4.6 Field Screening for Drought Tolerance in Groundnut

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Drought is a major abiotic stress affecting yield and quality of rainfed groundnut worldwide. Yield losses due to drought are highly variable in nature depending on its timing, intensity, and duration, coupled with other location-specific environmental factors such as irradiance and temperature. The effects of drought on groundnut are manifested in several ways, affecting both quantity and quality of the crop. Water deficits, depending on the timing of occurrence, can cause significant reduction in yield by affecting physiological processes such as nitrogen fixation, photosynthesis, and calcium uptake by developing pods. The end-of-season drought can predispose the crop to aflatoxin contamination, which can severely affects the economic value of the crop. The importance of genetic enhancement for improved adaptation to water-limited conditions and efficient water use has long been recognized by ICRISAT.

Drought Patterns and Genetic Options

The extreme variability of the nature of drought has made it difficult to define plant attributes required for improved performance under drought, consequently limiting plant-breeding efforts to enhance drought tolerance in groundnut. The most frequently encountered drought patterns can be grouped into three types i.e., early-season drought, mid-season drought, and end-of-season drought. Genetic options for improvements in drought tolerance vary with most drought patterns experienced in a given environment.

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Early-Season Drought

Once the crop is established, early-season drought does not have much effect on groundnut. As a matter of fact, a 20–25 day moisture stress early in the season and its subsequent release by applying irrigation is encouraged, as it induces heavy and uniform flowering, leading to increased groundnut productivity.

Mid-Season Drought

Mid-season droughts affect the most vulnerable stages (pegging, and pod and seed development) of plant growth in groundnut. A poor relationship between the yield potential (achieved under adequate water availability) and the sensitivity of genotypes to mid-season drought suggested the possibility of identifying/or developing genotypes with high yield potential and relatively low sensitivity to mid-season droughts.

End-of-Season Drought

End-of-season drought affects the seed development most. It also predisposes the produce to aflatoxin contamination. Genotypic yield accounts for 90% of the variation in pod yield sensitivity to water deficit during the seed filling stage. Where the growing season is short and terminal drought predominates, matching of phenological development of a cultivar with the period of soil moisture availability is an important drought escape strategy to minimize the impact of drought stress on crop production. Using the concept of thermal time and staggered harvesting, ICRISAT has made considerable progress in shortening crop duration of groundnut without unduly penalizing realized yield. However, it is still necessary to screen genotypes in a given maturity group for tolerance to end-of-season drought because of two reasons: 1) to identify genotypes with reasonable pod yields and better vegetative growth (as groundnut haulms are valuable fodder in most semi-arid environments), and 2) to identify genotypes with resistance to *Aspergillus flavus* infection and aflatoxin production.

Development of Drought Genotypes at ICRISAT

Empirical Approach

Most of the drought tolerance breeding activity at ICRISAT Center, Patancheru, is conducted during the postrainy season (Nov–April), when there is least interference from the rains. ICRISAT adopted a holistic approach in screening and selecting groundnut genotypes with superior performance under two most critical droughts i.e., mid-season and end-of-season. For the development of genotypes with superior yield performance under drought conditions, germplasm and segregating populations are evaluated/selected in the postrainy season under simulated drought conditions. In addition, the advanced breeding lines are also evaluated under rainfed conditions in the rainy season (June–October).

Germplasm Screening

Using a line-source sprinkler irrigation system, germplasm lines are screened for early-season and mid-season drought in the field. Based on harvest index (HI) and biomass production, germplasm lines are selected for resistance to different kinds of drought. Several lines with superior performance under different kinds of drought (ICG# 3086, 3141, 2738, and 1163, and ICGV# 91151, 94127, 92209, and 91109 for mid-season drought; ICG 2213, ICGS 76, ICGV# 90226, 91074, 91185, 91192, 92004, 92022, 92023, 92028, 92029, and 92033 among others for end-of-season drought) are now available for use in breeding programs.

