cm.  
Data on the main plant or tillers are to be recorded according to the objectives of the experiment.

Diameter of the stem  
The diameter of 3rd internode from the top (mm)

Leaf area  
The area of the third leaf from the top in cm<sup>3</sup> calculated by multiplying the length (cm from the base of lamina to its tip) x breadth (cm of the maximum width of the lamina) by 0.7236.



Downy mildew: (*Sclerospora graminicola* (Socc.) Schroet)

- 1 = no symptoms
- 2 = symptoms on nodal tillers only
- 3 = symptoms on main tillers but > 50% heads normal
- 4 = symptoms on many main tillers and > than 50% normal heads
- 5 = symptoms on main stems and tillers, no productive heads (seedlings died at early stage leaving gaps)

Ergot: *Claviceps fusiformis* (Lov.)

Record mean percentage of infected florets from 10 heads using the standard drawings (Fig. 24).

- 1 = no symptoms
- 2 = < 5% of grain sclerotic
- 3 = 6-10% of grain sclerotic
- 4 = 11-20% of grain sclerotic
- 5 = > 20% of grain sclerotic

Smut: *Tolyposporium penicillariae* (Bref)

Record mean percentage of infected florets on 10 bagged/inoculated heads using the standard drawings.

- 1 = no symptoms
- 2 = < 5% of grain as smut sori
- 3 = 6-10% of grain as smut sori
- 4 = 11-20% of grain as smut sori
- 5 = > 20% of grain as smut sori

#### At maturity stage

Leaf senescence

- 3 = slow
- 5 = intermediate
- 7 = fast

Leaf number

- 3 = low
- 5 = intermediate
- 7 = high

Earhead shape (Fig. 5)

- 1 = cylindrical
- 2 = conical
- 3 = spindle
- 4 = club
- 5 = candle
- 6 = dumb-bell
- 7 = lanceolate
- 8 = oblanceolate
- 9 = globose

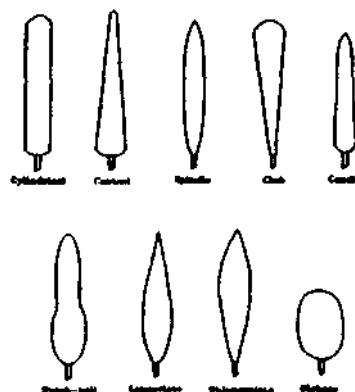


Figure 5. Earhead shapes.



Spike/ear head shattering

- 1 = spontaneous shattering
- 2 = shattering at touch
- 3 = nonshattering and free threshing
- 4 = nonshattering and difficult to thresh

Bristle structure/texture (Fig. 6)

- 3 = scabrous(rough)
- 5 = ciliate (fine hairs)
- 7 = plumose (feathery)

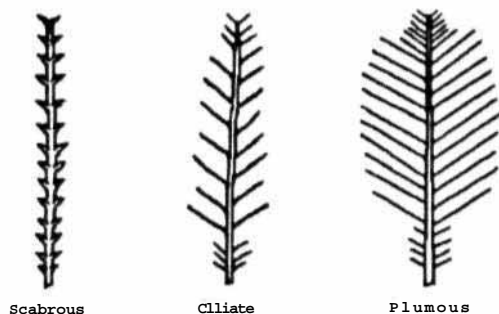


Figure 6. Bristle structures.

Seed coverings (Fig. 7)

- 3 = exposed
- 5 = intermediate
- 7 = enclosed

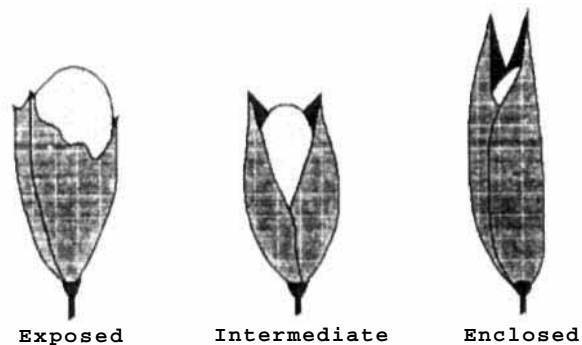


Figure 7. Seed covering with glumes.



Seed shape (Fig. 8)

- |               |                |                |
|---------------|----------------|----------------|
| 1 = obovate   | 2 = lanceolate | 3 = elliptical |
| 4 = hexagonal | 5 = globular   |                |
- Seed density on panicle
- |           |                  |             |
|-----------|------------------|-------------|
| 3 = loose | 5 = intermediate | 7 = compact |
|-----------|------------------|-------------|
- Seed color
- |           |               |                  |
|-----------|---------------|------------------|
| 1 = ivory | 2 = cream     | 3 = yellow       |
| 4 = grey  | 5 = deep-grey | 6 = grey-brown   |
| 7 = brown | 8 = purple    | 9 = purple-black |
- Yield potential
- |         |                  |          |
|---------|------------------|----------|
| 3 = low | 5 = intermediate | 7 = high |
|---------|------------------|----------|
- Lodging
- |         |                  |          |
|---------|------------------|----------|
| 3 = low | 5 = intermediate | 7 = high |
|---------|------------------|----------|
- Drought tolerance
- |         |            |          |
|---------|------------|----------|
| 3 = low | 5 = medium | 7 = high |
|---------|------------|----------|
- Tillers: Number of effective (physiologically matured) tillers plant<sup>-1</sup>.

Note: Tillers in flowering, milky, or soft dough stage are not counted.

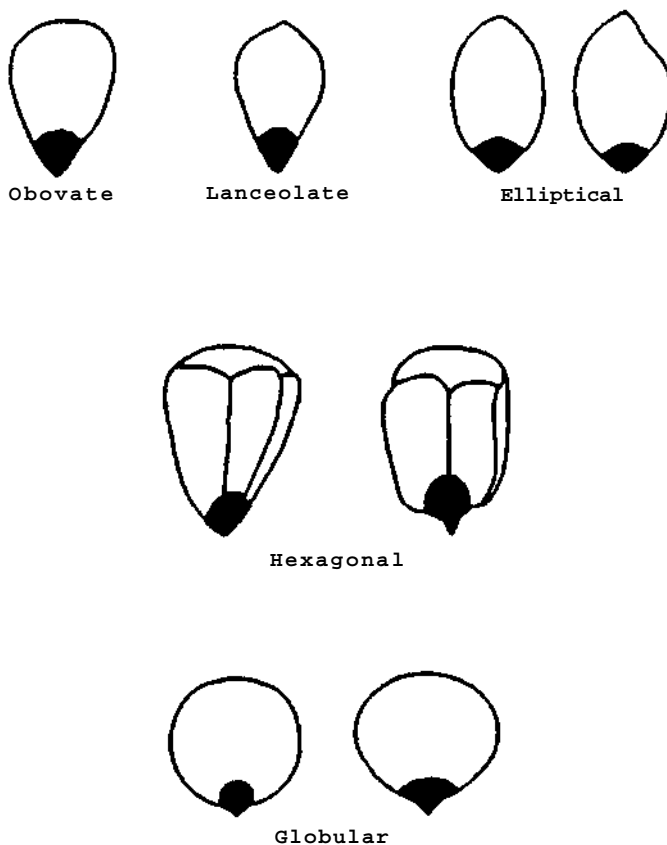


Figure 8. Shapes of the seed.



Exertion

The distance (cm) between the ligule of the flag leaf and the base of the earhead

Earhead length

The length (cm) from the base to the tip of the earhead

Width

The width (cm) at the middle of the earhead (widest section)

Earheads harvested  $h^{-1}$

Number of earheads harvested in net plot rounded to '000s  $ha^{-1}$

**At harvest stage**

Wet mass of earheads

Grams of earheads from the net plot recorded immediately at harvest to nearest 100 g

**Postharvest stage**

Endosperm color

1 = deep-yellow                      2 = amber (light-yellow)  
3 = deep-slate                        4 = light-slate  
5 = white

Endosperm texture

3 = corneous                      5 = partially corneous                      7 = starchy

Dry mass of earheads

Kg of earheads from the net plot. (Drying and weighing are continued until a constant mass is obtained.)

Mass of grain

Mass of grain  $plot^{-1}$  is calculated as  $kg\ ha^{-1}$  (corrected to 10 kg)

Mass of 1000 grain

Mass of 1000 grain to nearest 0.01 g (at 12% moisture)

Volume of seed

Volume of 1000 seeds to nearest  $cm^3$

Density of seed

Calculated by dividing the g of 1000 grain by its volume

Grain quality expressed as percentage of dry mass

Protein percentage of grain

Lysine percentage of grain

Methionine percentage of grain

Tryptophane percentage of grain

**At the appropriate stage**

Pest scoring -insect damage scores as compared to the check

3 = Damage < the check

5 = Damage approximately equal to the check

7 = damage > the check



## MP 11. Shoot Fly

Shoot fly (*Atherigona approxlmata*) incidence was reported in India and in several African countries. The single eggs are laid on the undersurface of seedling leaves. After hatching the larvae move to and cut the central growing point in the stem resulting in a deadheart. The egg period lasts for 1-2 days, the larval period lasts for 7-9 days, and pupal period lasts for 6 days. The maggots of this fly (Fig. 9) can also cause damage to the earhead (Seshureddy and Davies 1979; Rachie and Majmudar 1980; Sharma and Davies 1988).

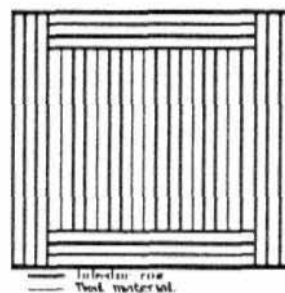


Figure 10. Screening for shoot fly resistance.

Figure 9. Earhead damage by shoot fly.

To screen for shoot fly resistance, 100 flies were introduced into a cage (2 x 2 m) 7-10 days after seedling emergence. The cultivars may be sown in single 2 m rows and replicated under a multiple-choice arrangement (different varieties) or with the same cultivar sowed over the whole area under no-choice conditions. Data on egg laying, deadhearts, and panicle damage were recorded (Sharma 1986).

Shoot fly populations can be monitored with fish meal traps. The screening of the test material is conducted at a time when the shoot fly population is very high to insure less plants escape infestation. The infester-row technique is adopted to screen the test material (Fig. 10). Four rows of the most susceptible cultivar are sown 20 days before sowing the test material, leaving 16 to 20 rows in between each block of infester rows. Four rows of infester rows are sown around the testing area as a border. Fish meal is applied to the infester rows to attract the shoot flies. The material to be tested is sown 20 days later between the infester rows. Data on egg laying, deadhearts, and earhead damage are recorded and the percentage of incidence calculated (Taneja and Leuschner 1985; Sharma 1986; Sharma and Davies 1988).

## MP 12. Stem Borers

The stem borer (*Acigona ignefusalis*) is the most important borer attacking pearl millet in Africa. It lays eggs in groups of 2 to 50 in between the leaf sheath and the stem; thus the survival rate of this larvae is very high. The eggs hatch in 8-11 days. The larvae feed on to the growing point of the stem resulting in a deadheart. The larvae tunnel through the stem. The development of the larvae is completed in 30-40 days. The diapaused larvae can survive for 6 months to 1 year (Fig. 11). The pupal period lasts for 13 days inside the stem and three generations per year are possible (Sharma 1986).



Figure 11. Diapausing larvae.

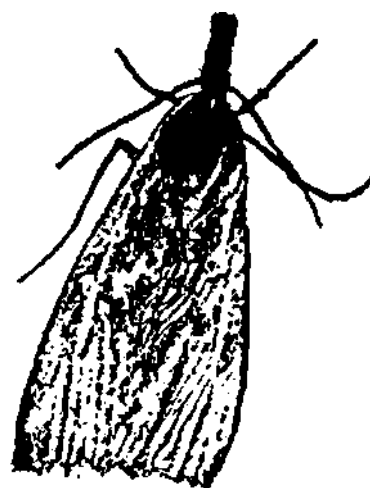


Figure 12. Stem borer adult.

The spotted stem borer (*Chilo partellus*) causes damage to pearl millet in India and African countries. The adult moth (Fig. 12) is nocturnal, light-brown to gray and has long palpe on the front of the head. It lays eggs in groups on the under surface of the leaf near the midrib. The eggs are flat and oval and hatch in 2-5 days. The young larvae cause leaf scarification and produce "shot holes" in the leaves. The larvae (Fig. 13) then reach the growing point and cut the main shoot resulting in a deadheart. The larvae also cause stem tunneling. The larval period is 28-50 days in summer and 190 days in winter. The diapause stage is facultative (might or might not occur). The larvae hibernate (rest in winter) and aestivate (dormant during summer) in the stems and stubbles. The pupal period is 12-15 days inside the stem before the adult emerges (Rachie and Majmudar 1980; Sharma and Davies 1988).

