SOME ASPECTS OF DROUGHT WITH SPECIAL REFERENCE TO GROUNDNUT DROUGHT RESEARCH AT ICRISAT

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1. INTRODUCTION

Drought decreases the yields of dryland crops over vast areas of the world. The incidence of drought is generally higher in the semi-arid regions which constitute 36% of the total land area according to Raheja (1966). Much of the remaining area undergoes temporary drought during the crop season. Since ICRISAT's objective is to breed crops with adaptation to the semi-arid tropics it is a corollary that we should breed for drought resistance in ICRISAT mandate crops. It is generally well recognized that on a world wide basis the major factors limiting groundnut production are foliar diseases, drought and nutrient stress (Gibbons, 1981). In the SADCC region 75% of the area is semi-arid and characterized by low, unreliable and/or poorly distributed rainfall. Mid-season droughts are of common occurrence and the need for breeding drought resistant groundnut cultivars for this region has been stressed by several researchers (Nigam & Bock, 1984; Chiteka, 1984; and Doto, 1984). Also the SADCC Food Security Consultative Technical Committee for Agricultural Research has emphasized the need for short duration drought resistant varieties for this region (Manda, 1984).

In addition to causing substantial yield reductions, drought can result in poor seed grades (Davidson et al, 1983; Stansell et al, 1976), decreased subsequent germination (Pallas et al, 1977) and an increased incidence of aflatoxin in groundnuts (Diener & Davis, 1977). The present paper deals with some aspects of drought resistance and the progress that has been made at ICRISAT in groundnut drought research.

2. THE KNOWLEDGE OF THE ENVIRONMENT

The strength of the relationship between genotype and phenotype is determined by the nature of environments. In similar environments the genotype can more consistently be identified by its phenotype. In dissimilar environments it is hard to identify the genotype since its expression may change and hence the genetic gains will be low in such environments. Breeding crop plants for drought prone conditions requires an appreciation and knowledge of the environmental factors which interact with rainfall deficits to creat an array of complexes collectively referred to as 'drought'. The range of variability among the salient environmental factors is extremely location specific.

Although many edaphic, biotic and agronomic factors characterize the location specificity of drought and its consequences on crop yields, the primary factors are the rainfall pattern and the soil's capacity to store and supply the water requirement of the plant. So the first step in planning for breeding drought resistant cultivars is to understand the direct (water deficit) and indirect (attendant physical, chemical and biological changes) contributing factors. The compilation and analysis of rainfall data with reference to the traditional cropping schedule of rainfed farming will aid in the determination of the crop growth stages prone to water deficit conditions. A knowledge of the regional soil characters such as texture, depth and drainage characters is also essential. These climatic and edaphic factors along with the identification of problematic yield determing growth stages help us in employing appropriate adaptive mechanisms.

3. ADAPTIVE MECHANISMS

Empirical field screening of traditional cultivars and breeding lines in drought prone areas has been the most common and efficient approach in selecting and breeding genotypes adapted to this stress (Chang et al, 1975; Hurd, 1971). Although this method of selecting for field resistance without investigating the causal factors has been successful, it may prove to be limited in scope in the long term.

Adaptive mechanisms which confer field resistance have been classified as escape, avoidance, tolerance and recovery mechanisms (Table 1).

Escape : The escape mechanisms have been broadly selected for in rainfed agricultural systems and these allow the crop to undergo their growth and development during periods of adequate moisture. Early maturity in wheat, rice and sorghum (Derera et al, 1969; Krishnamurthy et al, 1971; Blum, 1970) and photoperiod sensitivity in rice (Oka, 1958 and Vergara & Chang, 1976) have been found to ensure the completion of the drought-sensitive reproductive stages during the periods of adequate moisture. However, yield is known to be positively correlated with maturity duration under favourable conditions, and the greatest yields will come from exploiting the season length to the full. Caution should be exercised in not overplaying the importance of breeding cultivars with shorter growth periods as they have set limits of yield potential. Earlier maturing cultivars are also more sensitive to droughts if they occur since any given drought constitutes a greater proportion of the crop's life i.e. a 35 day drought is 50% of a 70 day crop life but only 30% of a 115 day crop.

Avoidance : A wide range of mechanisms are involved in the avoidance of drought stress when it occurs. These include denser and deeper rooting habit, stomatal resistance, culticular resistance, leaf rolling and positive leaf movements. A combination of a denser root habit with deeper rooting enables a crop to maintain water uptake. Extensive root systems have been found to be associated with drought resistance. This has been reported in soybeans (Raper and Barber 1970), durum wheat (Hurd, 1974), grain sorghum (Nour & Weibel, 1978) and in rice (Steponkus et al, 1980). In groundnut Ketring (1984) demonstrated a considerable diversity in root volume within virginia, spanish and valencia botanical types using a simple technique of growing the groundnut plants in PVC tubes containing fritted clay. The differences among entries in these limited samples of peanut germplasm suggest selection for more extensive rooting traits is feasible for this crop and may prove useful for developing more drought tolerant peanut cultivars. Work at ICRISAT has shown that difference in rooting characters contribute to differences in drought responses of cultivars.

Stomatal resistance has been investigated as a tool in determining drought resistance in sorghum (Blum, 1974; Henzell et al, 1976), wheat (Kaul, 1974) and rice (IRRI, 1973, 1975). However, in view of the dynamics of stomatal behaviour and variability of environmental factors contributing to drought, meaningful and repeatable screening procedures would be difficult to develop.

