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# Effect of imposed drought conditions on genetic variation and association of physiological and yield traits in groundnut, *Arachis hypogaea* L.

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## Abstract

**A field experiment was conducted at ICRISAT centre, Patancheru, A.P. during rabi/summer season of 1999-2000 to evaluate twenty genotypes of groundnut for variability, heritability and genetic advance under normal growing environment, mid-season drought and end-of-season drought conditions. Selection for characters, crop growth rate (CGR), pod growth rate (PGR), no. of mature pods and oil percentage under normal conditions should be preferred. Similarly selection for harvest index and shelling percentage under mid-season drought, specific leaf nitrogen content (SLN), partitioning of dry matter to pods (PDM) and sound mature kernel percentage under end-of-season drought, relative leaf water content (RWC) under both the stress conditions and specific leaf area (SLA) under either normal or mid-season drought and hundred kernel weight under either normal or end-of season drought conditions should be preferred.**

**Under normal growing environment, CGR, PGR and SLN were positively correlated with pod yield and SLA negatively. Under mid-season drought, SLA was negatively correlated with pod yield and under the end-of–season drought, SLN, PGR, 100-kernel weight and sound mature kernel percentage positively. It would be useful to integrate SLA and SLN in a selection scheme for pod yield in a breeding program as they provide easily measurable indirect estimates for it.**

**Key words:** Peanut, variability, heritability, genetic advance, correlation, moisture regimes

## Introduction

Groundnut (*Arachis hypogaea* L) is a major leguminous oilseed crop in India. About 84% of groundnut in the country is grown in rainy season under rainfed conditions with little or no input. The crop often suffers from drought because of low and erratic rainfall during the season. The productivity of the crop under rainfed conditions remains low (997 kg/ha) as compared to irrigated post rainy season conditions (1512 kg/ha) (Anonymous, 2000). For any significant improvement in groundnut production in the country, its productivity under rainfed conditions will have to be improved substantially by growing drought-tolerant (including tolerance to other major stress factors), water-use efficient cultivars.

The past efforts, based on empirical approach, to develop drought tolerant genotypes have been inefficient and tardy. Recently, the focus in resistance breeding has shifted towards physiological traits associated with drought. Many physiological traits are associated with drought tolerance/increased water-use-efficiency in groundnut. These include, among others, relative leaf water content (Ravindra *et al.*, 1990), specific leaf area and radiation use efficiency (Wright *et al.*, 1994), leaf nitrogen content (Nageswara Rao *et al.*, 2001), crop and pod growth rates (Greenberg *et al.*, 1992; Nageswara Rao *et al.*, 1993) and partitioning and harvest index (Nageswara Rao *et al.*, 1993). Genotypic differences for these traits are also reported in literature.

Economic yield in groundnut, like any other crop species, is a complex character determined by various physiological processes through its components. There are several reports on genetic and phenotypic variation, heritability, expected genetic advance and correlation studies for yield and its components under normal or irrigated conditions (Chaudhary, 1993; Reddi *et al.*, 1991), but such reports are limited under imposed drought or limited moisture conditions (Reddy and Gupta, 1992; Chavan and Dhoble, 1994). For physiological traits, such information is very limited (Jayalakshmi *et al.*, 1999; Reddy and Gupta, 1992). Some of the physiological traits contributing to drought tolerance are reported to be associated with each other (Greenberg *et al.*, 1992; Wright *et al.*, 1994; Nageswara Rao *et al.*, 1995; Jayalakshmi *et al.*, 1999). But association of physiological and yield components with yield under moisture stress conditions are limited. So the present investigation was conducted to study phenotypic and genetic variability, heritability,

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expected genetic advance and correlation for physiological traits associated with drought and yield and its components in selected groundnut germplasm in three moisture regimes.