The stem borer *Sesamia inferens* causes damage to pearl millet in African countries and India. The adult moth lays round and creamy eggs

in between the leaf sheath and the stem in 2-3 rows; and sometimes on the surface of the soil. The egg stage lasts for 4-9 days in summer and 9-25 days in winter. The larvae, after hatching disperse, to the neighboring plants, but more than one larvae may be found on a plant. The larvae initially cause leaf scarification and produce "shot holes" in the leaves. The 3rd instar larvae reach the growing point and cut the main shoot resulting in deadhearts. In mature plants the larvae bore the stems and make tunnels. The larval development is 3-4 weeks with 5-7 larval instars. The fully grown larvae are pink with a dark-brown head. Pupation is inside the larval tunnel or outside under the leaf sheath lasting 5-12 days in summer and 12-36 days in winter (Sharma and Davies 1988).

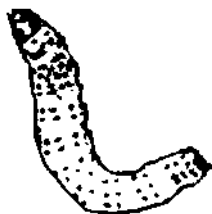


Figure 13. Stem borer larva.

The stem borer (*Eldana Baccharina*) has been observed throughout Africa. The eggs are laid on the leaves and hatch in 5-7 days. The young larvae cause damage to the midrib. The adult larvae cut the growing point and cause deadhearts. The larval development is 20-60 days and pupation inside the stem is for 8-13 days. The infestation is calculated as the percentage of deadhearts (Sharma and Davies 1988).

The (*Sesamia calamistis*) is another stem borer found widespread in Africa. The eggs are laid in between the leaf sheath and internode. The young larvae feed on the content of the stem. The larval development takes 8 weeks and pupation inside the stem 10 days. Diapause has not been noticed. The infestation is presented as a percentage of deadhearts in the total plants (Sharma and Davies 1988).

### Screening

Screening pearl millet for stem borer resistance under natural infestation is not possible as the level of infestation may not be uniform in every season or year, but reliable screening can be done with artificial infestation. The larvae of the stem borers *Chilo partellus*, *Sesamia inferens*, and *Acigona ignefusalis* can be artificially reared in laboratory conditions and used to infest the test material in the field (Sharma 1986).

In places where facilities for mass rearing are not available, screening in a limited way can be done by using diapause larvae. At the end of the season the diapause larvae are collected, put in 2% agar agar

in petri dishes, and carried to the next season. By creating optimal environmental conditions the diapause larvae can be made to pupate. Adults emerge and lay eggs. The egg masses can be used for artificial inoculation by applying one egg mass  $m^{-1}$  row. Larval infestation can also be done by mixing the larvae with poppy seed. About 500 egg masses at the blackhead stage are mixed with 80 g of carrier in a glass jar, kept over night and the first instar larvae are allowed to emerge. Then the contents are transferred to the bottle of the 'Bazooka' applicator. A fixed quantity of poppy seed is mixed with the larvae and applied in the whorls with the 'Bazooka' applicator. Each application will provide at least 7 larvae per whorl. This is sufficient to infest 1000 plants each with 5 to 7 larvae. One person can infest 1000 plants in 30 to 40 min. About 84 females will provide enough larvae to screen 100 entries with two replications. Usually infestation is done 5-20 days after plant emergence to obtain maximum deadhearts; delayed infestation results, at the most, in leaf damage and stem tunneling, but no deadhearts (Sharma 1986; Sharma and Davies 1988).

Screening pearl millet under natural conditions is done by identifying the "hot spots" for the stemborer. Monitoring of the pest intensity in the hot spot is done with pheromones or light traps and screening is done at a time when the pest incidence is high. The stubbles containing pupa from the previous crop may be incorporated in the field where stemborer resistance is to be tested. A susceptible pearl millet variety is sown every 10th row as an indicator row that should show a minimum of 80% borer infection for the results from the test rows to be reliable (Sharma 1986).



## MP 13. Midge

Midge (*Geromyia penniseti*) is an important pest of pearl millet in India, Sudan, Uganda, Niger, Nigeria, Burkina Faso, Ghana, Senegal, and Madagascar. This midge emerges after sunset and is most active between 2100 and 0100 and all activity ends by 0400. The eggs are elongate and are inserted in the space between the spikelets and involucre of bristles or between two spikelets. The eggs hatch in 3 days and the larvae crawl to and start eating the ovary. The larvae fully develop in 8 days. The pupal stage lasts 2 days and adults start emerging at 1800 with peak emergence at 1930. The *Geromyia penniseti* adult is strictly nocturnal. From egg to adult takes 13 days with 4 to 5 generations in a rainy season. The diapause, up to a maximum of 10%, occurs late in the season (Sharma and Davies 1988).

Screening for midge resistance should be conducted in "hot spots". Artificial rearing of midge flies is very difficult. The head cage technique can be adopted (Fig. 14). In this technique, the midge flies are collected from the flowering panicles and about 40 midge flies are released into the dark-blue cloth cage which is fixed on the head of the test material and the susceptible check. The infested florets do not produce grain. If the florets are pressed between two fingers at the milk to dough stage, a red fluid (the body contents of the maggot) ooze out of the floret. At maturity, empty glumes containing an empty cocoon can be observed. The percentage of affected spikelets to the total is calculated to express the midge infestation (Sharma and Davies 1988).

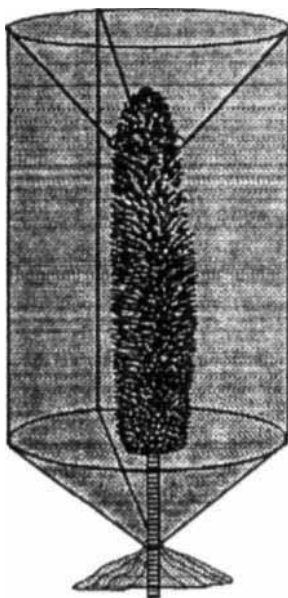


Figure 14. Head cage used for screening.

## MP 14. Other Pests

Armyworms (*Mythimna separata*) become occasionally important in Asia. The eggs are laid in batches on the underside of the leaves. The larval development lasts for 14-22 days and the pupal stage 8-9 days. The adults survive for 4-5 days and mate on the 3rd day with oviposition occurring by the 4th day. The larvae feed in the night and remain in the cracks of the soil during the day (Sharma and Davies 1988).

The armyworm (*Spodoptera exempta*) is an occasional pest in Africa. The eggs are laid on the undersurface of the leaves, and hatch in 3-4 days. The larval development takes 10-20 days and pupal development is in the soil for a week. The migration of the adults is at night. It is more serious in a season with heavy rainfall (Sharma and Davies 1988).

The armyworm (*Spodoptera frugiperda*) attacks millet and defoliates it in northern, southern, and central America and Mexico. The eggs are laid during the night in 2-10 days. The larvae develop in 20 days with 6 instars. Pupation is in the soil for 10 days. The females migrate several km before laying eggs (Sharma and Davies 1988).

The armyworm can be reared on an artificial diet in the laboratory. The larvae can be distributed to a leaf whorl with a 'Bazooka' applicator and the percentage of infection can be calculated. The armyworm (*Mythimna separata*) tends to migrate to other plants and hence the results require confirmation in a greenhouse. The seedlings of 15-20 days are infested with 5 first instar larvae or one third-instar larva plant<sup>-1</sup>. The percentage of infected plants can be calculated (Sharma 1986).

Blister beetles, *Mylabris* sp. (Fig. 15), *Cyaneolytta* sp., and *Cylindrothrorax* sp. (Fig. 16) are the common blister beetles found on pearl millet in India and African countries. The adult can be metallic-blue, green, black and redish-yellow, or brown. The adults feed on the inflorescences, resulting in poor seed-set. The beetles produce an irritating fluid called cantharidin. The eggs are laid in the soil and the grubs feed on the eggs of other insects. The infestation is recorded as the percentage of seed-set on individual heads (Sharma and Davies 1988).



Figure 15. Blister beetle (*Mylabris* sp.).



Figure 16. Blister beetle (*Cylindrothorax* sp.)

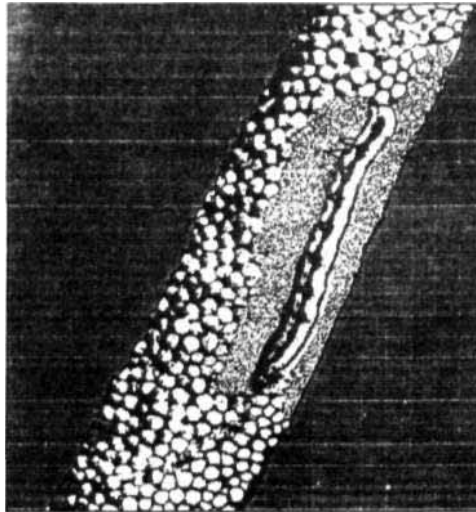


Figure 17. Larva of *Helicoverpa armigera*.

Earhead caterpillars, *Masalia* sp. and *Raghuva* sp. are the two important earhead caterpillar pests in Africa. *Eublemma silicula* and *Helicoverpa armigera* (Fig. 17) are also recorded. In *Masalia* sp. eggs are laid on the flowers. The eggs hatch in 4 days and the larval period lasts for 28 days. The pupation is in the soil and adults emerge from



pupa in 12-24 days. Diapausing is extended up to 11-12 months. The adult is a green moth with fine white-stripes. The caterpillar feeds on the developing grain. The infestation is recorded as percentage of seed loss per head (Sharma and Davies 1988).

Artificial infestation can be made by rearing *Helicoverpa armigera* larvae in the laboratory, while in the other two species rearing techniques need to be developed.

*Raghuva* sp. lay eggs in the involucre of bristles in pearl millet. The young caterpillars, after emerging from the eggs, feed on the contents of the spikelets. The caterpillars are yellow to green with two light bands on each side. The older larvae cut the floral stalks and prevent grain formation. They take shelter between the rachis and the spikelets. The damage is caused spirally on the earhead, a characteristic feature caused by the insect (Fig. 18). The percentage of damaged spikelets to the total spikelets is calculated for each head (Sharma and Davies 1988).



Figure 18. Earhead damage by *Raghuva albipunctella*.

The white grub, *Holotrichia consanguinea*, damages the plants by eating the roots of pearl millet in India and African countries (Fig. 19). The young grubs hatch by June and reach full size in 8-10 weeks. They feed on the roots near the surface during the crop season, but in dry conditions they descend 45-60 cm into the soil. Application of BHC or dieldrin at the rate of 2-4 kg a.i. ha<sup>-1</sup>, or phorate granules at 7 kg of a.i. ha<sup>-1</sup> effectively control this pest (Sharma and Davies 1988).





Figure 19. White grub larvae.

### Birds

Birds are one of the major pests of millet in Africa. The weaver bird *Quelea quelea quelea* is the major bird pest in western Africa. The *Quelea quelea aethiopica* occurs in eastern Africa and *Quelea quelea lathamii* is found to be damaging millet in southern Africa (Rachie and Majmudar 1980). Control measures of burning the nests, using explosives, and spraying toxic substances gave considerable results in controlling this bird in western Africa.

The chemical, Queletox, was successfully used in controlling this bird in wheat in Zimbabwe and Tanzania. The roosts of the birds were identified and the chemical was sprayed on the roosts at 1900 when the birds return to their roosts. The birds die on the roosts and are collected the next morning. They can be consumed without an injurious effect to human beings. The Queletox spraying is being extended to other millet- and sorghum- growing areas of southern Africa (La Grange 1986).



## MP 15. Downy Mildew (*Sclerospora graminicola*)

### Inoculum

Two types of downy mildew inoculum are used to inflict the disease artificially:

a) Oospore inoculum. Infected dried leaves and dried malformed earheads are collected at the end of the growing season and ground into fine powder. This powder contains oospores for inoculating the soil in pots.

b) Sporangial inoculum. The old sporangial growth on the infected leaves is removed with moist cotton. The leaves are cut into small bits; placed in a humid chamber and incubated for 6 h at 20°C along with a beaker of water. The fresh sporangial growth is collected in water in the beaker and kept on an ice-bath to keep the temperature low. The sporangial concentration is determined with a hemacytometer. A concentration of 60 sporangia per hemacytometer field (0.1 mm<sup>3</sup>) is used to spray the sporangial inoculum. This is 600 000 sporangia mm<sup>3</sup> (Singh and Gopinath 1985).