High cultivar resistance to water loss has been noted as a potential attribute of drought resistant crop species (Martin & Juniper, 1970; Ebercon et al, 1977). In rice it has been found that the epicuticular wax deposition varied between the rice cultivars with differing cuticular resistance values (IRRI, 1976). The amount of epicuticular wax on the leaf is believed to be indicative of the cuticular resistance and lends itself to rapid screening. Ebercon et al, (1977) developed a colorimetric test to quantify wax removed by dipping sorghum leaves in chloroform.

Leaf rolling has been identified as a resistant and alternatively as a susceptible trait. In some Mediterranean grasses leaf rolling has been found to reduce transpiration by 46 to 63%. The onset of leaf rolling, the extent of rolling and the elasticity in unrolling among rice cultivars during a diurnal cycle of water stress has been extensively used in IRRI as an indirect score of drought resistance (Chang et al, 1974; O'Toole & Chang, 1979). Groundnuts when stressed may actually fold their leaves and there by decrease energy interception which will decrease the stress occurring in the leaf. It is possible that selection for this attribute will improve the crops' drought avoidance.

The basic purpose of incorporating avoidance mechanisms is to maintain a favourable internal plant water balance for a longer time under drought conditions. The advent of portable field equipment for the measurement of plant water potential has greatly aided selection for the combined effect of avoidance mechanisms (Blum, 1974; O'Toole & Moya, 1978). Aerial infrared photography is another practical means of screening for relatively high leaf water potential (Blum et al, 1978).

Tolerance : Drought tolerance is another adaptive mechanism frequently mentioned in the literature and has been used as an interchangeable term for avoidance by some workers. So in discussing tolerance we must make the assumption that escape and avoidance are excluded. It is then possible to assume that the plant is actually suffering internal water stress and is showing the capacity to withstand it.

In groundnuts variations in drought tolerance do occur. At ICRISAT with the Cooperation of University of Nothingham Scientists we have shown that some lines have greater photosynthesis at a given water potential than others.

Although tolerance mechanisms are of great importance in countering droughts they are rather difficult for plant breeders to make use of as no good established screening methods are available. Unfortunately, in studying differences in tolerance between crop species and within species researchers too often utilize only severe or sustained water stress. Although varietal differences have been demonstrated by means of heat tolerance tests (Sullivan, 1972), proline accumulation (Singh et al, 1972) and desiccation survival (Levitt, 1972) it has not been shown conclusively that the basic characters on which these tests are based confer field resistance.

Recovery : Droughts vary in duration but when rains occurs the attribute of rapid recovery and return to active growth and development is important. Recovery is a very important trait in combating mid-season droughts and has been recognised as such by all the crop improvement programs at ICRISAT (Williams, 1983). Long duration cultivars have better chances for recovery and further development (Loresto et al, 1976). The nature of partitioning after the release of drought is important as has been reported by Williams (1983). In groundnuts it has been observed that some lines rapidly initiate reproductive growth while others put their initial emphasis on vegetative growth. In continued favourable conditions the latter attribute is advantageous whereas in short periods of favourable conditions the opposite attribute is benificial.

4. BREEDING STRATEGIES

The methods employed by various breeders for developing drought resistant genotypes can be classified broadly into the three following approaches :

4.1. Breeding under optimal or near optimal conditions : It is based on the assumption that the genotypes giving superior performance under optimal conditions will all perform relatively better under suboptimal conditions. This approach deals with yield and stability as one complex. In doing so, it requires an improvement in yield under optimal conditions which may often prove to be irrelevant in breeding for suboptimal conditions.

4.2. Breeding under drought conditions : According to this approach superior cultivars for drought-prone environments should be selected *in situ*. In view of the great variability of drought-prone environments, the heritabilities tend to be low and very slow progress is expected because of the operational problems - such as sample size - in the breeding program.

4.3. Breeding for drought resistance mechanisms : This approach involves the selective incorporation of relevant drought-resistance factors into cultivars with superior yielding ability under optimal conditions, thus making them perform better under suboptimal conditions. This approach calls for multidisciplinary efforts by breeders, physiologists, biochemists etc. for the full exploitation of available germplasm.

5. RELATIONSHIPS BETWEEN VARIOUS TAXONOMIC TYPES AND DROUGHT RESISTANCE IN GROUNDNUT :

The choice of a variety for a given location is of prime importance and it has been the farmer's first and oldest line of approach for combating local problems including drought. A thorough knowledge of the germplasm available for a crop species is required not only for identifying the natural locations of their adaptation, but also for more effective planning of hybridization with a view to recombine complimentary factors that confer advantage to the crop against a given stress. Groundnut is indeterminate in growth habit and a large range of variability occurs within the species which has considerable implications in the adaptation of the crop to drought environments. Krapovickas (1968) taxonoxically classified the cultivated groundnut species into two subspecies which in turn are divided into two varieties each : (1) subspecies *hypogaea*; variety *hypogaea* (commercially known as virginia bunch and runner) and variety *hirsuta*; (2) subspecies *fastigiata*; variety *fastigiata* (valencia type) and variety *vulgaris* (spanish type). The differences among these subspecies are not only of botanical but also of agronomic significance.

Bunting and Elston (1980) have suggested that the sequencial branching pattern of *fastigiata* types confers on them early maturity and they are the characteristic varieties of dry climates like those of the Mediterranean regions and the drier parts of India. Although it has been argued by Williams (1981) that sequential branching does not determine earliness and the seasonally dry environments are not the natural home of the non-dormant short season *fastigiata* types, the early maturity trait in these types could be profitably exploited by the breeder for escaping end season drought.

