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Selection for Water-use Efficiency in Grain Legumes

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Report of a workshop held at ICRISAT Centre, Andhra Pradesh, India, 5–7 May 1993

Editors: G.C. Wright and R.C. Nageswara Rao

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Drought Research on Groundnut at ICRISAT Centre

R.C. Nageswara Rao*

DROUGHT research on groundnut conducted at ICRISAT Centre (IC) over the past decade can be grouped into three broad areas: screening and evaluation of genotypes for drought tolerance; strategic research on physiological mechanisms; and some applied research on drought management. Due to limitations of time, I wish to concentrate on progress made in the first two areas, which are relevant to the present workshop. Drought research in groundnut at IC began in 1980, with experiments to examine the timing of irrigation and plant population. Screening of genotypes for drought tolerance began after the 1981–82 post-rainy season.

Screening of Genotypes for Drought Tolerance

Drought is a complex syndrome involving three main factors — timing, intensity and durations — all of which vary widely in nature. The extreme variability in these environmental components between years and sites has made it difficult to define plant attributes required for improved performance under all drought situations. Selections of drought tolerant genotypes can be made by testing large numbers of genotypes in multiple seasons and locations, but this, together with selection procedures based on yield measurements at harvest, will be costly in terms of time and space. Therefore, in the long run, reliable indices for drought tolerance are needed to complement conventional improvement programs.

Philosophy

We adopted a holistic approach in selecting genotypes with drought tolerance. Initially, genotypes are evaluated on the basis of yield and total dry matter produced under simulated drought conditions in the field. The basic advantage in this approach is that the selection criteria integrate all the additive effects of many underlying mechanisms of drought tolerance. Secondly, the material identified as drought tolerant/susceptible is then examined for the physiological basis of genotypic differences in yield under drought conditions so as to identify physiological attribute(s) contributing to drought tolerance. It is recognised that this knowledge on physiological mechanisms can improve existing screening methods or permit development of new ones. The screening for single attributes is important, we believe, for the selection of complementary parents which may have different reasons for drought tolerance.

Screening Methodology

Drought screening experiments at IC are conducted mainly during the post-rainy season (Nov–Apr) to avoid interference from rains. In the early studies we investigated genotypic sensitivity to various patterns of drought (single and multiple droughts) and its relationship with yield potential (yield under non-stress conditions) in a range of groundnut genotypes. These results have shown that when water deficit occurred at seedfilling phase genotypic yield potential accounted for about 90% of the variations in pod yield sensitivity to drought (Nageswara Rao et al. 1989), suggesting lack of scope for combining yield potential with low sensitivity to acute droughts spanning seed-filling phase. However, pod yield potential accounted for less of the variation in drought sensitivity (15–60%) in early and mid-season drought, suggesting that for mid-season droughts it may be possible to identify genotypes with both high yield potential and relatively low sensitivity to drought. Currently, genotypes are screened for the two most predominant droughts, i.e., mid-season and terminal drought. A range of water deficits is created within a given drought treatment, using a line-source sprinkler system (Hanks et al. 1976). Genotypes are evaluated on the basis

Legumes Program, ICRISAT, Andhra Pradesh, India.

of total dry matter and pod yield produced across a range of water deficits relative to the mean of all entries in the experiment. (Nageswara Rao 1991; Singh et al. 1991).

Under mid-season drought conditions, recovery of growth when water becomes available plays an important role. Significant genotypic differences in rate of recovery from mid-season drought were found (Harris et al. 1988). Numbers of genotypes screened for drought tolerance at IC since 1981 are given in Table 1.

As a part of screening methodology, selected genotypes are further evaluated for their performance under rainfed conditions in drought-prone regions such as Anantapur in Andhra Pradesh, and through national and international drought nurseries conducted in collaboration with various national research systems (NARS) (Table 2). This activity enabled NARS to participate in screening, and to identify material suitable for a given region. In the national drought nursery conducted by the All India Coordinated Research Project on Oilseeds (AICORPO) during the 1988–1990 rainy seasons in India, five genotypes were identified as being superior to local checks in performance (18–30%) under drought conditions. The flow of material through the screening process is indicated in Figure 1.

