CENTRE D'ETUDE REGIONAL
POUR L'AMELIORATION DE L'ADAPTATION
A LA SECHERESSE

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GUIDELINES FOR A SCREENING TO IMPROVE PEAR MILLET PRODUCTION IN DRY AREAS.

ELEMENTS POUR LA MISE EN PLACE D'UN SCREENING POUR L'AMELIORATION DE LA PRODUCTION DU MIL EN ZONES SECHES.

R. KENGA
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Mission Report for the ROCAFREMI network.

April / 5-16 /1993.

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PREAMBULE

Drought stress is one of the major constraints to pearl millet production in West and Central Africa. The Project P_1 initiated by the **West and Central African Millet Research Network (ROCAFREMI)** aims to screen various accessions of pearl millet (local and improved varieties) for drought tolerance.

The Network has requested the help of C.E.R.A.A.S. a regional center for drought research to provide a technical assistance for elaboratihg an adapted research protocol. Richard Kenga therefore visited the center for ten days to elaborate the following document. This proposal gives general indications that could be used as basic guidelines for field screening. It does not deal with all physiological aspects of drought adaptation. The help of MM. D.Annerose and J.M.Lacape was greatly appreciated

INTRODUCTION

Pearl millet is one of important cereals in semiarid regions of sub-Sahara. Its production has decreased sharply. Rainfall variation and shortage during the cropping season has increased the frequency of drought occuring during panicle differentiation and grain-filling period. In addition, plants are not able to complete their cycle because of early termination of rains. Land race varieties which are supposed to be adapted to the changing environment have been consistently poor yielders. New varieties should have appropriate maturity cycle and possess various degrees of drought adaptation. These drought resistant varieties may limit yield losses. Drought is a complex problem and breeding for resistance merges many differents disciplines: climatology, physiology, agronomy and plant breeding. The deployment of physiological selection indices in a breeding program involves several considerations:

- A rapid and reliable physiologically based screening technique for large germplasm (breeding materiel & land race varieties) must be available. These physiological attributes have to bear proven relevance to stability of high yield production in the stress environment (Blum, 1985). It therefore emerges that selection for better and stable yield for drought prone environment should be built upon a genetically high yield potential crop having some drought resistance/tolerance characteristics.
- Techniques for screening or selecting for drought resistance within large germplasm must be rapid, fairly accurate and inexpensive (Winter, 1988).
- Adequate genetic diversity for response to drought stress must exist within the germplasm.
- The heritabilities of the traits selected as indicators of drought tolerance/resistance need to be high.
- Genetic variations in plant phenology must be accounted for by comparing genotypes of similar maturities.

DROUGHT CHARACTERIZATION OF THE REGION

Semi-arid regions of West Africa has been suffering severe crop yield losses due tu poor ditribution and/or reduced rainfall. Yield losses could be minimized if rainfall characteristics were established.

Rainfall characteristics in West Africa have been studied. But these studies do not provide information on rainfall partitioning and occurence of dry spells for each month of the season. A study of rainfall partitioning carried out by Nyanguila Muleba (1986) reveals that:

- In Northern Guinea savana of Burkina, rains are well distributed from July 15 to September 20; they are poorly distributed from the end of May to July 15. Thus drought is more likely to cause damage during flowering in September and grain filling period in late September to early October.
- In Sudanese savanna, rains are well distributed from mid-July to mid-September; from June 1st to mid-July and later September there is an increase of frequencies of dry spells. Crop calendar may not differ from Guinea savanna zone. However the poor distribution of rains in June, early July and fate September in sudanese zone indicates that crop varieties should be more drought resistant, particularly during vegetative and grain filling growth stages.
- In the Sahel, rains are poorly distributed throughout the cropping season. June up to midJuly and September are high drought risky periods. Eight to 10 days dry spells are frequent. The crop season is thus much shorter and requires the use of short cycle or more drought resistant (at all growth stages) crop varieties.

The characterization of rainfall or determination of ecological zones in each participating country would help define appropriate objectives and focus on specific drought.