The alternatively branching *hypogaea* types are reported to withstand the consequences of internal competition better than the *sequential* types (Bunting and Elston, 1980) because of the supply of adequate assimilates as vegetative growth continues for a longer time in the former types.

To gain some impressions about the performance of various botanical types under rainfed conditions, the pod yields under rainfed conditions in various parts of India over years were examined. The All India Coordinated Research Project on Oilseeds (AICORPO) conducts separate tests for virginia bunch (VB) virginia runner (VR) and spanish bunch (SB) types. The mean yield performance of these types is compared by a paired 't' test. Out of 31 comparisons studied between VR and SB types, the yields were significantly different only in 12 cases out of which VR types were superior in 7 and the SB types in 5 cases (Table 2). Of the 37 comparisons between VB and SB types, 12 cases showed significant differences and the SB types were superior in 9 cases (Table 3). In the 18 comparisons between VR and VB types, where significant yield differences were observed, VR types were superior in 12 cases (Table 4). These observations suggest that both virginia runner and spanish bunch types are superior to virginia bunch types in rainfed agriculture and the superior yielding ability of VR types is not attributable to the alternate nature of their growth habit.

A comparison of yield data of VR and SB types in two contrasting years with regard to the rainfall pattern during the crop season at ICRISAT Centre and Junagadh, Gujarat State in India suggested that VR types can do better under mid-season (Fig. 1) and long-term (Fig. 2) stress conditions. Because of their long duration, the VR types may possess better recovery ability. Also, since calcium becomes a limiting factor during droughts, it is possible that VR types with their reproductive sinks separated wide apart are more efficient in obtaining their calcium requirements from the soils compared to that of SB types with a clustered podding habit.

6. DROUGHT RESEARCH AT ICRISAT IN GROUNDNUTS

Drought research in groundnut was started at ICRISAT in 1980 on the following aspects.

6.1. Drought screening : Since none of the chemical, biochemical and plant physiological attributes are universal predictors of performance under various drought situations, these are not being investigated as screening methods. The methods of drought screening being used are based on the principal that yield is the best integrator of the factors which impart resistance to the crop against drought. However, now that some drought resistant lines are identified, these are being examined for the factors that confer resistance to them. This single attribute screening procedure is important for identification of parents with complimentary resistances for the hybridization program.

The drought screening experiments are conducted during the postrainy season (November-April) when there is the least chance of interference from rains. Drought screening was started in the 1980/81 postrainy season with a set of 81 genotypes. Drought was created by withholding water at different stages of crop growth viz. flowering, pod setting and grain formation. Irrigation every 7 to 10 days served as control. Although, unexpected rain (70 mm) at the pod setting stage prevented full development of stress, and pod rots and *Spodoptera litura* confounded the effects of drought, some significant inferences could be made. Water stress at all stages significantly reduced the yield and the genotypes responded differently to different types of stress indicating the importance of timing of stress. Considerable genotypic differences existed for shelling percentages under stress treatments. Some varieties were able to achieve nearly normal pod filling under drought, while the average of all 81 cultivars was only 45 percent of the control treatment (i.e. no stress).

During 1981-82, different intensities of drought were created by using six irrigation treatments across the gradient of a line-source system developed by Hanks *et al.* (1976) at three growth phases while a fourth treatment was long term stress (Table 5). The line source system consists of a line of overhead sprinklers fitted with appropriate nozzles. When operated correctly they apply water in patterns which generate a gradient with amount of water applied becoming gradually reduced as distance from the sprinkler line increases. Drought timings were selected with the intention of choosing the phases of crop growth for which the greatest amount of genetic variability existed and seeing if responses at these times could be related to drought responses in different growth phases. These treatments also represented the most commonly occurring droughts in the SAT. A set of treatments represented variations in end season, mid-season and early droughts, and the fourth represented environments where rainfall is always less than potential evaporation.

Lines from this screening were tested at Anantapur, a site where drought commonly occurs, and two of them were found to be significantly better than the local check cultivars (Fig.3). In a season with no rainfall for 63 days after sowing, and a total of only 22 cm rainfall during the crop's life, yields of 1.15 t/ha were achieved for the drought resistant line, NC Ac 17090 compared with 0.5 t/ha for Robut 33-1. Cultivars varied widely in total dry matter accumulated and proportions of dry matter used for pod growth.

In 1982-83, 500 lines were screened but with a change in the treatments applied. The long term stress and end season stress patterns were retained but the midseason variations were replaced by a long term stress interrupted by irrigation on 2 occasions. This change was made because the preliminary analysis on the total dry matter of these treatments showed only small effects and the intercepted long stress was thought to present an opportunity to score for recovery from drought. These ideas were shown to be incorrect in the light of final analysis and a midseason stress has been re-introduced into the present drought screening exercise. In 1982/83 a drought screening evaluation was done on 25 lines selected from the previous drought screening, using twelve patterns of drought stress each with 8 intensities of stress. These treatments were designed to examine the genetic variability and interactions of genotypes to single and multiple droughts, with variable durations and timings of drought. The trial provided 96 sites differing mainly in the water component of the environment (temperature, photoperiod, and most other aspects of the environment being constant); The results from this trial indicated that early stress definitely provides adaptive advantage in the event of a second drought at a later stage. Also genotypes differed considerably in their ability to recover from the mid-season drought (Fig.4). With regard to mid-season drought, only a correlation of 0.2 was found between the sensitivity to drought and yield potential whereas in the end season drought a very high correlation (r=0.99) was observed.