### Inoculation

a) Oospore inoculation. The oospore bearing material (powder) is incorporated into the soil in the pots. Seed which is dressed with oospore powder is sown in the pots. After a week, the downy mildew infected plants can be observed.

a) Sporangial inoculation. The sporangial inoculation is done with any one of the following methods:

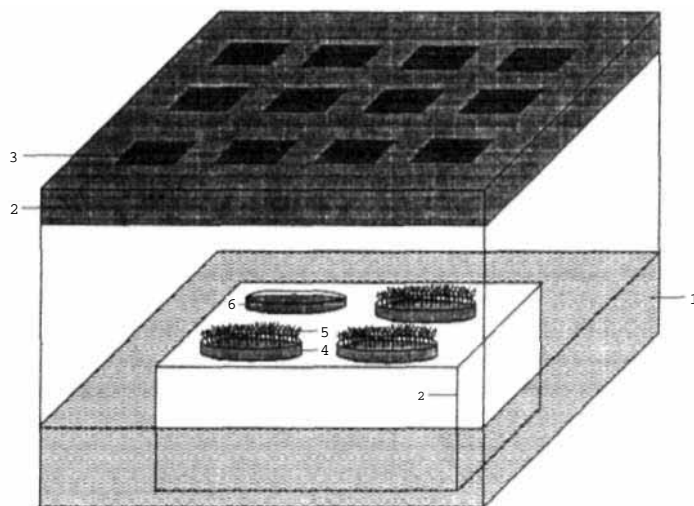
Drop inoculation. In this technique developed at ICRISAT, the inoculum is placed at the tip of the seedling with a hypodermic syringe. The inoculated seedlings are marked with a tooth pick to differentiate the late emerging seedlings and covered with a plastic bag. After inoculation the pots are incubated at 20°C for 24 h. Then the bags are removed and plants are maintained at 30°C for the development of the symptoms. Downy mildew symptoms begin to appear by the 4th day (Singh and Gopinath 1985).

Spray inoculation. In this method the inoculum is sprayed on the seedlings with a hand sprayer and then incubated at 20°C for 24 h (Singh and Gopinath 1985).

Seedling tower technique. This technique developed at ICRISAT is carried out in a rectangular metal box (Fig. 20). Petri dishes containing germinating pearl millet seeds are placed on a raised platform on the bottom of the box. An agar-plated petri dish is placed on the platform as a control. The bottom of the box is filled with water to create high humidity inside the box. The open end of the box is covered with mosquito netting. Downy mildew infected leaf bits are placed on a cloth with their adaxial side facing the cloth. The entire box



is placed in an incubator for 24 h at 20°C. The sporangia will develop on the side of the leaf facing the cloth. The matured sporangia drop through the holes of the cloth and fall on the seedlings in the petri dishes.



1. Water
2. Raised platform
3. Infected leaf bit
4. Petri dish
5. Germinating seed
6. Petri dish with agar
7. Mosquito netting

**Figure 20. Screening tower technique for downy mildew.**

The sporangial count is taken in the agar plate to confirm the dropping of sporangia from the infected leaf bits. The seedlings are then transplanted into pots and maintained at 25 to 30°C for the disease development. The seedlings develop disease symptoms within 4 days (Gopinath 1988). After inoculation the number of seedlings showing downy mildew symptoms are recorded once a week. The percentage of diseased seedlings is calculated (Gopinath 1988).

#### **Field-screening procedure**

This technique is called the infector row system (Fig. 21). A mixture of the genotypes 7042 and NHB 3 (downy mildew susceptible) is sown on every 9th ridge 20 days prior to sowing eight central rows of test materials. Soon after emergence the seedlings in the infector rows are spray-inoculated with a sporangial suspension. The test materials are sowed in the blank ridges 20 days after having sown the infector rows which have developed the disease and will be producing the sporangia. While sowing



the test material a known susceptible line is sown after every 10th test row. This is the indicator row. From the date of emergence, the seedlings should be perfo-spray irrigated daily to provide high humidity. The test material are exposed to sporangia released from the infector rows and then develop the disease (Williams et al. 1981).

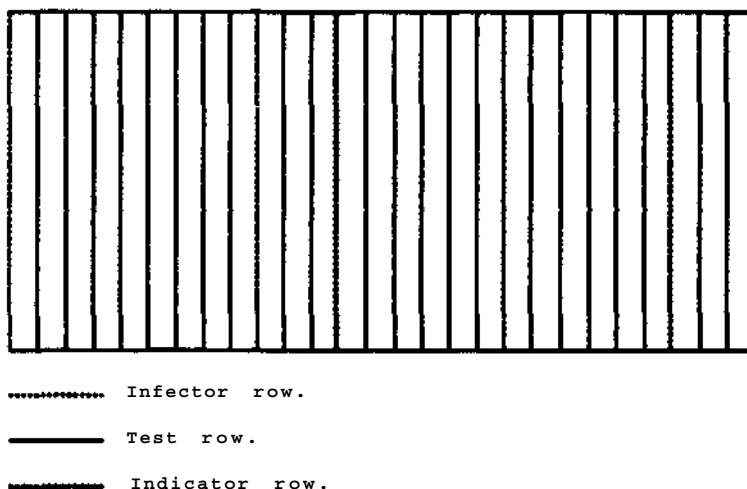


Figure 21. Field screening for downy mildew.

A disease incidence of 80% in the indicator rows will indicate that the spread of the disease was effective. Thirty days after sowing the test material, the first rating of downy mildew infection should be taken. Infected seedlings are marked by red topped bamboo pegs. A second rating of the incidence should be taken 1 month after the first observation (Singh 1979).

Disease (infection index) at the dough stage (Singh 1979).

Score description on tillers:

- |   |                         |   |                            |
|---|-------------------------|---|----------------------------|
| 1 | No disease              | 2 | Disease on nodal tillers   |
| 3 | > 50% effective tillers | 4 | > 50% ineffective tillers. |
| 5 | Entire plant diseased   |   |                            |

Severity is calculated by :

$$\frac{y(1-1)+v(2-1)+v(3-1)+v(4-1)+v(5-1)}{n \times 4} \times 100 = \text{INF \% index)}$$

y = Number of plants in each category; n = Total number of plants

Example

Categories: 1, 2, 3, 4, 5; Number of plants: 10, 3, 6, 5, 5 = 29

$$\frac{10(1-1)+3(2-1)+6(3-1)+5(4-1)+5(5-1)}{29 \times 4} \times 100 = \frac{5000}{116} = 43\%$$

## MP 16. Ergot (*Claviceps fusiformis*)

### Inoculum

a. Primary. Early-maturing hybrids should be sown along with the test material in the screening nursery. The primary inoculum should be prepared from the sclerotia collected from the ergot infected pearl millet heads of the previous year. Five grams of sclerotia should be crushed and mixed in 1 L of water and the mixture is filtered. The filtrate with conidia is used as inoculum. This inoculum is sprayed on the early-maturing hybrid at the protogynous stage. Homogeneity for stylar emergence and nonavailability of outside pollen make the hybrids develop high levels of ergot and they provide adequate secondary inoculum (Thakur et al. 1984; Thakur and King 1988a).

b. Secondary. Honeydew globules develop (Fig. 22) on the styles of the hybrids sprayed with primary inoculum. Two or three heads with honeydew globules are shaken in 5 L of water and the mixture is filtered. This inoculum is sprayed on the plants to be tested (Thakur et al. 1984; Thakur and King 1988a).

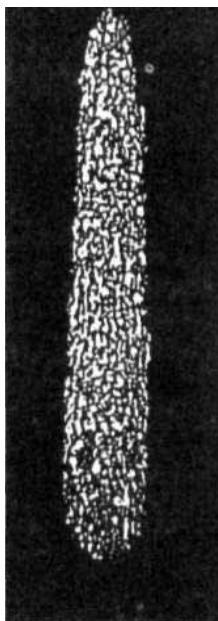


Figure 22. Honeydew stage of ergot.

Inoculation. The panicles of the test plant material are to be bagged at the boot stage to avoid external pollen contamination. The stigmas will emerge within 48-72 h after the boot stage. At the protogynous stage the conidial suspension is sprayed on the panicle by removing the bags and then the panicle is immediately rebagged. Minimal time must be



taken for spraying the inoculum on the heads to avoid pollen contamination from the air. The stigmas are fresh on the nonpollinated heads, while they are withered on the pollinated head. High humidity is to be provided in the testing area with over head sprinklers. Honeydew symptoms are observed 5 to 6 days after spraying the inoculum. Ten days after spraying the bags are to be removed to avoid mold development on grain of the ergot resistant panicles. Honeydew solidifies to form sclerotia (Fig. 23) (Thakur and King 1988a).

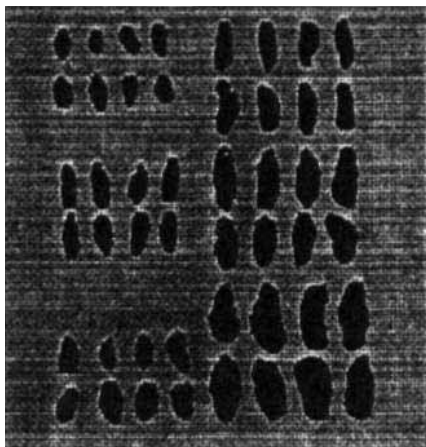


Figure 23. Sizes of sclerotia of ergot.

Twenty days after inoculation the heads in an infected row are scored with a standard chart to estimate the percentage of ergot infection (Fig. 24). The mean of the percentages are to be calculated if it is an observation nursery. But in advanced trials the percentages can be analyzed.



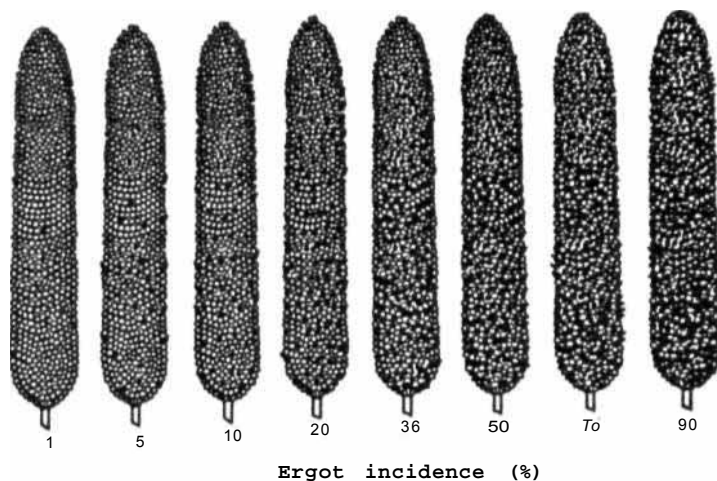


Figure 24. Standard drawings for ergot scoring.

## MP 17. Smut (*Tolyposporium pencillariae*)

The smut inoculum is cultured on a potato-agar medium made from 200 g of peeled potatoes and 15 g of agar that are boiled separately in 500 mL of distilled water. After boiling, they are mixed and the solution is made up to 1000 mL by adding distilled water. The mixture is steam-sterilized at 15 lb pressure (121°C) for 20 min. The medium is then poured into petri dishes (Thakur et al. 1983; Thakur and King 1988b).

Matured nonbroken sori are collected from smut infected pearl millet panicles. The sori are surface-sterilized with 1% mercuric chloride solution for 2 min to destroy any other spores present on the surface of the sori. The sori are thoroughly washed two or three times in distilled water to remove all traces of mercuric chloride. The sori are ruptured with sterilized forceps and the mass is transferred to the potato agar medium in the petri dishes. The inoculated petri dishes are incubated at 35°C for 5 days. The medium with sporidia is mixed with distilled water and adjusted to 10 conidia mL<sup>-1</sup> of inoculum, using a hemacytometer.

The sporidia which emerge from the spore balls in the agar media are of two types (+ve and -ve). When the positive and negative strains are deposited in the top of the boot they unite and produce a dicaryotic mycelium. It is this dicaryotic mycelium that infects the florets of the panicle as they are emerging from the boot. The dicaryotic mycelium enter the spikelet and convert the ovary into a sorus (Thakur et al. 1983; Thakur and King 1988b).

When the inoculum is stored more than 90 days the positive and negative sporidia unite and chains of sporidiospores are formed. The





chlamydospores are formed in the intercalary or terminal positions of sporidiospores. Being dicaryotic the chlamydospores are the resting spores and can directly infect the spikelets. The stored inoculum with the developed chlamydospores can be used for artificially creating the disease (Thakur et al. 1983; Thakur and King 1988b).