## Material and methods

Twenty groundnut genotypes were included in the study (Table 1). The experiment was conducted at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) during the 1999/2000 *rabi*/Summer season (Dec-April) under three moisture regimes in a strip plot design with three replications. The moisture regime 'No drought' received full irrigation during the whole crop duration through the line source sprinkler irrigation system and served as the control. The mid-season and end-of-season droughts were imposed by withholding irrigation between 50-100 days after sowing (DAS) and 100 DAS to final harvest, respectively. For the remaining period, these treatments received full irrigation. A buffer area of 3.6 m width was left between the moisture regimes in the field to arrest the seepage across the treatments. There was no rain during the cropping period. The experiment was sown on 4th December 1999. The plot size was 4 m x 1.2 m with spacing of 30 cm x 10 cm. The experiment received 40 kg $P_2O_5$/ha as basal application and 400 kg gypsum/ha at the peak flowering stage. The crop was fully protected against diseases and insect pests. The observations on physiological traits were recorded before harvest. A net plot area of 2m x 1.2m (2.4 $m^2$) was harvested at maturity to record the observations on yield and its components. The following observations were recorded on the experimental material.

**Relative leaf water content (RWC):** From each plot, 2nd or 3rd healthy leaf from the apex of the main stem of each of eight randomly selected plants was sampled in the morning hours in plastic bags. The fresh weight of each leaf was recorded immediately in the laboratory. Turgid weight of leaves was recorded after floating them in water for 5-6 hrs. in plastic trays. Dry weight of leaves was recorded after oven drying them at 80° C for 48 hrs. The RWC was calculated as

RWC (%) = [(Fresh weight (g) – Dry weight (g))/Turgid weight (g) – Dry weight (g))] x 100

**Specific leaf nitrogen (SLN) and specific leaf area (SLA):** Either the 2nd or the 3rd healthy leaf from the apex on the main stem was collected in plastic bags from each of eight randomly selected plants in each plot. These leaves were brought to laboratory and on each leaf, eight SPAD Chlorophyll Meter readings were taken (two readings/leaflet) as a measure of leaf nitrogen content (Nageswara Rao *et al.*, 2001). The values for eight leaves were averaged. After measuring the SPAD values, leaf area of each leaf was measured by an automatic leaf area meter (LICOR 3100). Dry weight of leaves was recorded after oven drying them at 80° C for 48 hrs. The SLA was calculated as, SLA ($cm^2$/g) = Leaf area ($cm^2$)/ Oven dry weight (g).

**Light interception (LI %):** Canopy light interception (LI) was measured at mid-day by a Ceptometer (Degagon Instruments, Washington, USA). The readings were recorded in each plot by placing the sensor across the rows at two canopy levels (below and above the canopy). The fractional radiation intercepted by the canopy at a given time was calculated as follows:

LI (%) = $[(I_o-I)/I] \times 100$

Where,

$I_o$ = Total incoming radiation (reading above the canopy)

$I$ = Radiation transmitted to the ground (reading below the canopy)

**Growth rates (CGR and PGR) and PDM:** Growth analysis was conducted in each plot on plants harvested from a ground area of 0.6 $m^2$ [1.2m (4 rows width) x 0.5 m (length)] at 50 DAS, 100 DAS and at final harvest. Plants were separated into leaves, stems, and pods. Roots were discarded. These separated components were oven dried at $80^0$ C for 48 hrs and their dry weight was recorded. Dry weights of all these were converted into dry weights per meter square area. Pod weight $m^{-2}$ area was calculated and adjusted by multiplying it with a factor 1.65 (Duncan *et al.*, 1978). Crop growth rate (CGR) (g $m^{-2}$ $day^{-1}$) and Pod growth rate (PGR) (g $m^{-2}$/day) were calculated by regressing adjusted biomass weight $m^{-2}$ (oven dried leaf + stem+ adjusted pod weights per $m^2$ area) and adjusted pod weight $m^{-2}$ with days after sowing respectively. Then partitioning of dry matter to pods (PDM) was worked out as PDM = PGR/CGR.