Across all these environments those with the greatest drought resistance (± intercept) had low yields in good environments (low slope values) (Table 6)

From this series of drought screening trials lines which have consistantly performed better than the mean of all varieties have been identified (Table 7).

6.2. Drought Physiology Studies : These have been conducted to investigate the GXE interactions in greater detail. They include effects of time and intensity of drought, plant population effects on water used, and the development of drought and the effect of timing of stress on the drought recovery responses.

The research on the effects of timing of stress has shown that early stress can increase yield by 14 to 30% (Nageswara Rao et al ., 1985) and that for Robut 33-1 late stress has a much greater impact on yield than mid-season stress. In terms of water management and water efficiency, it was found that irrigation management to withhold water early and apply evenly deficient amounts during pod growth was better than utilizing the available water early leaving no irrigation at later stages.

The investigations of population effects on water use and the development of drought stress have provided basic information on the interactions between leaf area, light interception, dry matter production and root growth.

A detailed comparison of four contrasting genotypes revealed differences in water use efficiency. Major differences in reproductive development during the drought and subsequent to the release of stress were found to be the reasons for differential performance.

6.3. Gypsum and drought interactions : Large increases in yields due to Ca application in a wet year were reported in groundnut by Hallock and Allison, (1980). However, they observed only marginal yield increases during a dry year when drought prevailed during pod formation. Balasubrahmanyam and Yayock

(1981) from a pot study reported that gypsum reduces the detrimental effect of late moisture stress on pod yields of groundnut. Gillier (1969) reported that drought decreases Ca uptake and thus induces Ca deficiency in groundnuts. To substantiate these observations studies on the interaction of cultivar x gypsum x drought were undertaken at ICRISAT. In a field experiment, six cultivars were fertilized with gypsum at 0 or 500 kg/ha. Irrigation was applied regularly in all treatments until 60 days after sowing after which irrigation was either continued to ensure no water stress or withheld until 90 days after sowing. The results confirmed that some cultivars benefited significantly when gypsum has been applied and a drought occurred during the seedfilling phase. This effect was not apparent in other cultivars.

The reasons for this interaction of cultivar, gypsum and drought have been investigated utilizing three cultivars, where gypsum was applied in three concentrations and drought imposed by the line source method. This experiment has shown that in droughts, gypsum has increased the pod number and development of subterranean pegs and this effect results in the yield benefits observed from gypsum when droughts have occurred in the later part of the season. However, if the stress is released the benefit of gypsum may be eliminated by compensation during subsequent growth. It was found that although pod numbers had been incrased by gypsum in an initial drying cycle, subsequent pod growth was inversely related to pod numbers at the time that water stress was released.

6.4. Breeding for drought escape mechanisms : Groundnut cultivars which mature in 80-85 days may escape end season drought as has been reported in other crops. So efforts have been underway from the very inception of the groundnut program at ICRISAT to identify and breed for early maturing cultivars with increased yield levels and acceptable pod and seed characters.

In the initial years of the program two early spanish types (Chico and 91176) and a mid-early virginia cultivar (Robut 33-1) were extensively utilized in the hybridization program with other high yielding bunch and runner types. Recently several new sources such as L.No.95A, TG 1E, TG 2E, TG 3E and Ah 316/S have been identified as new sources of earliness and used extensively in crossing work. From several hundred crosses, selections have been made for earliness and high yield among the segregating material and lines with uniform growth habit, maturity, pod and seed characters have been developed. The yield levels of some of the best early maturity selections in 1982 rainy season are given in Table-8. More recently, some extra early groundnut lines have been isolated from the crosses of early maturing but agronomically poor parents, and high yielding late maturing parents. These lines have yielded 3000 to 3400 kg/ha of dry pods in 75 days after sowing in the 1984 rainy season at the ICRISAT Center (M.J.V.Rao, personal communication).

The early maturing spanish cultivars are characterised by non-seed dormancy. Hence considerable crop losses may occur due to sprouting when there are rainfalls on the mature crop. Eight lines with seed dormancy of at least 15 days have been isolated and purified by our physiologists from the derivatives of early maturity non-dormant spanish cultivars crossed with dormant virginia cultivars. These lines are being crossed with the early maturity advanced breeding lines to incorporate the limited seed dormancy into the latter.

6.5. Breeding for drought resistance : Five lines which were found to show promise under the line source irrigation consistently for two years for one or more types of stress (Table 9) have been utilized in the breeding program. These lines were crossed with two high yielding cultivars, Robut 33-1 and JL-24 and with one high yielding advanced line, ICGS-30 in a 8x8 diallel cross.

The segregating material will be handled by both bulk-pedigree and single pod descent methods. In the bulk-pedigree method (Fig. 5), two lots of seeds from each F2 plant will be made. One lot will be kept in cold storage for any contingency. The second lot will be planted at Anantapur and very light selection pressure for yield will be made from F3 onward. Only very poor yielding plants will be rejected in F3 to F5. The plants will be bulked on the basis of their yield performance, growth habit and pod and seed characteristics. The likely F6 uniform bulks will be yield tested at Anantapur. In the F7, a multilocation test both under stress and non- stress conditions will be conducted to identify lines with stable performance. The most advanced promising lines as revealed by a detailed physiological study, will be used as parents in the new cycle of crossing and selection.