About 5-7 mL of the inoculum are injected into the boot of the pearl millet plant with an atomizer. After inoculation the boot is bagged with a white parchment paper bag to avoid external pollination. Humidity (80%) is maintained in the experimental area with overhead sprinklers. The first symptom of infection is observed 12 days after inoculation as green sori. These sori finally turn dark-brown (Fig. 25). The earheads are scored with standard charts 20-25 days after inoculation for the incidence of smut (Fig. 26) (Thakur et al. 1983; Thakur and King 1988b).

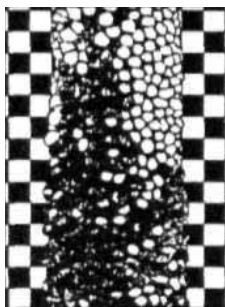


Figure 25. Smut sori on pearl millet.

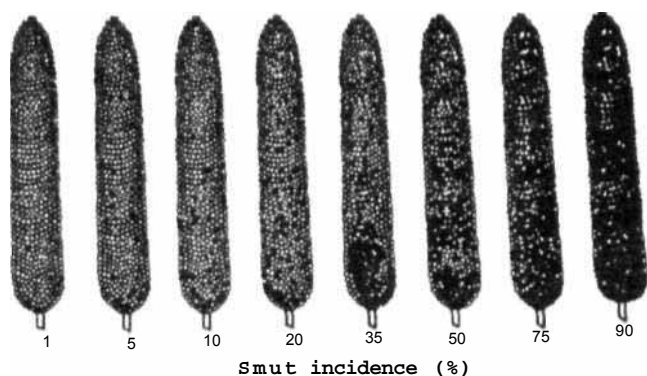


Figure 26. Smut severity assessment.



Scoring

0-5 resistant, 5-10 less susceptible, and above 10 susceptible

A mean percentage of infection is calculated for the observation nursery. The transformed percentages are statistically analyzed for the advanced trials.

## MP 18. Fungal, Bacterial, and Viral Diseases

### Rust (*Puccinia penniseti*)

The typical erupting pustules containing reddish-brown powder (uredospores) appear on the older leaves. As the leaves age, dark-brown teliospores are produced. The pustules can occur on the upper and lower surface of the leaves and are most common on the upper surface. In highly susceptible cultivars, large pustules are densely grouped on leaf blades and on sheaths. The infestation is assessed on the top four leaves at the dough stage by severity grades (Fig. 27) (Rachie and Majmudar 1980).

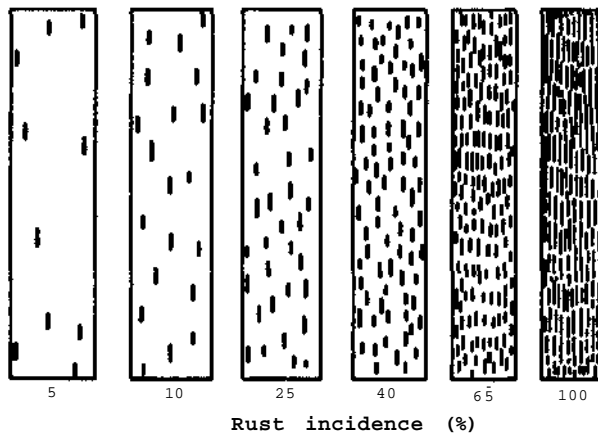


Figure 27. Rust incidence scale.

Grade	Description	Grade	Description
1	5% infection	2	10% infection
3	25% infection	4	40% infection
5	65% infection	6	100% infection

### Leaf blast (*Pyricularia setariae*)

The lesions are circular, up to 1-cm long with dark-brown margins, and light centers. Lesions have chlorotic yellow halos. In humid conditions



the lesions develop light-gray conidiospores and conidia in the center. Screening is done using six grades of symptoms on the leaf surface as for rust (Rachie and Majmudar 1980).

**Zonate leaf spot (*Gloeocercospora* sp.)**

Circular lesions with alternating roughly concentric straw and brown bands appear on the leaf blades. The lesions may coalesce and the entire leaf is covered. Black sclerotia are produced on the lesions. It is scored as for rust and blast (Williams et al. 1978).

**Twisted top (*Fusarium moniliforme*)**

This disease is also called pokkah boeng. The upper leaves of the affected plant do not unfold and spread out as in normal plants, but their tips are rolled into one another; consequently a series of foliar arches are formed on one side. The panicles are not formed or could not escape from the boot. The rolled tips of the leaves rot. Some times the plants are stunted and the top leaves are twisted. The percentage of the affected plants to the total number of plants is presented as the infection score (Rachie and Majmudar 1980).

**Curvularia leaf blight/mold (*Curvularia lunata*)**

The infection is first noticed on the lower leaves and gradually spreads upward. Small yellowish-brown spots are formed on the margins of the leaf blades. These may coalesce, forming large patches, killing the tissue. The center of the spot is dirty-brown with a yellowish margin. Infected portions become brittle with age. The infection may spread to ears. The disease starts from the tip of the spikelet and spreads to the whole spikelet. The affected spikelets have a black-moldy growth at the tip. In the badly affected head few grains develop. The leaf damage is to be scored in six grades like the rust and blast. When the spikelets are affected the percentage of affected spikelets to the total is determined while scoring (Rachie and Majmudar 1980).

**Helminthosporium leaf spots (*Helmiotiosporium stenospilum*)**

This pathogen causes seed rot or seedling blight and affects the stems, leaves, and panicles of pearl millet. Seedlings are mostly affected by this pathogen. The percentage of the affected seedlings to the total number of seedlings is determined (Rachie and Majmudar 1980).

**Cercospora leaf spots (*Cercospora fusimaculans*)**

Circular brown spots with white centers and a yellow halo are formed on the leaves. The damage is scored in six grades similar to the rust and blast incidence (Rachie and Majmudar 1980).

**Bacterial leaf spot (*Xanthomonas* sp.)**

This disease appears as water soaked spots on the upper surface of the leaf which then turns reddish within 2-3 days. The spots become rectangular increasing in size to measure about 2.5 x 1.3 mm. They have a vascular margin, are chocolate brown, and without a halo. At maturity

the spots are markedly depressed from the surface of the leaf. The causal organism is confined to vascular bundles. Scoring is done in six grades like rust and blast (Rachie and Majmudar 1980).

#### **Viral disease**

Sugarcane mosaic (*Saccharum virus 1*) is found to infect millet in both India and USA causing mosaic-like symptoms. The symptoms include minute creamy-yellow specks or dots arranged in rows between the leaf veins. The specks sometime coalesce to form broad yellow bands and heads are not formed. The shoot bug (*Parogrinua maidis*) serves as a vector. The percentage of affected plants to the total number of plants is to be determined (Rachie and Majmudar 1980).

#### **Nematode**

Root exudates of pearl millet are found to attract the nematode, *Hemocyclus paradoxus*. Thus reproduction of the nematode is found in the presence of pearl millet. This nematode may be controlled by rotating crops with pearl millet (Rachie and Majmudar 1980).

## **MP 19. Laboratory Screening for Resistance to *Striga* spp.**

*Striga* is an important parasitic weed in large areas of the semi-arid tropics.

As many as 30 species of *Striga* are known. Those which cause economic yield loss are *Striga asiatica* and *S. densiflora* in India; *S. asiatica* and *S. forbesii*, in southern Africa and *S. hermonthica* in eastern and western Africa (Parker 1965; Jones 1953). It is a partial root parasite attacking several crops (sorghum, maize, pearl millet, and cowpea). The seed germinates in the presence of the root exudates of these crops. The haustoria of *Striga* establish contacts with the host plant roots and draw nutrients for its growth and development. *Striga* plants appear above the ground 5 to 6 weeks after sowing the crop (Parker 1983). However, maximum damage is done to the host plant during these 5 weeks when the *Striga* plant is below the soil surface. When it emerges, it can synthesize food material with its green foliage. The host plant becomes stunted and the earhead fails to emerge from the boot; even if it emerges the seed setting will be poor with reduced grain size. Heavy infestation of *S. hermonthica* is observed on sorghum in heavy black soils while pearl millet is nearly immune; the reverse is true on sandy soils where the pearl millet is heavily attacked and sorghum only lightly so (Jones 1955).

The *Striga* produces pods each containing 700 to 900 seeds. A single plant may produce 40 000 to 50 000 seeds (Jones 1953). The seed is viable for up to 20 years. Breeding for resistant varieties offers a long-term economic control of *Striga* for the SAT farmers. The laboratory and field screening and breeding methodologies have been standardized at

ICRISAT for identifying the resistant genetic material.

### Laboratory Screening

The standardized technique known as double-pot screening (Parker et al. 1977) is based on low stimulant production of the test genotypes as the mechanism of resistance to *S. asiatica*. There are three main steps:

1. Growing sorghum seedlings in paper ice-cream cups:
  - i) Sterilize the sorghum seeds with 1% sodium hypochlorite for 25 min (surface sterilization for preventing fungal growth).
  - ii) Wash the seeds thoroughly with distilled water till the chlorine smell disappears.
  - iii) Place these sterilized seeds in petri dishes for germination.
  - iv) Transfer germinated sorghum seeds (after 24 h) to ice-cream cups which are filled with sterilized sand as follows:
    - a) Make a few holes in the bottom of an ice-cream cup to provide drainage and for collecting exudate by using a suction pump.
    - b) Place a filter paper on the bottom and fill half the cup with sterilized silica sand (150 g).
    - c) Place 15 germinated sorghum seeds in the cups and add 100 g of sterilized sand.
    - d) Place this cup inside another ice-cream cup into which excess water is drained (use two replications for each genotype).
  - v) Add 25 mL of distilled water on the first day and 15 mL on each succeeding day.
  - vi) Allow the seedlings to grow for 1 week.
  - vii) Extract the root exudate from each cup separately with a suction pump.
  - viii) Test this exudate on pretreated *Striga* seeds.
2. Pretreatment of *Striga* seeds:
  - i) Sterilize the *Striga* seeds with 1% sodium hypochlorite for 5 min.
  - ii) Wash the seeds thoroughly with distilled water until the chlorine smell disappears.
  - iii) Leave the seeds on a filter paper overnight to dry.
  - iv)
    - a) Place two glassfiber filter papers of 90 mm diameter in a petri dish and moisten them with distilled water.
    - b) Cut the glass fiber filter paper into discs of 8 mm diameter using a cork borer and arrange them in the petri dish.
  - v) Sprinkle about 25 to 30 sterilized *Striga* seeds on to each disc. Add distilled water, sufficient to saturate the filter paper.
  - vi) Place the petri dishes in a polyethylene bag and seal it so that there is no drying of the discs and leave them in the incubator for 10 to 12 days at 25°C.
3. Testing exudate for *Striga* seed germination:
  - i) Take four discs of pretreated *Striga* seeds for each variety and dry the discs on a filter paper.



- ii) Add 20 mL of exudate (which is just sufficient to moisten the disc) to each disc with a microdosimeter.
- iii) The same procedure is repeated for the second replication,
- iv) Keep the petri dishes in a polyethylene bag. Seal it and leave in the incubator at 33°C for 24 h.
- v) Calculate the percentage of *Striga* seed germination after counting the germinated *Striga* seeds (use a microscope).

Controls:

- 1. Distilled water check. Ice-cream cups are filled with 250 grams of sand without sorghum seeds and watered daily as with the test material.
- 2. Susceptible variety. Set up with a known susceptible variety (Swarna) and treat in the same way as for test materials.

Equipment required to conduct the laboratory screening test:

<u>Permanent items</u>	<u>Day to day items</u>
1. Incubators (2)	1. Ice-cream cups
2. Microscope (1)	2. Petri dishes
3. Seed germinator (1)	3. Specimen tubes
4. Distillation unit (1)	4. Plastic funnels
5. Suction pump (1)	5. Whatman glass fiber filter paper
6. Microdosimeter (2)	6. Test tubes
7. Counter (1)	7. Measuring cylinders
8. Cork borer (1)	8. Sodium hypochlorite (NaOCl <sub>2</sub> )
9. Forceps (2)	9. Sodium bicarbonate (NaHCO <sub>3</sub> )
10. Buckets (5)	10. Blotting paper
11. Tubs (5)	11. Filter paper
12. Trays (12)	12. Butter paper bags
	13. Sand (silica)
	14. Polyethylene bags



## MP 20. Field Screening for Resistance to *Striga* spp.

Field screening of the laboratory identified resistant lines was carried out by growing the test lines in a field naturally or artificially infested with *Striga* (Rao et al. 1983).