Strategic Research

Strategic research on drought in groundnut has been conducted in close collaboration with national and international institutions (Table 3). We examined the physiological basis of genotypic difference in yields under water deficit conditions, based on a central relation which has been applied to many arable crops:

$$Y = T \times \mathrm{WUE} \times p$$

where pod yield (Y) can be expressed as the product of the total amount of water lost by transpiration (T), dry matter: water-use ratio (WUE), and ratio of pod yield to total dry matter (p). Significant variability among genotypes has been found for all the three parameters (Mathews et al. 1988; ICRISAT 1990; Nageswara Rao et al. 1993), which suggested scope for selection of genotypes based on single attributes. However, accurate measurement of T, WUE and p in the field is a difficult task.

Table 1. Number of genotypes screened for drought tolerance at IC since 1981

Year (post-rainy season)	Genotypes screened[a]	New material from:		Carryover from:	
		breeding lines	germplasm accessions	breeding lines	germplasm accessions
1981–82	EB 200	9	191	–	–
1982–83	EB 242	63	111	8	60
1983–84	EB 477	295	182	–	–
1984–85	EB 128	–	10	56	62
1985–86	–	–	–	–	–
1986–87	144	135	–	2	7
1987–88	EB 124	29	62	29	4
	VB 20	20	–	–	–
1988–89	EB 291	29	62	29	4
	VB 100	83	9	6	2
1989–90	EB 432	264	86	51	31
	VB 261	229	25	5	2
1990–91	EB 49	48	–	–	1
	VB 25	24	–	–	1
1991–92	EB 181	155	–	22	4
	VB 81	80	–	–	1
1992–93	EB 173	119	49	2	3
	VB 92	85	29	8	–
Total	3020	1764	810	220	226

[a] EB = spanish and valentia types; VB = virginia bunch types.