In the single pod descent method (Fig. 6) the crosses will be advanced without selection by collecting a single pod from each plant upto F4. For each cross, 2000-2500 plants will be maintained. The possibility of rapid generation advance by using the greenhouse facilities will be explored. One thousand F4 derived lines in F5 will be evaluated in an unreplicated nursery by planting a check cultivar after every 10th plot at Anantapur. Based on the moving average of the check, 100 top progenies will be selected and further yield tested in a replicated trial. The top 25 to 30 lines from this trial will be further evaluated both under stress and non-stress conditions in a multilocation test where these lines will also be screened for other important traits. A new cycle of crossing and selection will be initiated by using the most promising advanced lines as parents as revealed by a detailed physiological study.

CONCLUSIONS

Drought in groundnut, besides causing direct yield losses can adversely affect the quality of seeds. Since none of the screening techniques based on chemical, biochemical and physiological attributes are universal predictors of performance under various drought situations, a holistic approach simulating droughts on whole plants and evaluating crop responses to these on the basis of yield and total crop growth is being followed at ICRISAT. Using the line source irrigation technique, genotypes which showed consistently good levels of drought resistance have been identified. Detailed physiological investigations revealed that early drought confers adaptive advantage to groundnut crop in the event of another drought occurring at a later stage. Also genotypic differences exist for resistances to mid-term and long term drought and the cultivars differ considerably in their capacity to recover from mid-season drought. Strong positive correlations were observed for sensitivity to terminal stress and high yield potential. However, low correlation coefficients between sensitivity to mid-season stress and high yield potential were found suggesting the possibility of breeding cultivars with high yield potential and resistance to mid term stress. Studies on gypsum x drought x cultivar interactions revealed significant differences among cultivars for their response to gypsum application under drought conditions.

Breeding for drought resistance has just been initiated to incorporate resistances to various types of stress into good agronomic backgrounds. Breeding for drought escape mechanisms has resulted in the development of lines which can mature in 75 days with high yield potential. These lines are expected to escape end season droughts.

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Table 1 : Mechanisms of drought resistance

Escape	Avoidance*	Tolerance*	Recovery
1. Early maturity	1. Dense root growth	1. Heat tolerance tests	1. Rapid recovery and return to active growth & development
2. Photoperiod sensitivity	2. Stomatal resistance	2. Proline accumulation	2. Long growth duration
3. Early seedling virgour	3. Cuticular resistance	3. Desiccation survival	3. Effective partitioning
4. Rapid stand establishment	4. Leaf rolling		
	5. Positive leaf movement		

* The terms 'avoidance' and 'tolerance' are used interchangeably in the literature; In using the term 'tolerance' here we make the assumption that 'escape' and 'avoidance' are precluded.
Another term 'adaptation' is used to include mechanisms such as osmotic adjustments and changed root/shoot ratios.

TABLE 2 : POD YIELDS OF VIRGINIA RUNNER vs SPANISH BUNCH GROUNDNUT TYPES IN AICORPO TRIALS, INDIA

YEAR	LOCATION	MEAN YIELDS (KG/HA) OF		'T' VALUE
		VR TYPES	SB TYPES	
1977	TINDIVANAM	360 (8)$	753 (11)	3.70**
	PANTNAGAR	2526 (7)	1492 (6)	4.92**
	KHARGONE	326 (9)	599 (10)	3.83**
1978	KHARGONE	1364 (19)	877 (40)	3.84**
	CHIPLIMA	1230 (21)	817 (40)	4.00**
1979	CHIPLIMA	578 (15)	760 (21)	2.48**
	ICRISAT	965 (10)	760 (22)	2.33*
	KHARGONE	620 (17)	981 (26)	3.17**
	VRIDDHACHALAM	362 (16)	89 (25)	7.40**
1980	JUNAGADH	1905 (24)	1453 (30)	5.40**
1981	ICRISAT	1315 (15)	1568 (19)	2.24*
1982	KADIRI	2209 (20)	1632 (40)	6.06**

$ Number of entries tested for each type.
No.of comparisons studied : 31
*,** Significant at 0.05 and 0.01 levels, respectively.

TABLE 3 : POD YIELDS OF VIRGINIA BUNCH vs SPANISH BUNCH GROUNDNUT TYPES IN AICORPO TRIALS, INDIA

YIELD	LOCATION	MEAN YIELD (KG/HA)		'T' VALUE
		VB	SB	
1976	KHARGONE	291 (3)$	614 (25)	2.67*
	DHARWAR	556 (9)	1747 (16)	11.10**
	POLLACHI	427 (4)	1366 (23)	12.96**
1977	TINDIVANAM	482 (6)	753 (11)	2.16*
1978	CHIPLIMA	1507 (3)	817 (40)	2.25*
	DHARWAR	1622 (8)	2207 (40)	5.31**
1979	JUNAGADH	774 (5)	1536 (26)	3.48**
1981	KANKI	2466 (18)	1621 (42)	5.18**
	CHIPLIMA	699 (24)	1068 (45)	2.76**
	VRIDDHACHALAM	870 (17)	1049 (43)	3.69**
	ICRISAT	1150 (12)	1568 (19)	3.87**
1982	KADIRI	1925 (17)	1632 (40)	3.31**

$ No. of entries tested for each type.
No.of comparisons studied : 37
*,** Significant at 0.05 and 0.01 levels, respectively.