### 1. *Striga* 'sick field' management

The field screening can be conducted in a natural 'sick field' if the level of *Striga* infestation was relatively high, uniform, and regular over seasons.

But, generally it was not found, hence there was need to infest the field with *Striga* seed regularly to insure that an adequate *Striga* seed population was maintained.

The *Striga* 'sick plot' was maintained as follows:

- i) Select a low fertility field with good slope and drainage.
- ii) Prepare the field with minimum tillage and ridge it.
- iii) Open furrows on the ridges and manually infest with *Striga* seed, preferably by mixing seed with sand and placing the *Striga* seed in the top 5-10 cm of the soil,
- iv) Keep the application of fertilizer at low levels (based on the fertility level of the field up to 20 N ha<sup>-1</sup>)
- v) Sow, the test material at least a fortnight after the *Striga* seed infestation,
- vi) Avoid intercultivation and top dressing with nitrogen during the season,
- vii) Complete the thinning, mechanical operations, and weeding before the *Striga* emerges (about 25-30 days after sowing),
- viii) Remove the volunteer host plants before the test material is sown. One way to prevent this problem is to have two sick plots to permit a fallow season or rotation with a nonhost crop in alternate years.

### Field Experiment Designing

If many lines are to be screened, sowing of a susceptible variety at frequent intervals (augmented design) seems to be the best approach.

With limited entries a randomized complete block design with systematic checks (susceptible variety), which were arranged so that every test plot will have one check plot adjacent to it, can be used.

However, with few entries and with sufficient area of sick field, a checkerboard layout was a better choice (Rao 1985). In this layout, the test entries were arranged so that each entry plot was surrounded by susceptible check plots on four sides giving the field a checkerboard appearance.

The entire trial was bordered with a strip of the susceptible check variety.

A three-stage *Striga* screening methodology has been developed and used at ICRISAT (Fig. 28).

### **Observation Nursery**

This first stage was a nonreplicated trial of many test entries with a frequently repeated susceptible check grown in the sick field. Test entries may be grown in three-row plots in one or multiple-location nurseries (Fig. 28).

### **Preliminary Screening**

The second stage of testing includes those nursery entries that were agronomically good in stage I and displayed some resistance. The entries were tested in three-row plots and were replicated at least three times. Check plots, using a *Striga*-susceptible variety, were systematically arranged so that every test entry plot has one check plot adjacent to it. This arrangement resulted in each replication being divided into units of nine plots. Each unit will have eight plots of test lines surrounding one plot of a susceptible check line (Fig. 28).

### **Advanced Screening**

The third and final stage tests the entries, selected from the preliminary screening, in larger plots with four susceptible check plots surrounding each test entry plot.

Each entry was tested in a five-row plot so that yield estimates and *Striga* reactions were obtained from a fairly reliable plot size, with border effects minimized. The field, which looks checkerboarded with alternating susceptible and test entry plots in both the directions, was therefore called a checkerboard layout. The entire trial was sown on all four sides with a strip of a susceptible check variety. Statistically this was not an experimental design, but rather a field layout within which some of the standard experimental designs can be used.

### **Data Recording and Interpretation**

Data on morphological characters and *Striga* counts were obtained on the host lines which appear uniform. Since each entry was grown in a three-row plot in an observation nursery/preliminary screening, *Striga* counts and other characters were recorded on the central row. *Striga* counts of the test line were standardized by expressing the reaction as a percentage of the average of the nearest two susceptible check plots. In advanced screening, the *Striga* reactions of test entries were calculated as a ratio of *Striga* numbers in the test entry plots to the positional check average expressed as a percentage (Fig. 29). The positional check average was the average *Striga* counts of the four susceptible check plots surrounding each test entry plot. Test entries showing <10% *Striga* reaction were classified as resistant. The *Striga* reaction of the test entry (SRTE) was calculated: PS1 = 103 *Striga* plants, PS2 = 102 *Striga* plants, PS3 = 110 *Striga* plants, PS4 = 105 *Striga* plants, and TE = 8 *Striga* plants.



$$\text{Positional check average} = \frac{103 + 102 + 110 + 105}{4} = 105$$

$$\text{SRTE} = \frac{8}{105} \times 100 = 7.6\%$$

The test entry was recognized as resistant since its reaction to *Striga* was below 10%.

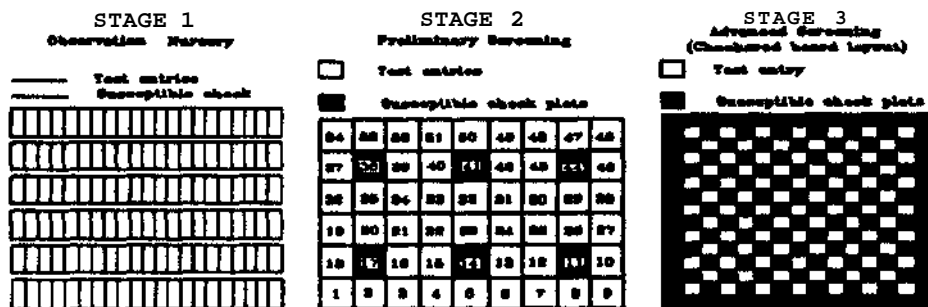


Figure 28. Three-stage screening methodology for *Striga* resistance breeding. (Sourcet Rao et al. 1983)

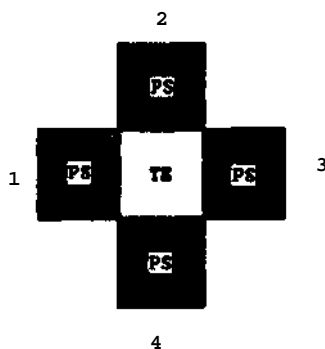


Figure 29. TE = Test entry; PS-Positional check

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## Evaluation

Select the most appropriate answer and check the correct answer at the end of the booklet.

### MP 1. Uniformity Trial

1. Uniformity trials are conducted to identify the
  - a) alkaline soils.
  - b) the topography of soils,
  - c) slope.
  - d) field variations.
2. The number of varieties grown in uniformity trials is/are.
  - a) four.
  - b) one.
  - c) two.
  - d) many.
3. For accurate information and mapping field differences the plot size should be \_\_\_\_\_ in uniformity trials.
  - a) big
  - b) any size
  - c) very big
  - d) small
4. The use of smaller plots in uniformity trials would permit
  - a) convenient weeding operations.
  - b) easy harvesting.
  - c) easy irrigation operations.
  - d) mapping of differences in fertility.
5. The management in an uniformity trial is
  - a) treatment specific.
  - b) uniform,
  - c) plot specific.
  - d) block specific.
6. Uniformity trial harvesting is by
  - a) individual row.
  - b) plot,
  - c) block.
  - d) machine.
7. The field variation in the pearl millet uniformity trial was
  - a) across the field.
  - b) erratic,
  - c) gradually decreasing.
  - d) gradually increasing.
8. The differences in a field's variation may be reduced by growing
  - a) a cereal.
  - b) a legume,
  - c) a cereal followed by a legume.
  - d) any crop.
9. An appropriate plot size is identified when the treatment differences are
  - a) not significant.
  - b) significant at 5%.
  - c) significant only at 1%.
  - d) significant at 0.1%.
10. The plot size identified by the uniformity trial is considered acceptable if the
  - a) coefficient of variation is high.
  - b) covariance is high.
  - c) coefficient of variation is low.
  - d) covariance is low.

11. The best plot size in this pearl millet uniformity trial was
- a) 9 m x 6 m.
  - b) 3 m x 6 m.
  - c) 3 m x 3 m.
  - d) 6 m x 6 m.

## MP 2. Sampling for Soil Testing

1. The tools required for taking soil sample are
- a) test tube, auger, and calculator.
  - b) containers, sampling tube, and roller.
  - c) spade, containers, and auger.
  - d) sampling tube, spade, and containers.
2. Prior to the sampling of soil in a field it is necessary to identify the
- a) location, implements used, and crop grown.
  - b) distance from road, area, and fertilizers used.
  - c) date of sowing, seed rate, and duration of crop.
  - d) pattern of cropping, fertilizers used, and past treatment.
3. The field is divided into uniform areas having the same
- a) soil color, soil texture, and cropping history.
  - b) fertilizer, seed rate, and pesticide.
  - c) intercultivation, weeding, and fertilizer.
  - d) elevation, slope, and cropping history.
4. The number of samples to be taken in a 0.5 ha field is
- a) 5.
  - b) 10.
  - c) 3.
  - d) 2.
5. The amount of soil sample to be collected should be equal to a
- a) 50 cm depth.
  - b) 100 cm depth,
  - c) 200 cm depth.
  - d) plow or cultivation depth.
6. The sampling of soil is done \_\_\_\_\_ to the direction of cultural operation.
- a) perpendicular
  - b) parallel
  - c) diagonal
  - d) criss-cross
7. The sampling of soil in a sloping field is done in a
- a) straight line.
  - b) zig-zag path,
  - c) circular way.
  - d) criss-cross method.
8. The mixed soil sample should be dried in the
- a) air.
  - b) sun.
  - c) oven.
  - d) thermostat.
9. The amount of soil to be sent to the laboratory is
- a) 4 L.
  - b) 2 L.
  - c) 1 L.
  - d) 1 L.

10. The sub soil samples are taken in the
- |                       |                  |
|-----------------------|------------------|
| a) low calcium soils. | b) saline soils, |
| c) peat soils.        | d) acid soils.   |

### MP 3. Seed Calibration

Given : 1 ha = 10 000 m<sup>2</sup>. Plot size = 12 m<sup>2</sup>. Area row<sup>-1</sup> = 3 m<sup>2</sup>

Required population = 180 000 ha<sup>-1</sup>  
 Seed mass of pearl millet = 9 g 1000<sup>-1</sup>  
 Germination = 85%. Over sowing = 25%.

- Seed required to sow 1 ha is
 

a) 3.4 kg.	b) 4.4 kg.
c) 1.4 kg.	d) 2.4 kg.
- The seed required to sow one plot is
 

a) 18 g.	b) 38 g.
c) 48 g.	d) 28 g.
- The seed required to sow one row is
 

a) 0.7 g.	b) 2.7 g.
c) 1.7 g.	d) 3.7 g.

Given: Area of the field - 1.25 ha, plot size = 15 m<sup>2</sup>,  
 area row<sup>1</sup> = 3.75 m<sup>2</sup>, required population = 150 000 plants  
 ha<sup>-1</sup>, over sowing = 50%, 1000 seed mass = 10.2 g, and  
 germination = 92%.

- The seed required to sow the field is
 

a) 1.49 kg.	b) 3.49 kg.
c) 2.49 kg.	d) 4.49 kg.
- The seed required to sow one plot is
 

a) 1.73 g.	b) 2.73 g.
c) 4.73 g.	d) 3.73 g.
- The seed required to sow one row is
 

a) 3.93 g.	b) 0.93 g.
c) 1.93 g.	d) 2.93 g.

### MP 4. Density of Seed

- Given : 1000 seed mass = 11.7 g, volume of 1000 seed - 9.7 cm<sup>3</sup>.  
 The density of the seed is
 

a) 2.2 g cm <sup>-3</sup> .	b) 1.2 g cm <sup>-3</sup> .
c) 0.38 g cm <sup>-3</sup> .	d) 0.83 g cm <sup>-3</sup> .
- Given 1000 seed mass - 10.9 g, vol. of 1000 seed - 9.08 g.  
 The density of the seed is
 

a) 0.83 g cm <sup>-3</sup> .	b) 2.10 g cm <sup>-3</sup> .
c) 1.20 g cm <sup>-3</sup> .	d) 1.83 g cm <sup>-3</sup> .