DROUGHT RESISTANCE MECHANISMS IN PEARL MILLET

Various mechanisms of drought resistance have been described. These include drought escape, drought avoidance, and drought tolerance. They have been seldom applied to selection work.

A/ Drought escape

Drought escape is achieved by short growth duration. Early maturity invotves a reduction of evapotranspiration during growth stages. It is efficient where a water stress occurs during the latter half of the growing season (Blum, 1970). It does not involve any interaction with the stress environment. Thus screening or breeding for drought escape may focus on early maturity genotypes. Short cycle genotypes have reduced growth duration, reduced leaf area and thus use less water during the growth period (Blum and Arkin, 1984). They would retain a favorable leaf water status in stress condition.

Earliness is sometimes associated with reduction of yield potential, nevertheless stability under stress may be improved; thus to optimize yield potential the maturity cycle should be adjusted to the length of the rainy season.

B/ Drought avoidance

Dehydration avoidance is achieved by the maintenance of a higher turgor potential under a moisture stress, by maintenance of a higher leaf water potential or by osmotic adjustment. Osmotic adjustment reduces the stress experienced by cells for a given leaf water potential and retains more open stomata and gas exchange.

Dehydration avoidance and/or osmotic adjustment can be evaiuated under field stress conditions using several indirect methods (Rosenow et al., 1983 ,1986), these are:

Leaf rolling that is a response to water stress in some plants.

Leaf firing or various fonns of leaf necrosis : large sections of leaf die rapidly and usually at about flowering time. This is caused by high ieaf heating due to low transpiration.

Leaf bleaching that refers to as ioss in green color during the hottest portion of the day causing a bleached effect.

"Saddle effect" whereby plants at the center of the nursery row are shorter than the plants at its edges, which have border effect. Plant at the edges of the row serve as "less stressed" control within each genotype, the development of "saddle effect" is indicative of poor drought adaptation. This is more applicable to plants which are not able to maintain a high ievei of dehydration avoidance by stomatal sensitivity to water.

Delav in flowering: evaiuated by comparison with non stressed plants.

Poor panicule exertion and reduced panicle sire.

These criteria can well be used for peari millet drought screening program. The seiection for drought resistance in terms of dehydration avoidance and/or osmotic adjustment can be carried out oniy under drought stress condition.

C/ Drought Tolerance

Dehydration tolerance is expressed in the abiiity to sustain the least injury to essential life process under water stress.

Injury to the cellular membranes has been taken by many scientists as a measure of susceptibility to various stresses (heat, freezing, salinity). The understanding of dehydration tolerance in terms of cellular reaction is in progress, but is yet remote, especiaily for practical breeding or screening for stress tolerance.

DIFFERENT STAGES OF GROWTH AND STRESS SYMPTOMS

Considering the limit of available information, dehydration avoidance appears to be the most effective component of drought resistance in sorghun and pearl millet. Once adequate phenology growth stages has been determined, dehydration avoidance can be screened for by several methods.

Three important phenologically distinct growth stages are recognized in pearl millet as they relate to drought stress. Seedling establishment, mid-season (from panicle differentiation to flowering) and the grain filling period. In the region, droughts occuring in mid-season and grain filling periods are the most damaging. The approach taken to a pratical drought screening program is essentially the same for ail the 2 stages (Peacock J.M. and al., 1986). High level of tolerance for both types of stress are not usually found in the same genotype; some genotypes may however possess acceptable level of tolerance in both types.

Although a number of physiological measurements have been reported, only those which showed differences between the visually identified susceptible and resistant lines can be rated in the field.

A/ Symptoms Indicating mid-season or pre-flowering stress

- Leaf rolling
- Leaf bleaching
- Leaf tip and margin bum

These symptoms can easily be scored using a 1 to 5 scale were 1= less than 20% damage and 5 = over 80%. In other words, score less than 3 = "resistant". Rating can be made separately, but often combined into simple overall drought susceptibility rating. Others symptoms are:

- Delayed flowering: Flowering notes should be taken on all plots and comparison made only among entries of similar maturities
- Poof panicle exeftion
- Saddte effect
- Panicle blasting and floret abortion

In order to develop a reliable data set, scoring should be done periodically during stress development.