TABLE 4 : POD YIELDS OF VIRGINIA RUNNER vs VIRGINIA BUNCH TYPES IN AICORPO TRIALS, INDIA

YEAR	LOCATION	MEAN YIELD (KG/HA) VR	MEAN YIELD (KG/HA) VB	'T' VALUE
1976	KHARGONE	583 (9)$	291 (3)	2.68*
	KADIRI	1446 (2)	821 (3)	2.82*
1977	KADIRI	1420 (8)	1748 (7)	2.74*
	DIGRAJ	513 (9)	744 (7)	2.24*
	MAINPURI	936 (9)	1083 (7)	2.16*
1978	DIGRAJ	1310 (25)	1027 (18)	2.39*
	DURGAPUR	1769 (20)	937 (17)	5.78**
1979	AMADALAVALASA	626 (10)	364 (5)	4.56**
	MAINPURI	521 (17)	1650 (5)	4.08**
1980	KADIRI	885 (25)	1015 (11)	2.07*
	LATUR	1966 (15)	1411 (14)	5.48**
1981	KHARGONE	1816 (16)	1301 (19)	3.56**
	MAINPURI	4296 (8)	2815 (16)	4.14**
	JUNAGADH	1040 (18)	806 (5)	2.13*
1982	KADIRI	2209 (20)	1925 (17)	2.57*
	ALIYARNAGAR	1205 (19)	978 (25)	3.58**
	DHOLI	1770 (15)	1430 (21)	2.04*
	LATUR	1205 (19)	2280 (27)	12.20**

$ No. of entries tested for each type.
No. of comparisons studied : 61

,** Significant at 0.05 and 0.01 levels, respectively.

TABLE 5 : TREATMENTS IN DROUGHT SCREENING EXPERIMENT IN GROUNDNUTS

YEAR	TREATMENT	EMERGENCE-FLOWERING	FLOWERING-PEGGING	PEGGING-POD SET	POD FILLING-MATURITY
1981/82	T1	U	LS	LS	LS
	T2	U	LS	U	U
	T3	U	LS	LS	U
	T4	U	U	U	LS
1982/83	T1	U	LS	LS	LS
	T2	U	LS *U	LS *U	LS
	T3	U	U	U	LS

U = Uniform irrigation.
LS = Line source sprinkler irrigation.
*U = One uniform irrigation to release water stress

TABLE 6 : REGRESSIONS OF POD WEIGHTS OF 25 GENOTYPES GROWN IN 96 MOISTURE ENVIRONMENTS ON MEAN POD WEIGHTS OF ALL GENOTYPES

S.NO.	ICG/GNP	IDENTITY	SLOPE[1]	INTERCEPT[2]
1.	35 #	CGC-4063	0.92*	- 5.5
2.	402 #	J-11 x Robut 33-1	1.12**	-12.0
3.	404 #	ICGS-24	1.10**	- 2.8
4.	405 #	ICGS-36	1.23**	- 0.3
5.	406 #	ICGS-11	1.02	- 6.5
6.	408 #	ICGS-35	1.17	0.0
7.	409 #	ICGS-21	0.86**	10.4
8.	411 #	X41-X-X-1-B x Golcin-1	0.98	-21.1*
9.	413 #	Manfredi x X-14-4-B-19-B	0.80**	31.4**
10.	414 #	Robut 33-1 x NC Ac 2821	0.98	-12.3
11.	712 #	ICGS-20	0.93	3.7
12.	221	TMV-2	0.91**	7.3
13.	799	Robut 33-1	1.17**	-21.5*
14.	1104	Faizpur 1-5-2	1.14**	- 9.7
15.	1326	J-11	1.01	0.1
16.	1697	NC Ac 17090	1.15**	-14.9*
17.	1712	NC Ac 17142	1.11**	4.0
18.	2738	Gangapuri	0.84**	13.0
19.	3605	EC 76444	0.67**	32.4**
20.	3657	EC 109271 (55-437)	1.05	15.8
21.	3704	EC 21024	1.11**	9.2
22.	3730	Manfredi-107	0.95	9.8
23.	4790	Krapovicas Str. 16	1.03	-23.4**
24.	5094	NC Ac 16129	0.91*	3.0
25.	7827	JL-24	0.85**	- 9.9

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1 *,** denotes significant difference from 0.0 at the 5% and 1% levels.

2 *,** denotes significant difference from 1.0 at the 5% and 1% levels.

TABLE 7 : GROUNDNUT LINES PROMISING FOR DROUGHT TOLERANCE IN THREE YEARS OF DROUGHT SCREENING AT ICRISAT CENTRE, 1980 TO 1983 POSTRAINY SEASONS

ICG NO.	SYNONYM	PEDIGREE	BOTANICAL TYPE/VARITY	ORIGIN
1660	NC Ac 2666	-	fastigiata	Brazil
3386	KG 61-38	-	fastigiata	India
3736	Harur Local	-	vulgaris	India
296	NC Ac 569	-	fastigiata	Tanzania
405	NC Ac 2663	-	fastigiata	Paraguay
1697	NC Ac 17090	-	fastigiata	Peru
3073	59-127	-	vulgaris	Upper Volta
5274	EC 97131	-	vulgaris	Upper Volta
3500	TMV-7	Selection from Tennessee white	vulgaris	India
4790	KU No.24	-	fastigiata	Argentina
4747	PI 259747	-	fastigiata	Peru
6997	KU No.134	Released cultivar 'Chiba Shoryi'	vulgaris	Japan
-	GNP # 35	CGC 4063	vulgaris	ICRISAT
2960	Pollachi-2	Pollachi Red x Ah 2105	vulgaris	India
3301	Florigiant	Small Spanish x NC Runner	hypogaea	USA
4544	Ah 687	-	vulgaris	-
4728	Voleta	-	vulgaris	Upper Volta
3657	55-437	-	fastigiata	Argentina