## MP 5. Plant Nutrient Role and Requirement

1. Carbon and oxygen are obtained by the plant from the
  - a) soil amendments.
  - b) fertilizer,
  - c) air and soil water.
  - d) atmosphere.
2. Iron and copper are taken up by the plant from the
  - a) air.
  - b) bacteria,
  - c) fungi.
  - d) soil.
3. Nutrients that are required in large quantities are
  - a) secondary nutrients.
  - b) micro nutrients,
  - c) major nutrients.
  - d) basic nutrients.
4. Nutrients that are needed in appreciable quantities are
  - a) major nutrients.
  - b) minor nutrients,
  - c) micro nutrients.
  - d) essential nutrients.
5. Nutrients that are required in very small quantities are
  - a) trace elements.
  - b) primary nutrients,
  - c) important nutrients.
  - d) secondary nutrients.
6. Primary nutrients are
  - a) manganese, copper, and iron.
  - b) magnesium, molybdenum, and zinc.
  - c) calcium, iron, and chlorine.
  - d) nitrogen, phosphorus, and potassium.
7. Secondary nutrients are
  - a) molybdenum, potassium, and zinc.
  - b) calcium, magnesium, and sulfur.
  - c) nitrogen, chlorine, and zinc.
  - d) copper, phosphorus, and boron.
8. Micro nutrients are
  - a) calcium, nitrogen, and potassium.
  - b) sulfur, phosphorus, and calcium.
  - c) zinc, copper, and boron.
  - d) nitrogen, magnesium, and potassium.
9. An important constituent of protein and nucleic acid is
  - a) molybdenum.
  - b) chlorine,
  - c) nitrogen.
  - d) copper.
10. The element that is needed for the synthesis of chlorophyll is
  - a) boron.
  - b) chlorine,
  - c) calcium.
  - d) iron.
11. An important constituent of cell walls is
  - a) zinc.
  - b) calcium,
  - c) sulfur.
  - d) molybdenum.





12. A key element in the chlorophyll molecule is
  - a) magnesium.
  - b) sulfur.
  - c) boron.
  - d) zinc.
13. An element that is involved in the biosynthesis of indole acetic acid is
  - a) sulfur.
  - b) iron.
  - c) zinc.
  - d) chlorine.
14. An element that promotes the formation of vitamin A is
  - a) nitrogen.
  - b) calcium,
  - c) magnesium.
  - d) copper.
15. An element that is associated with uptake and utilization of calcium is
  - a) chlorine.
  - b) magnesium.
  - c) iron.
  - d) boron.
16. An element that is associated with nitrogen utilization and fixation is
  - a) sulfur.
  - b) molybdenum.
  - c) copper.
  - d) iron.
17. An element that influences the water holding capacity of plant tissue is
  - a) zinc.
  - b) iron.
  - c) magnesium.
  - d) chlorine.
18. An element that promotes uptake and translocation of phosphorus is
  - a) magnesium.
  - b) copper,
  - c) potassium.
  - d) calcium.
19. An element that enhances disease resistance in plants is
  - a) calcium.
  - b) magnesium,
  - c) copper.
  - d) potassium.
20. The yellowing of older leaves, starting from tip to the base, indicates the deficiency of
  - a) chlorine.
  - b) zinc.
  - c) calcium.
  - d) nitrogen.
21. The grain yield of pearl millet that is expected to remove 40 kg nitrogen, 14 kg phosphorus and 49 kg potassium is
  - a) 500 kg ha<sup>-1</sup>.
  - b) 1500 kg ha<sup>-1</sup>.
  - c) 2500 kg ha<sup>-1</sup>.
  - d) 3000 kg ha<sup>-1</sup>.
22. An element that is involved in the oxidation of carbohydrate to CO<sub>2</sub> and H<sub>2</sub>O is
  - a) manganese.
  - b) iron.
  - c) boron.
  - d) calcium.
23. An element that induces plumpness of seed and improves the quality of fruits is
  - a) potassium.
  - b) magnesium.
  - c) copper.
  - d) zinc.

24. Stunted plant growth and reduction in internode and leaf length results from a deficiency of
- a) chlorine.
  - b) iron.
  - c) sulfur.
  - d) phosphorus.

### MP 6. Fertilizer Calibration

1. Ammonium sulfate (AS) and single super phosphate (SSP) required for 1 ha to meet the 50-10-0 recommendation are
  - a) AS 150 Kg and SSP 143 kg ha<sup>-1</sup>.
  - b) AS 250 kg and SSP 243 kg ha<sup>-1</sup>.
  - c) AS 250 kg and SSP 143 kg ha<sup>-1</sup>.
  - d) AS 243 kg and SSP 243 kg ha<sup>-1</sup>.
2. Ammonium sulfate (AS) and single super phosphate (SSP) required to supply 80-17-0 for 1 ha are
  - a) AS 400 kg and SSP 242 kg ha<sup>-1</sup>.
  - b) AS 500 kg and SSP 302 kg ha<sup>-1</sup>.
  - c) AS 450 kg and SSP 280 kg ha<sup>-1</sup>.
  - d) AS 550 kg and SSP 350 kg ha<sup>-1</sup>.
3. Amounts of DAP and urea required for 1.5 ha at the recommended rate of 100-34-0 are
  - a) DAP 255 kg and urea 226 kg.
  - b) DAP 355 kg and urea 326 kg.
  - c) DAP 155 kg and urea 126 kg.
  - d) DAP 455 kg and urea 426 kg.
4. The amounts of DAP and urea required for 2.25 ha at the recommended rate of 60-10-0 are
  - a) DAP 230 kg and urea 139 kg.
  - b) DAP 430 kg and urea 239 kg.
  - c) DAP 330 kg and urea 339 kg.
  - d) DAP 130 kg and urea 439 kg.

### MP 7. Thinning

Given : 1 ha .. .. .10 000 m<sup>2</sup>  
 Required population .. 180 000 ha<sup>-1</sup>  
 Row width .. .. . 0.75 m

1. The number of seedlings to be found in a 2-m row is
  - a) 13.
  - b) 16.
  - c) 26.
  - d) 46.

Given: Required population .. 150 000 ha<sup>-1</sup>  
 Row width .. .. . 0.6 m

2. The number of seedlings found in a 4-m row is
  - a) 26.
  - b) 16.
  - c) 46.
  - d) 36.



## MP 8. Weed control

1. The proper time for manually removing weeds is
  - a) when weeds are 8 cm in height.
  - b) before weeds germinate.
  - c) just after weeds germinate.
  - d) when weeds are 15 cm in height.
2. The two pre-emergence herbicides which control weeds in a pearl millet field are
  - a) alachlor and simazine.
  - b) metolachlor and chlorprophan.
  - c) propham and trifluralin.
  - d) atrazine and propazine.
3. The amount of atrazine (70% a.i.) required to spray a 100 m<sup>2</sup> pearl millet plot at the rate of 0.5 kg a.i. ha<sup>-1</sup> is
  - a) 0.71 g.
  - b) 71 g.
  - c) 7.1 g.
  - d) 0.07 g.

## MP 9. Growth and Development of Pearl Millet

1. The grain filling stage in pearl millet is
  - a) GS<sub>0</sub>.
  - b) GS<sub>1</sub>.
  - c) GS<sub>2</sub>.
  - d) GS<sub>3</sub>.
2. The phase that is extended in the late varieties of pearl millet is
  - a) GS<sub>0</sub>.
  - b) GS<sub>1</sub>.
  - c) GS<sub>2</sub>.
  - d) GS<sub>3</sub>.
3. The start of flowering indicates the end of
  - a) GS<sub>0</sub>.
  - b) GS<sub>1</sub>.
  - c) GS<sub>2</sub>.
  - d) GS<sub>3</sub>.
4. The formation of a small dark layer of tissue in the hilar region of grain indicates
  - a) physiological maturity.
  - b) the soft dough stage.
  - c) the hard dough stage.
  - d) the milk stage.
5. The time taken from flowering to physiological maturity in pearl millet is \_\_\_\_\_ days.
  - a) 30-35
  - b) 10-15
  - c) 40-45
  - d) 20-25
6. The stage following the milk stage in pearl millet is the
  - a) boot stage.
  - b) soft dough stage,
  - c) flag leaf stage.
  - d) hard dough stage.
7. The durations of the three growth stages (GS<sub>1</sub>, GS<sub>2</sub>, and GS<sub>3</sub>) in Mil Zongo pearl millet are \_\_\_\_\_ days.
  - a) 28, 25, and 22
  - b) 38, 35, and 32
  - c) 18, 15, and 12
  - d) 48, 45, and 42

8. At Hyderabad the west Africa landraces take \_\_\_\_\_ days to reach panicle initiation after emergence.
  - a) 80-120
  - b) 130-140
  - c) 40-50
  - d) 20-30
9. Day length affects the time to \_\_\_\_\_ in pearl millet.
  - a) grain hardening
  - b) flowering
  - c) grain filling
  - d) panicle initiation
10. Temperatures affect the duration of \_\_\_\_\_ in pearl millet.
  - a) tiller formation
  - b) root development
  - c) panicle emergence
  - d) grain filling

## MP 10. Characters and Field Note Codes

1. The characters that are recorded at panicle emergence in pearl millet are
  - a) internode number, bristle length, and stem diameter.
  - b) height, leaf number, and senescence.
  - c) seed size, shape, and color.
  - d) leaf angle, leaf color, and sheath color.
2. Characters that are recorded at the dough stage in pearl millet are
  - a) leaf number and senescence.
  - b) seed shape and size.
  - c) juice type of stem and node pigmentation.
  - d) endosperm color and texture.
3. Characters that are recorded at maturity in pearl millet are
  - a) color of bristles and bristle length.
  - b) dry mass of earheads and mass of grain.
  - c) node pubescence and 50% bloom.
  - d) earhead length and width.
4. Characters that are recorded at the post harvest stage in pearl millet are
  - a) seed size, shape, and color.
  - b) bristle color, length, and plant height.
  - c) 1000 grain mass, volume, and density of seed.
  - d) lodging, drought, and tiller number.
5. Scoring for rust in pearl millet is done at the
  - a) dough stage.
  - b) maturity stage.
  - c) flowering stage.
  - d) harvest stage.
- e. The scoring for downy mildew, smut, and ergot in pearl millet is done at the
  - a) maturity stage.
  - b) head emergence stage.
  - c) post harvest stage.
  - d) dough stage.
7. The grain quality in pearl millet is evaluated at the
  - a) harvest stage.
  - b) post harvest stage.
  - c) maturity stage.
  - d) dough stage.



8. Leaf senescence is recorded in pearl millet at the  
a) dough stage. b) maturity stage.  
c) flowering stage. d) harvest stage.
9. Endosperm characters are recorded in pearl millet at the  
a) post harvest stage. b) maturity stage,  
c) harvest stage. d) dough stage.
10. The disease caused by *Claveiceps fusiformis* (Lov) is  
a) downy mildew. b) rust.  
c) smut. d) ergot.
11. Days to 50% bloom in pearl millet are recorded when 50% of the plants reach  
a) 50% anther emergence. b) 50% spikelet emergence.  
c) 50% earhead emergence. d) 50% stigma emergence.
12. Scoring for rust in pearl millet is done by assessing the disease on the  
a) top leaves. b) middle two leaves.  
c) top four leaves. d) bottom three leaves.
13. The diameter of the stem in pearl millet is recorded at the  
a) top internode.  
b) third internode from the bottom.  
c) third internode from the top.  
d) bottom internode.
14. The leaf area in pearl millet is calculated by multiplying the product of length and breadth by the factor  
a) 0.8236. b) 7.2360.  
c) 1.7236. d) 0.7236.
15. The elliptical, hexagonal, and globular shapes in pearl millet refers to the \_\_\_\_\_ descriptor.  
a) leaf b) earhead  
c) seed d) spikelet
16. The colors gray, deep gray, and gray brown in pearl millet refer to the \_\_\_\_\_ descriptor.  
a) leaf sheath b) seed  
c) anther d) internode
17. The spindle, club, and candle shapes in pearl millet refer to the \_\_\_\_\_ descriptor.  
a) node b) earhead  
c) peduncle d) spikelet
18. The flag leaf is the  
a) bottom leaf. b) third leaf from the top.  
c) third leaf from bottom. d) top leaf.