Germplasm Breeding lines

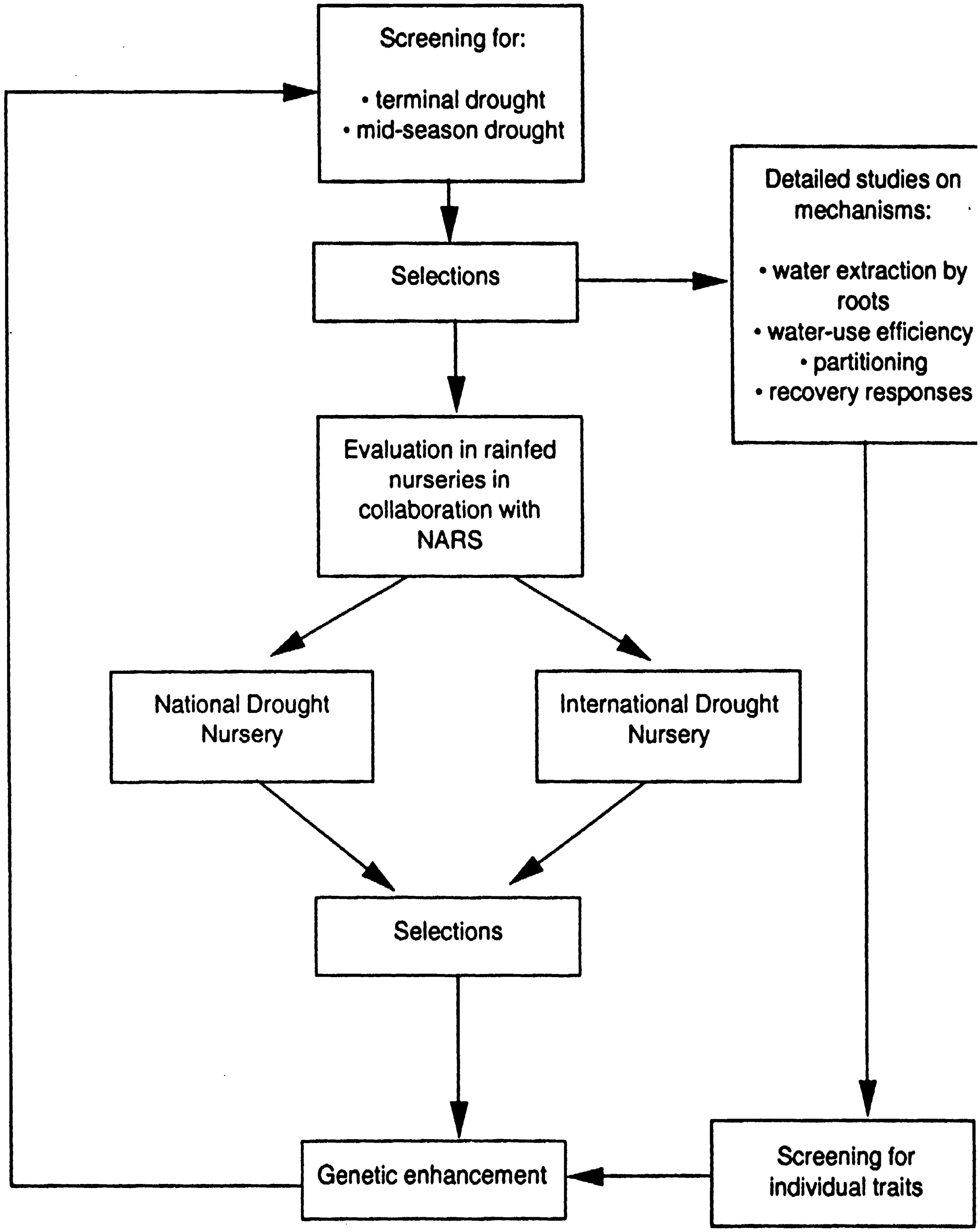

Figure 1. Flow of groundnut genotypes in drought screening program at ICRISAT

Table 2. List of national and international drought nurseries sent to various countries

Year	No. of drought nursery sets supplied		
	National	International	Countries
1988	6 sets (18 entries)	–	
1989	6 sets (18 entries)	4	Indonesia, Thailand, Philippines, India
1990	6 sets (22 entries)	2	Indonesia, India
1991	6 sets (22 entries)	10	Bangladesh, China, Honduras, Saudi Arabia, Sierre Leone, Thailand, Vietnam
1992	6 sets (22 entries)	15	Bangladesh, Brazil, Ethiopia, India, Indonesia, Mali, Nigeria, Republic of Yemen, Sudan, Vietnam

A close positive relationship between dry matter production and transpiration in groundnut genotypes (Azam-ali et al. 1989) suggested that productivity cannot be enhanced by limiting the transpiration whereas any genetic trait(s) or management practice(s) enhancing T can improve productivity. Studies conducted with a limited number of genotypes indicated significant variability in root characteristics and the ability of roots to extract water from deeper soil profile (Watterott 1991; ICRISAT 1990; Wright et al. 1993). However, we need to know more about the extent of variation in roots, and the benefits or penalties associated with selection for root characteristics in groundnut.

Significant variation among groundnut genotypes for WUE (defined as g dry matter produced per kg of water transpired) under field conditions has been observed (Mathews et al. 1988). Close collaboration between ICRISAT and ACIAR in the past few years, in studies on the groundnut drought physiology, has resulted in very productive research in WUE (Wright et al. 1993, 1994; Nageswara Rao and Wright 1994). These significant findings formed the basis for the enhanced cooperation between ICRISAT, ACIAR and ICAR in WUE research.

Table 3. National and international cooperation in drought research on groundnut at ICRISAT

Year	Lead cooperator(s)	Research area
1981–85	Dr J.L. Monteith et al. Univ. of Nottingham, U.K. (ODA-funded project)	Physiological basis of drought tolerance
1986–87	Dr F. Lenz et al. Univ. of Bonn. (GTZ-funded project)	Root studies in drought tolerant and susceptible genotypes
1986–Cont	Dr M. Udaykumar et al. University of Agricultural Sciences (ICRISAT–ICAR collaborative project)	Basic studies on drought tolerance traits
1988–Cont	AICORPO[a] (ICRISAT–ICAR collaborative project).	National Drought Nursery of groundnut
1989–Cont	Dr G.C. Wright, QDPI, Kingaroy Dr G.D. Farquhar, Australian National University, Canberra (ICRISAT–ACIAR collaborative project)	Water-use efficiency and carbon isotope discrimination

[a] All India Coordinated Research Project on Oil seeds.

The physiological basis for genotypic differences in recovery responses (after release of mid-season drought) is being examined in collaboration with the University of Agricultural Sciences, Bangalore. The results available so far indicate that reproductive development during recovery period seems to be related to cytokinin flux from the root systems. The role of hormones in general, and cytokinin in particular, on reproductive development and partitioning of dry matter to pods, requires further research.

Future Plans

Screening of germplasm and breeding lines for drought tolerance at IC, and evaluation of selected lines through nurseries will continue. Novel methods will be used to identify genotypes with greater WUE and partitioning.

Research on genotype × environment interactions for WUE will continue in collaboration with ACIAR and ICAR through the present collaborative arrangement.

Research on the role of hormones in reproductive growth during recovery from mid-season drought will continue in collaboration with the University of Agricultural Sciences, Bangalore.

Strategic research on high-temperature tolerance will be initiated.

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