TABLE 8 : PERFORMANCE OF FIVE BEST EARLY-MATURING GROUNDNUT SELECTIONS, ICRISAT CENTER, 1982 RAINY SEASON

ENTRY	1982 RAINY SEASON	
	DAYS TO FLOWERING	POD YIELD (KG/HA)
(Ah 330 x 91176 F5-B1	18	2440
(NC Ac 2748 x Chico) F10B1	22	2120
(72-R x Chico) F9B	23	2130
(JH 89 x Chico) F9B	23	2000
(Chico x NC 344) F5B	19	1980
Chico (Early maturity parent)	20	1780
J 11 (National check cultivar)	27	1920
JL 24 (Local check cultivar)	27	2190
SE	± 0.6	± 116
CV (%)	5	13

TABLE 9 : DROUGHT RESISTANT LINES BEING UTILISED IN THE BREEDING PROGRAM

GENOTYPES	TOTAL BIOMASS UNDER T1[a]		T2		T3		REMARKS
	INTERCEPT (g/m)	SLOPE (g/m /cm)	INTERCEPT (g/m)	SLOPE (g/m /cm)	INTERCEPT (g/m)	SLOPE (g/m /cm)	
ICG-1697	131	18	30	19	491	31	**Resistant to 'T1 & T3' Stress**
GNP No.406 (ICGS-11)	246	10	163	13	458	20	**Resistant to 'T1,T2 & T3' Stress**
ICG-4728	197	11	225	11	423	25	**Resistant to 'T2' Stress**
ICG-3657	169	12	135	12	532	22	**Resistant to 'T3' Stress**
ICG-4790	185	14	20	20	553	22	**Resistant to 'T2 & T3' Stress**
Mean (Population)	172	11	156	11	392	17	

a = T1 = Continuous stress; T2 = Intermittent stress and T3 = Terminal stress

b = Intercept gives the theoretical yields of the genotypes under driest conditions.

c = Slope indicates the genotype's response to unit amount of water added.

d = Genotypes are selected on the basis of higher intercept and/or slope values compared to the respective mean estimates of the population.

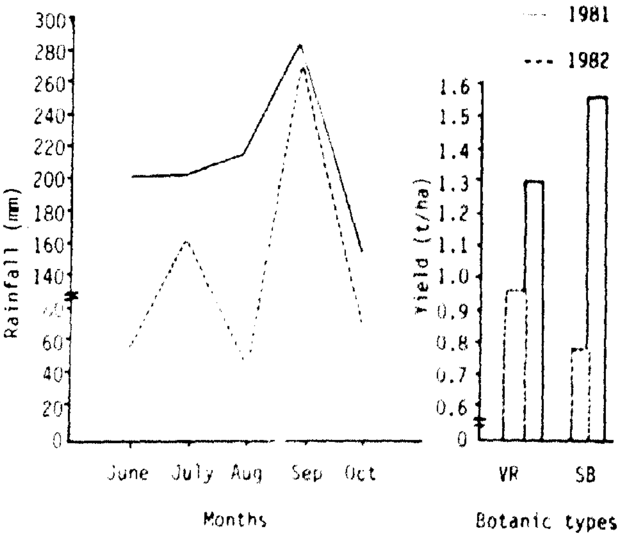

Fig.1 : Relationship between rainfall and pod yields in different groundnut botanical types at ICRISAT Centre, India.

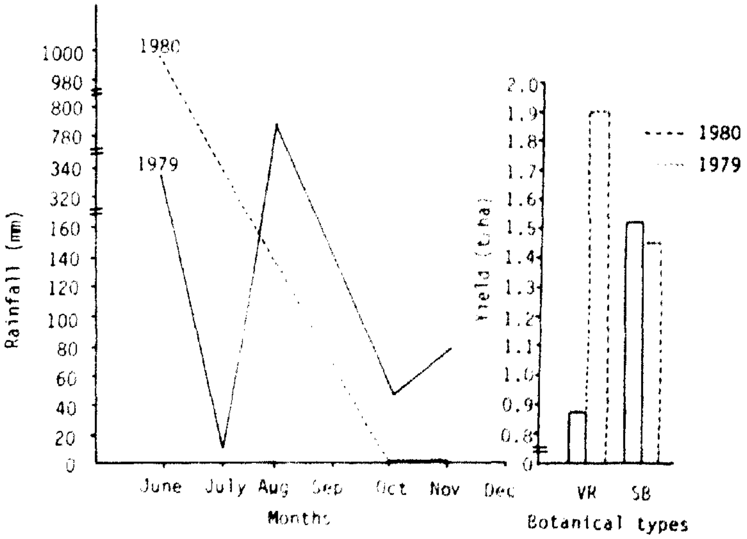

Fig.2 : Relationship between rainfall and pod yields in different groundnut botanical types at Junagadh, India

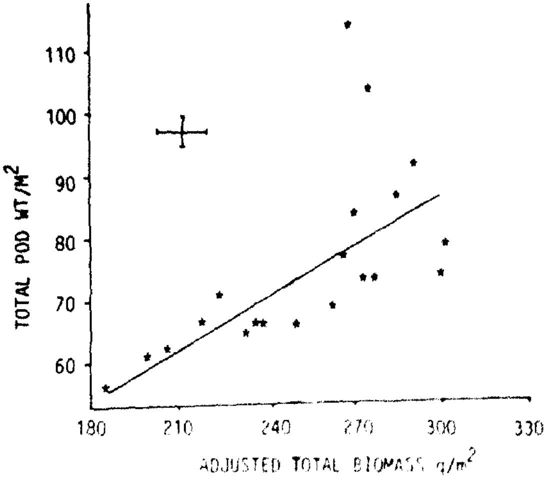

Fig. 3 : Relationship between total pod wt. and adjusted total biomass in 20 selected genotypes tested at Anantapur Kharif 1982