19. The corneous character in pearl millet refers to the \_\_\_\_\_ descriptor.
- |              |              |
|--------------|--------------|
| a) internode | b) leaf      |
| c) earhead   | d) endosperm |
20. The mass of 1000 grain is recorded at \_\_\_\_\_ % seed moisture.
- |       |       |
|-------|-------|
| a) 7  | b) 12 |
| c) 15 | d) 20 |

## MP 11. Shoot fly

1. The eggs of shoot fly are laid in
- |             |             |
|-------------|-------------|
| a) threes.  | b) doubles. |
| c) singles. | d) groups.  |
2. The larval period of shoot fly extends from
- |                |                |
|----------------|----------------|
| a) 2-4 days.   | b) 7-8 days.   |
| c) 17-19 days. | d) 20-22 days. |
3. The shoot flies are introduced into the screening cage \_\_\_\_\_ days after seedling emergence.
- |          |          |
|----------|----------|
| a) 1-2   | b) 17-20 |
| c) 20-25 | d) 7-10  |
4. When different varieties are sown in a shoot fly screening cage, the arrangement is
- |                     |                     |
|---------------------|---------------------|
| a) specific choice. | b) multiple choice. |
| c) straight choice. | d) no choice.       |
5. When a single variety is sown in the shoot fly screening cage, the arrangement is
- |                     |                     |
|---------------------|---------------------|
| a) specific choice. | b) indirect choice. |
| c) multiple choice. | d) no choice.       |
6. The monitoring of a shoot fly population can be done with a
- |                      |                    |
|----------------------|--------------------|
| a) fish-meal trap.   | b) light trap.     |
| c) black-light trap. | d) pheromone trap. |
7. The screening of test material is conducted when the shoot fly population is
- |              |               |
|--------------|---------------|
| a) low.      | b) very high. |
| c) very low. | d) moderate.  |
8. The infester row is sown with a variety which is
- |               |                   |
|---------------|-------------------|
| a) resistant. | b) high yielding. |
| c) popular.   | d) susceptible.   |
9. The infester row is sown \_\_\_\_\_ days before sowing test materials.
- |       |       |
|-------|-------|
| a) 10 | b) 5  |
| c) 50 | d) 20 |



10. The pupation of the spotted stem borer is
  - a) on the leaf sheath.
  - b) on the leaf lamina.
  - c) inside the stem.
  - d) on the nodes.
11. The color of the *Sesemia* stem borer eggs is
  - a) red.
  - b) creamy.
  - c) brown.
  - d) blue.
12. The inatar stage at which *Sesemia* stem borer starts cutting the main stem is
  - a) 1st.
  - b) 2nd.
  - c) 3rd.
  - d) 5th.
13. The color of fully grown larvae of *Sesemia inferens* is
  - a) pink.
  - b) white,
  - c) cream.
  - d) brown.
14. The eggs are laid by *Eldana* stem borer on the
  - a) roots.
  - b) leaf lamina,
  - c) internodes.
  - d) leaf sheath.
15. The young larvae of *Eldana* stem borer cause damage to the
  - a) leaf lamina.
  - b) roots,
  - c) internode.
  - d) midrib.
16. The pupal period of *Eldana* stem borer is
  - a) 8 - 13 days.
  - b) 2 - 3 days.
  - c) 15 - 20 days.
  - d) 21 - 25 days.
17. The larval period of the stem borer *Sesemia calamistris* is
  - a) 1 week.
  - b) 2 weeks.
  - c) 8 weeks.
  - d) 15 weeks.
18. The pupal period of *Sesemia calamistris* is
  - a) 10 days.
  - b) 2 days.
  - c) 15 days.
  - d) 20 days.
19. The seed that is mixed and applied with larvae in the "Bazooka" applicator is
  - a) pearl millet.
  - b) poppy.
  - c) sorghum.
  - d) pigeonpea.
20. The number of larvae that is placed on the plant with each application by the "Bazooka" applicator is
  - a) 7.
  - b) 17.
  - c) 27.
  - d) 2.
21. The number of plants one can infest in 30 min to 40 min with the "Bazooka" applicator is
  - a) 10.
  - b) 100.
  - c) 1000.
  - d) 10 000.
22. The number of females that will provide larvae to screen 100 entries in 2 replications is
  - a) 14.
  - b) 44.
  - c) 84.
  - d) 184.





23. Monitoring of the intensity of the moth population in a hot spot is done with a
  - a) fish-meal trap.
  - b) pheromone trap.
  - c) sticky trap.
  - d) water trap.
24. The indicator row in a stem borer screening nursery is sown with a variety which is
  - a) resistant.
  - b) high yielding.
  - c) early maturing.
  - d) susceptible.
25. It is desirable that the indicator rows in a stem borer screening nursery should show a minimum of \_\_\_\_\_ % stem borer damage for the infestation level to be adequate for a good test,
  - a) 80
  - b) 60
  - c) 40
  - d) 20

### MP 13. Midge

1. The scientific name of the midge that infests pearl millet is
  - a) *Chilo partellus*.
  - b) *Calacoris aungustratus*.
  - c) *Mythimna separata*.
  - d) *Geromia penneseti*.
2. The pearl millet midge egg is
  - a) round.
  - b) obovate.
  - c) elongate.
  - d) oval.
3. The eggs are laid by the pearl millet midge
  - a) inside the spikelet.
  - b) in between two spikelets,
  - c) inside the floret.
  - d) in between two florets.
4. Pearl millet midge eggs hatch in \_\_\_\_\_ days.
  - a) 10
  - b) 6
  - c) 3
  - d) 2
5. Pearl millet midge larvae develop in \_\_\_\_\_ days.
  - a) 2
  - b) 8
  - c) 12
  - d) 18
6. The peak emergence of adults from pupa of pearl millet midge is
  - a) 1230.
  - b) 0630.
  - c) 1930.
  - d) 0930.
7. The development period from egg to an adult in the pearl millet midge is
  - a) 33 days.
  - b) 23 days.
  - c) 13 days.
  - d) 3 days.
8. The number of generations a pearl millet midge can make in a rainy season is
  - a) 14-15.
  - b) 1-2.
  - c) 10-20.
  - d) 4-5.
9. The maximum amount of diapause in pearl millet midge is
  - a) 2%.
  - b) 20%.
  - c) 10%.
  - d) 30%.
10. The artificial rearing of pearl millet midge is
  - a) very easy.
  - b) easy,
  - c) very difficult.
  - d) impossible.



11. The number of flies released in a head cage to screen for pearl millet for midge resistance is
  - a) four.
  - b) 14.
  - c) 40.
  - d) 10.
12. Head cages used in pearl millet midge screening are
  - a) dark-red.
  - b) light-yellow,
  - c) light-green.
  - d) dark-blue.
13. The fluid that oozes from the midge affected spikelet when pressed is
  - a) blue.
  - b) red.
  - c) green.
  - d) yellow.
14. The midge affected pearl millet spikelets will have
  - a) normal grain.
  - b) shrivelled grain,
  - c) bold grain.
  - d) no grain.

## MP 14. Other Pests

1. The scientific name of the army worm is
  - a) *Amsecta albistriga*.
  - b) *Mythimna separata*.
  - c) *Calacoria aunquatratrus*.
  - d) *Atherigona soccata*.
2. The eggs of army worm are laid in
  - a) doubles.
  - b) batches,
  - c) threes.
  - d) singles.
3. The army worm larva period lasts for \_\_\_\_\_ days.
  - a) 4-12
  - b) 2-10
  - c) 24-32
  - d) 14-22
4. The adult army worm survives \_\_\_\_\_ days.
  - a) 4-5
  - b) 10-11
  - c) 14-20
  - d) 1-2
5. Army worm larvae feeds during
  - a) morning hours.
  - b) noon.
  - c) the afternoon.
  - d) the night.
6. The age to infest pearl millet seedlings with larvae to screen them for army worm resistance is
  - a) 5-10 days.
  - b) 30-35 days.
  - b) 25-30 days.
  - d) 15-20 days.
7. The number of 1st-instar larvae to be applied to each plant in army worm screening is
  - a) five.
  - b) 10.
  - c) 15.
  - d) one.
8. The number of 3rd-instar larvae to be applied in army worm screening is
  - a) eight.
  - b) one.
  - c) five.
  - d) 20.
9. The adults of blister beetles feed on the
  - a) leaves.
  - b) internodes.
  - c) roots.
  - d) inflorescences.







20. Given: Categories: 1, 2, 3, 4, and 5.  
Number of affected plants: 5, 6, 7, 8, and 9.  
The infection index is \_\_\_\_\_ %.
- a) 57                      b) 47                      c) 37                      d) 27

### MP 16. Ergot (*Clveiceps fusiformis*)

1. The primary inoculum is prepared from the
  - a) honey dew.
  - b) sporangia,
  - c) sclerotia.
  - d) oospores.
2. The primary inoculum is sprayed on a/an
  - a) late maturing variety,
  - b) early maturing variety.
  - c) late maturing population.
  - d) early maturing hybrid.
3. The homogeneity of stylar emergence is in a
  - a) population.
  - b) hybrid,
  - c) land race.
  - d) composite.
4. The secondary inoculum is prepared with
  - a) oospores.
  - b) honey dew.
  - c) uredospores.
  - d) sclerotia.
5. The test plants should be bagged at the
  - a) boot stage.
  - b) milk stage.
  - c) flowering stage.
  - d) head-emergence stage.
6. The time after the boot stage for the stigmas to emerge is
  - a) 6-12 h.
  - b) 20-28 h.
  - c) 32-40 h.
  - d) 48-72 h.
7. The inoculum should be sprayed on the test material at
  - a) anther emergence.
  - b) the dough stage.
  - c) the boot stage.
  - d) stigma emergence.
8. Time taken for the development of honey dew after spraying the inoculum is
  - a) 1-2 days.
  - b) 16 days.
  - c) 10-12 days.
  - d) 5-6 days.
9. The bags are to be removed \_\_\_\_\_ days after the spraying the inoculum.
  - a) 5
  - b) 10
  - c) 15
  - d) 20
10. The bags on the inoculum-sprayed earheads are removed to
  - a) improve the grain filling.
  - b) avoid shattering of grain.
  - c) avoid discoloration of grain.
  - d) avoid mold development.
11. The honey dew on the inoculated heads develops into a
  - a) small grain.
  - b) sorus.
  - c) sclerotium.
  - d) bold grain.



**MP 17. Smut (*Tolyposporiwa pencillariae*)**

1. Smut inoculum is cultured on \_\_\_\_\_ medium,  
a) agar    b) potato-agar    c) potato    d) sugar
2. The pressure at which the medium is sterilized is \_\_\_\_\_ in<sup>-2</sup>.  
a) 10 lb    b) 15 lb    c) 20 lb    d) 50 lb
3. The chemical used for surface sterilization of sori is  
a) formaldehyde.    b) mercuric chloride,  
c) potassium permanganate.    d) iodine solution.
4. The inoculated petri plates are incubated at  
a) 35°C for 5 days.    b) 15°C for 15 days,  
c) 20°C for 20 days.    d) 10°C for 10 days.
5. The concentration of conidia in the inoculum is adjusted to  
a) 5 conidia mL<sup>-1</sup>.    b) 1 conidia mL<sup>-1</sup>.  
c) 2 conidia mL<sup>-1</sup>.    d) 10 conidia mL<sup>-1</sup>.
6. The appliance used to adjust the concentration of conidia is a  
a) hygograph.    b) hygrometer,  
c) hemacytometer.    d) hydroscope.
7. The mycelium that is produced by the union of +ve and -ve sporidia is the  
a) diadelphous.    b) dichlamydeous.  
c) dicaryotic.    d) dimorphic.
8. The ovary of the smut affected spikelet is converted into a  
a) sclerotium.    b) sporangium,  
c) pustule.    d) sorus.
9. The smut inoculum is injected into the  
a) leaf sheath.    b) internode.  
c) boot.    d) node.
10. The relative humidity to be maintained in the smut screening nursery is  
a) 20%.    b) 30%.    c) 40%.    d) 80%.
11. It requires \_\_\_\_\_ days for the first appearance of green sori after inoculation.  
a) 2    b) 6    c) 24    d) 12
12. Scoring for smut incidence is done \_\_\_\_\_ days after inoculation,  
a) 2-5    b) 20-25    c) 5-10    d) 40-45
13. The chain like structures that are formed with the union of +ve and -ve sporidia in a 90 day-old inoculum are  
a) oospores.    b) sporangia.  
c) teliospores.    d) sporidiospores.

14. The structures that are formed from intercalary or terminal positions of dicaryotic chains are
- a) uredospores.
  - b) oospores.
  - c) chlamydospores.
  - d) sclerotia.