Development of Breeding Materials

Under imposed mid-season (withholding irrigation from 40–80 days after sowing) and end-of-season (withholding irrigation from 80 days after sowing until harvest) droughts, the selection in segregating populations is based on high pod and seed yields. In advanced breeding lines in replicated trials, yields under imposed drought conditions and normal (no moisture stress) conditions are considered. Following this approach, several drought-tolerant advanced breeding lines have been developed and distributed to national programs in the form of international drought tolerance groundnut varietal trials. Many of these lines have now been released as cultivars in different countries. In India, these include ICGS # 11, 37, 44, and 76, and ICG (FDRS) 10 and in Indonesia, ICGV 86021, released as Terapah.

Notwithstanding these success stories, the empirical approach to drought tolerance breeding remains resource-extensive and tardy. Because of larger genotype (G) × environment (E) interaction for seed yield in groundnut, its heritability is low. Unfortunately, the phenotypic model for yield provides little understanding of biological significance and reasons for G × E interactions. However, the empirical breeding approach continues because so far there are no tools to obtain better information about genotypic traits contributing to yield under drought conditions in a large-scale breeding program.

Physiological Approach

In recent years, there has been significant improvement in the understanding of the physiological basis of genotypic response to drought in groundnut. The traits contributing to superior performance under drought conditions in groundnut have been identified and substantial genetic variation observed in them. These include HI, total amount of water transpired (T), and transpiration efficiency (TE, defined as amount of dry matter produced per unit amount of water transpired). However, there are substantial difficulties in accurately measuring these physiological traits in the large numbers of plants/ populations needed for selection programs.

Earlier studies indicated that TE and HI were negatively correlated. However, a more strategic and comprehensive selection program, funded by the Australian Centre for International Agricultural Research (ACIAR), involving collaboration among Indian Council for Agricultural Research (ICAR), Queensland Department of Primary Industries (QDPI), and ICRISAT has been implemented to identify genotypes with high levels of the physiological traits in the vast germplasm pool at ICRISAT. These results suggested that the negative association between TE and HI, observed in earlier experiments, could be broken and there was scope for selecting for and combining TE and HI traits concurrently to improve yield performance. It was also apparent that high levels of at least two out of the three physiological traits were necessary for superior performance of a genotype. Interestingly, genotypes involving parents selected from drought screening at ICRISAT (e.g. ICGS# 44 and 76, ICGV# 86754, and 87354) had superior yield performance because of higher TE and HI or all the three traits, while for the other cultivars, the dominant contribution to the yield was from T and/or HI.

This analysis indicated scope for developing new cultivars by pyramiding the traits or identifying the deficient trait(s) in the popular cultivars so that the parental selection and genetic enhancement can be focused to improve levels of the deficient trait in the required agronomic background. It was interesting to note that the yield performance of some of these selected genotypes was superior even under irrigated conditions, suggesting that the physiological traits such as TE and HI could be used as selection criteria for crop improvement under irrigated conditions as well.

Use of Indirect Selection Tools

Recent studies have identified surrogate traits, such as carbon isotope discrimination in leaf (D) and specific leaf area (SLA), which are associated with TE in groundnut. Furthermore, SLA, which is a crude but easily measurable parameter, can be used as a rapid and inexpensive selection criterion for high TE.

Screening of groundnut germplasm for SLA indicated significant variability within and between taxonomic groups. It was interesting to note that the genotypes belonging to variety *hypogaea* (virginia bunch and runner types) had a lower mean SLA than those of variety *fastigiata* (Valencia and Spanish types) suggesting a likelihood of higher TE. However, the former had lower partitioning ability than the latter. There is new evidence that the groundnut genotypes having lower SLA (high TE) showed more stability in dry matter production under drought. It has recently been shown that a handheld portable SPAD chlorophyll meter can be used effectively following necessary protocols for rapid assessment of SLA and specific leaf nitrogen. This would facilitate screening of large numbers of segregating populations in the field.

An ongoing ACIAR-funded ICAR-QDPI-ICRISAT collaborative project is currently assessing the value of indirect selection tools in improving the efficiency of selection in large-scale groundnut breeding programs in India and Australia.