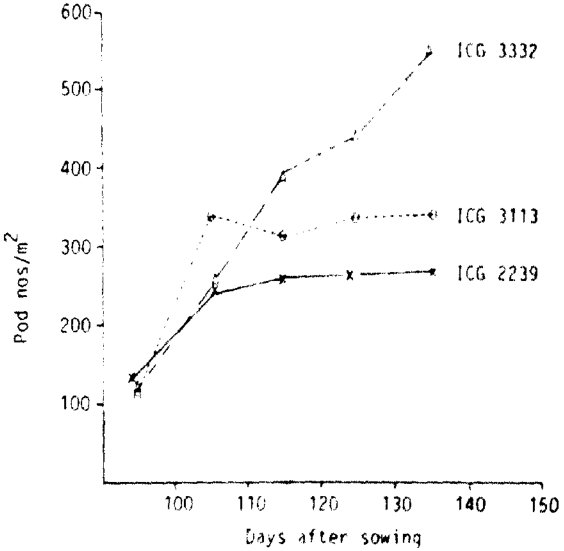

Fig. 4 : Recovery responses of 3 groundnut genotypes after release of drought

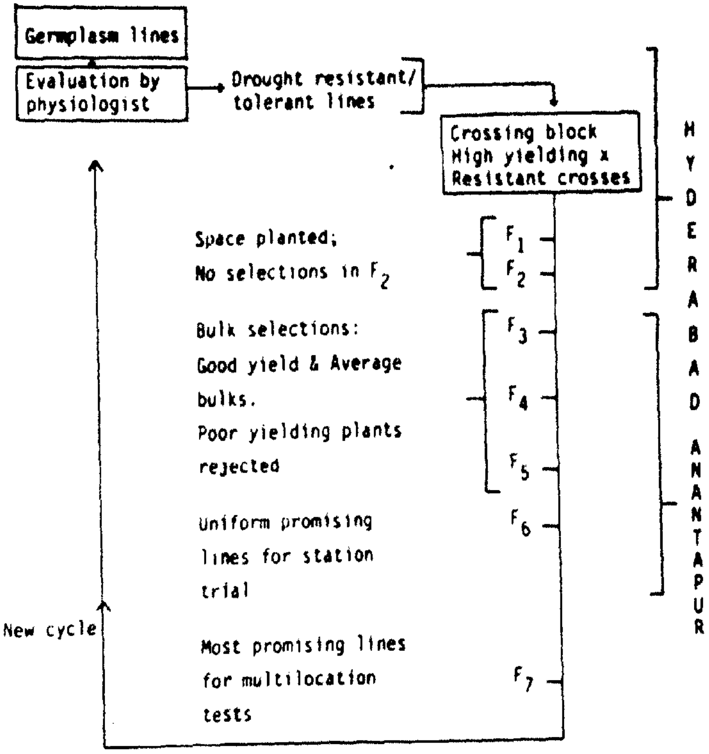

Fig. 5 : Breeding for drought resistance in groundnut by bulk pedigree method.

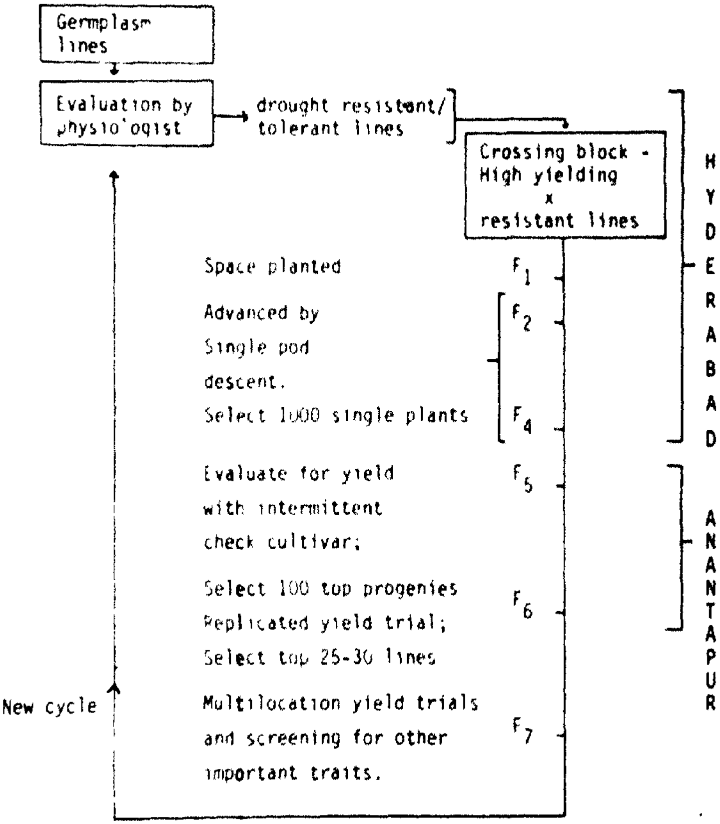

Fig. 6 : Breeding for drought resistance in groundnut by single pod descent method.