## MP 18. Fungal, Bacterial, and Viral Diseases

1. The scientific name of rust on pearl millet is
- a) *Puccinia graminicola*.
  - b) *Puccinia penniseti*.
  - c) *Fusarium moniliforme*.
  - d) *Piricularia aetariae*.
2. The reddish-brown spores formed in the early stages of rust incidence are
- a) sclerotia.
  - b) teliospores.
  - c) oospores.
  - d) uredospores.
3. The dark-brown spores found in the aged leaves affected by rust are
- a) teliospores.
  - b) uredospores.
  - c) sporangia.
  - d) sporidia.
4. The ~~middle two~~ leaves are assessed for rust infestation.
- a) middle two.
  - b) bottom four.
  - c) top four.
  - d) top two.
5. The scientific name of leaf blast is
- a) *Pyricularia setariae*.
  - b) *Cercospora fusimaculans*.
  - c) *Puccinia penniseti*.
  - d) *Xanthomonas* sp.
6. The shape of the leaf blast lesion is
- a) oblong.
  - b) oval.
  - c) circular.
  - d) rectangular.
7. The leaf blast lesion has a
- a) yellow margin and brown center.
  - b) red margin and yellow center.
  - c) dark-brown margin and light-colored center.
  - d) light-brown margin and dark-brown center
8. The scientific name of zonate leaf spot is
- a) *Helminthosporium stenospilum*.
  - b) *Curvularia lunata*.
  - c) *Gloeocereospora* sp.
  - d) *Fusarium moniliforme*.
9. The lesions of zonate leaf spot have
- a) concentric bands.
  - b) rectangular blocks.
  - c) square blocks.
  - d) linear stripes.
10. The structures found on zonate leaf spot lesions are
- a) brown pustules.
  - b) yellow oospores.
  - c) black sclerotia.
  - d) brown uredospores.





11. The presence of folded arches formed with unfolded leaves is a symptom of the disease
  - a) pokkah boeng.
  - b) smut.
  - c) leaf blast.
  - d) zonate leaf spot.
12. The lesion of *Curvularia* leaf blight has a
  - a) yellow spot with brown margin.
  - b) straw spot with red margin.
  - c) light-brown spot with brown margin.
  - d) dirty-brown spot with yellow margin.
13. The *Helminthosporium* leaf spot occurs mostly at the \_\_\_\_\_ stage in pearl millet.
  - a) boot
  - b) milk
  - c) seedling
  - d) dough
14. The disease, causing circular brown spots with white centers and a yellow halo on the leaves is
  - a) pokkah boeng.
  - b) zonate leaf spot.
  - c) leaf blast.
  - d) *Cercospora* leaf spot.
15. The disease caused by the *Xanthomonas* sp. is
  - a) *Cercospora* leaf spot.
  - b) bacterial leaf spot,
  - c) rust.
  - d) *Curvularia* leaf blight.
16. The chocolate-brown lesions, without halo, are caused by
  - a) zonate leaf spot.
  - b) *Helminthosporium* leaf spot.
  - c) leaf blast.
  - d) bacterial leaf spot.
17. The mosaic-like symptoms are caused by the \_\_\_\_\_
  - a) smut
  - b) sugarcane mosaic
  - c) rust
  - d) *Curvularia* leaf spot
18. The vector which is transmitting the sugarcane mosaic virus is
  - a) earhead bug.
  - b) shoot bug.
  - c) stem borer.
  - d) shoot fly.
19. The nematode, *Hemocylophora paradoxa*, is attracted by the pearl millet
  - a) leaves.
  - b) root exudates.
  - c) anthers.
  - d) grain.
20. The nematode on pearl millet is controlled by
  - a) intercultivation.
  - b) deep plowing,
  - c) intercropping.
  - d) crop rotation.
21. Broad yellow bands on the leaves are the symptoms of \_\_\_\_\_
  - a) leaf blast
  - b) bacterial leaf spot
  - c) sugarcane mosaic
  - d) pokkah boeng
22. The lesions of leaf blast which will develop under humid conditions are
  - a) light-grey conidiospores.
  - b) reddish-brown uredospores.
  - c) dark-brown teliospores.
  - d) black sclerotia.



10. A single *Striga* plant can produce \_\_\_\_\_ thousand seeds.  
a) 40-50                      b) 1-2                      c) 100-200                      d) 300-400.
11. The *Striga* seed retains viability for \_\_\_\_\_ years.  
a) 2                      b) 20                      c) 10                      d) 50
12. The \_\_\_\_\_ is a standardized screening technique used to identify the genotypes resistant to *Striga*.  
a) single-pot                      b) multiple-pot  
c) double-pot                      d) treble-pot
13. The *Striga* resistant genotype is selected based on the  
a) high nutrient absorption.                      b) high stimulant production.  
c) low moisture absorption.                      d) low stimulant production.
14. The *Striga* seed is sterilized with  
a) 2% sodium chloride.                      b) 1% sodium hypochlorite.  
c) 2% ferrous sulfate.                      d) 1% sodium bicarbonate.
15. The age of test material seedlings at which the root exudate are extracted in the *Striga* screening is  
a) one week.                      b) 2 weeks.  
c) 10 weeks.                      d) 4 weeks.
16. The filter paper used for *Striga* seed germination is  
a) glass fiber filter paper.                      b) cellulose filter paper.  
c) rough filter paper.                      d) smooth filter paper.
17. The sterilized *Striga* seed is incubated \_\_\_\_\_ days.  
a) 1-2                      b) 4-5                      c) 10-12                      d) 20-24
18. The temperature at which the sterilized *Striga* seeds are incubated is  
a) 50°C.                      b) 40°C.                      c) 15°C.                      d) 25°C.
19. The temperature and incubation period used for the exudate-treated *Striga* seed is  
a) 10°C, for 10 h.                      b) 33°C, for 24 h.  
c) 50°C, for 40 h.                      d) 20°C, for 48 h.
20. The \_\_\_\_\_ is used to measure the exudate in *Striga* screening.  
a) burette                      b) pipette  
c) micropipette                      d) microdosimeter.

## MP 20. Field screening for resistance to *Striga* spp

1. The screening for *Striga* resistance is carried in a  
a) fertile field.                      b) irrigated field.  
c) striga sick field.                      d) disinfected field.
2. The field chosen for the *Striga* resistance screening should be  
a) high in fertility.                      b) very high in fertility.  
c) medium in fertility.                      d) low in fertility.

3. The preparatory cultivation given to a *Striga* resistance screening nursery should be
  - a) extensive.
  - b) zero.
  - c) minimal.
  - d) moderate.
4. The amount of N that should be applied to the *Striga*-screening nursery is up to \_\_\_\_\_ ha<sup>-1</sup>.
  - a) 20
  - b) 60
  - c) 40
  - d) 80
5. The test material is sown a \_\_\_\_\_ the *Striga* infestation.
  - a) fortnight before
  - b) week before
  - c) month before
  - d) fortnight after
6. The kg N ha<sup>-1</sup> that can be applied to the *Striga*-screening nursery is
  - a) very high.
  - b) high.
  - c) low.
  - d) nil.
7. The intercultivation that is given to the *Striga*-screening nursery is
  - a) minimal.
  - b) nil.
  - c) moderate.
  - d) intensive.
8. Thinning and weeding in the *Striga*-screening nursery is done
  - a) after the *Striga* emerges.
  - b) before the *Striga* emerges.
  - c) just when *Striga* is emerging.
  - d) when *Striga* is flowering.
9. The sowing of a susceptible variety at frequent intervals in a *Striga*-screening nursery is in a
  - a) lattice design.
  - b) latin-square design.
  - c) split-plot design.
  - d) augmented design.
10. The design that has susceptible checks on all the four sides of the test entry in a *Striga*-screening nursery appears like
  - a) a checkered board.
  - b) a lattice design.
  - c) a latin square.
  - d) a split plot.
11. The plot in a *Striga*-screening nursery has \_\_\_\_\_ of each variety.
  - a) a single row
  - b) four rows
  - c) two rows
  - d) three rows
12. The entries in a preliminary trial are tested in a
  - a) split-plot design.
  - b) split-split-plot design.
  - c) observation plot.
  - d) replicated trial.
13. The advanced *Striga*-screening nursery is sown in
  - a) alternate plots.
  - b) an ABBA design.
  - c) an observation plot.
  - d) a checkered board pattern.
14. The reaction of test entries is expressed as percentage of *Striga* plants in the test entries to those in
  - a) the whole experiment.
  - b) each replication.
  - c) the positional check.
  - d) the resistant entries.

15. The average *Striga* count of the four susceptible check plots (around the test entry) is the  
 a) stable check average.                      b) sustainable check average.  
 c) unstable check average.                    d) positional check average.
16. The test entry is considered to be resistant when the *Striga* incidence in the test entry is \_\_\_\_\_ % of the incidence in the positional check.  
 a) 2    b) 20    c) 30    d) 10

**Correct responses to the questions**

**MP 1. Uniformty Trial**

1. d); 2. b); 3. d); 4. d); 5. b); 6. a); 7. b); 8. c);  
 9. a); 10. c); 11. a).

**MP 2. Sampling for Soil Testing**

1. d); 2. d); 3. a); 4. b); 5. d); 6. d); 7. b); 8. a); 9.  
 c); 10. b).

**MP 3. Seed Calibration**

1. d); 2. d); 3. a); 4. c); 5. d); 6. b).

**MP 4. Density of Seed**

1. b); 2. c).

**MP 5. Plant Nutrients Role and Requirements**

1. c); 2. d); 3. c); 4. b); 5. a); 6. d); 7. b); 8) c); 9.  
 c); 10. d); 11. b); 12. a); 13. c); 14. d); 15. d); 16. b);  
 17. d); 18. a); 19. d); 20. d); 21. b); 22. a); 23. a); 24.  
 d).

**MP 6. Fertilizer Calibration**

1. c); 2. a); 3. a); 4. d).

**MP 7. Thinning**

1. c); 2. d).

**MP 8. Weed Control**

1. c); 2. d); 3. c).

**MP 9. Growth and Development of Pearl Millet**

1. d); 2. c); 3. b); 4. a); 5. d); 6. b); 7. a); 8. a); 9.  
 d); 10. d).

**MP 10. Characters and Field Note Codes**

1. d); 2. c); 3. d); 4. c); 5. c); 6. b); 7. b); 8. b); 9.  
 a); 10. d); 11. d); 12. c); 13. c); 14. d); 15. c); 16. b);  
 17. b); 18. d); 19. d); 20. d).

**MP 11. Shoot Fly**

1. c); 2. b); 3. d); 4. b); 5. d); 6. a); 7. b); 8. d); 9.  
 d); 10. a); 11. c).

**MP 12. Steal Borer**

1. b); 2. a); 3. d); 4. a); 5. d); 6. b); 7. c); 8. d); 9. c); 10. c); 11. b); 12. d); 13. a); 14. b); 15. d); 16. a); 17. c); 18. a); 19. b); 20. a); 21. c); 22. c); 23. b); 24. d); 25. a).

**MP 13. Midge**

1. d); 2. c); 3. a); 4. d); 5. a); 6. c); 7. d); 8. d); 9. c); 10. c); 11. c); 12. d); 13. b); 14. d).

**MP 14. Other Pests**

1. b); 2. b); 3. d); 4. a); 5. d); 6. d); 7. a); 8. b); 9. d); 10. b); 11. c); 12. d); 13. c); 14. b); 15. d); 16. a); 17. d); 18. a); 19. c); 20. c); 21. a); 22. c); 23. b); 24. b); 25. b); 26. d); 27. c); 28. d); 29. b); 30. a).

**MP 15. Downy Mildew (*Sclerospora graminicola*)**

1. a); 2. a); 3. b); 4. d); 5. c); 6. b); 7. c); 8. d); 9. d); 10. a); 11. a); 12. c); 13. b); 14. a); 15. d). 16. b); 17. d); 18. c); 19. c); 20. a).

**MP 16. Ergot (*Claveiceps fusiformis*)**

1. c); 2. d); 3. b); 4. b); 5. a); 6. d); 7. d); 8. d); 9. a); 10. d); 11. c).

**MP 17. Saut (*Tolyposporium pencilariae*)**

1. b); 2. b); 3. b); 4. a); 5. d); 6. c); 7. c); 8. d); 9. c); 10. b); 11. d); 12. b); 13. d); 14. c).

**MP 18. Fungal, Bacterial and Viral Diseases**

1. b); 2. d); 3. a); 4. c); 5. a); 6. c); 7. c); 8. c); 9. a); 10. c); 11. a); 12. d); 13. c); 14. d); 15. b); 16. d); 17. b); 18. b); 19. b); 20. b); 21. c); 22. a); 23. c); 24. d); 25. b).

**MP 19. Laboratory Screening for Resistance to *Striga* sp.**

1. a); 2. c); 3. c); 4. b); 5. a); 6. d); 7. c); 8. d); 9. d); 10. a); 11. b); 12. c); 13. d)} 14. b); 15. a); 16. a); 17. c); 18. d); 19. b); 20. d).

**MP 20. Field Screening for Resistance to *Striga* spp.**

1. c); 2. d); 3. c); 4. a); 5. d); 6. d); 7. b); 8. b); 9. d); 10. a); 11. d); 12. d); 13. c); 14. c)} 15. d); 16. d).