B/ Symptoms occuring during grain filling or late season drought

- Premature (leaf or stem) death
- Lodging
- Stalk collapse
- Reduction in seed size

A scale of 1 to 5 can also be used to rate each symptoms. Rating are normally made at/or soon after physiologicai maturity. But can also be made when differences appear among genotypes. Percentage (%) of plant iodging due to stress may be noted.

APPROACHES AND DESIGN

Two designs can easiiy be used to evaiuate the drought response of peari millet in the field :

1- Plastic tarpaulin during normal cropping season,

2- Sprinkler irrigation in the off season.

1- Selection under naturally occuring drought condition. Large amount of diverse germplasm may be evaiuated in field screening nurseries at several locations having different stress environments, different water regimes. This approach helps to insure stress at different stages of growth. However in the natural semiarid environment iow rainfall is characterized by very high variation in spatial distribution. Under such conditions, stress shouid be controlled. Crop are allowed to growth up to the stage at which the stress must be imposed, and large black plastic tarpaulin are used to cover all stressed plots at surface ievel.

2- Duplicate nurseries are evaluated during off season under irrigation where yield potentiai is expressed. Regulation of moisture stress at different growth stages is essential for significant progress.

- Two treatments are made, one drought stressed and one irrigated control arranged in a randomired block design with two replications.

To ensure uniform establishement, both treatments should be irrigated with sprinklers approximately every week until 20 to 29 days after sowing (the frequency may be increased to match the increasing evaporation demand). There-after, irrigation should be discontinued to impose mid-season stress. The stress can last for a period of 60 days or up to flowering period, there-after the material can receive water and be scored for recovery abiiity. For post-flowering stress, irrigation is terminated at flowering (when stigmas has emerged on 50% of ail main-shoot inflorescences), which ailows moisture stress to develop 'beginning near the grain-filling period.

The control treatment may be irrigated at weekiy intervals throughout the season.

N.B.

irrigation can introduce large spatial errors into the nursery when low rates are used. Surface irrigation is not an appropriate method in this respect. Sprinkler irrigation when properly designed and applied is the least erratic method. The "line-source" sprinkler irrigation system appear to be the most effective in revealing genetic variations in drought X varieties interactions.

EXPERIMENT MANAGEMENT

Five repiications of 6 plots (3 in the stress treatment and 3 in the controi) will give a total of 30 plots.

- Plot size : 4 lines of 5 m long, 0.80 m between iines and 0.40 m between plants.
- The final thinning is done at 2 plants/hole.
- Fertiiizer : normal basal dressing of N P K is applied before sowing and top dressing with urea is applied after thinning.
- Additional data which shouid be considered are: grain yieid, 1000 grain weight, panicie weight, dry matter weight, number of panicie, number of plant, time to flowering.

To further assess cuftivars drought susceptibiiity, an index of drought susceptibiiity (Bidinger et al., 1987) may be calculated. it is based on the assumption that the grain yield of i^{th} genotype under stress conditions (Y_{si}) is a function of potential yield under irrigated condition (Y_{pi}), time of flowering (FI_i) and a drought response (DR_i), and E for the random error.

$$Y_{si} = a + bY_{pi} + cFL_i + DR_i + E$$

The modified equation of Fisher and Maurer (1978) can also be used :

$$S = (1-Y_d/Y_1) / D$$

- S = drought susceptibiiity index
- Y_d = yield with drought stress
- Y_1 = yield irrigated
- D = environment index

Larger values of the index indicate greater drought susceptibiiity.

OBSERVATIONS

- Selection for drought resistance requires a rigorous control over the stress and site homogeneity.
- Selection can be carried out in the field. It is important therefore to be familiar with the normal rainfall pattern, so that the effect of moisture stress would not be confused.
- Selection materials should be evaluated under both stress and nonstress conditions.
- It is important to be able to recognize the various drought responses at each Stage of growth.
- At the final stage of the program, multiple location testing (accross all countries involved in the project) is critical in order to evaluate the results in terms of yield performance of the few selected lines. The design should be a randomized complete block (RCBD) with 3 or 4 replicates.

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