**Yield and yield components:** Observations on yield per plot and the yield contributing characters, i.e. number of mature pods per plant, shelling percentage, hundred kernel weight and sound mature kernel percentage were recorded. Oil content was estimated on a random seed sample (20 gm) from each plot. Genotypic and phenotypic coefficient of variability (GCV and PCV) and heritability percentage (broad sense) were worked out as per Singh and Chaudhary (1977). The expected genetic advance per cent over mean (GAM %) was worked out according to Johnson *et al.* (1955). Correlations were computed. All these parameters were worked out for each moisture regime treatments separately.

## Results and discussion

The estimates of genetic parameters for physiological traits under three moisture regimes are presented in Table 2. As expected, the PCV (%) for all the traits in all the three moisture regimes was higher than the GCV (%) indicating that the environment had played a role in enlarging the phenotypic variability of these traits. Mid-season and end-of- season droughts operate at and influence different phenological stages of plant growth.

GCV for RWC, SLN, HI and PDM increased under moisture stress conditions. However, the reverse was true for CGR and PGR as their GCV was maximum under normal growing conditions. Full availability of moisture throughout the cropping season ensured maximum expression of these traits in each genotype. GCV for LI was maximum under mid-season droughts. Differential recovery of genotypes from mid-season drought creates variation in canopy affecting light interception (Williams *et al.*, 1986). The genetic variation in SLA was least affected by moisture regimes. It appeared a more stable trait at the genetic level. PCV for RWC and HI increased under moisture stress conditions. For traits, SLN, LI, PGR and PDM, it was maximum and for SLA minimum under mid-season drought conditions. PCV for CGR varied little across the three moisture regimes. Both GCV and PCV for RWC and HI were higher under moisture stress condition. Similarly, for LI, both of them were maximum at mid-season drought. For other traits, there was no agreement between GCV and PCV in their response to moisture regimes.

**Table 1 Information on groundnut genotypes used in the study**

| Genotype | Botanical type | Pedigree | Year of release |
|---|---|---|---|
| JL 24 | Spanish | Selection from EC 94943 | 1978 |
| TMV 2 | Spanish | Mass selection from 'Gudhiathum Bunch' | 1940 |
| S 206 | Spanish | Selection from Manvi local | 1969 |
| KRG 1 | Spanish | Selection from Argentina variety | 1981 |
| TAG 24 | Spanish | TMS 1 x TGE 1 | 1978 |
| D 39d | Spanish | VG 101 x KRG 1 | * |
| KRG 2 | Spanish | ICGS 11 x Chico | 1994 |
| KRG 3 | Spanish | JLM 1 x TG 23 | 1996 |
| R 9214 | Spanish | (ICGS 7 x NC Ac 2214) X ICGV 86031 | * |
| R 922s7 | Spanish | (ICGS 7 x NC Ac 2214) ICGV 86031 | * |
| K 134 | Spanish | Kadiri 3 x JL 24 | 1993 |
| ICGV 86031 | Spanish | F 334A-B-14 x NC Ac 2214 | 1982 |
| ICGV 86635 | Spanish | NC Ac 2768 x NC Ac 17090 | * |
| ICGV 92113 | Spanish | ICG 1697 x ICG 4790 | * |
| ICGV 92118 | Spanish | ICGV 87340 x ICGS 11 | * |
| ICGV 92120 | Virginia | ICG 3736 x (TMV 10 X Chico) | * |
| ICGV 93260 | Spanish | ICGS 11 x ICG 4728 | * |
| ICGV 93261 | Spanish | ICGS 11 x ICG 4728 | * |
| ICGV 93269 | Spanish | ICGS 11 x JL 24 | * |
| ICGV 93277 | Spanish | ICGV 87339 x Ah 7827 | * |

Spanish = *A. hypogaea* ssp. *fastigiata* var. *vulgaris*
Virginia = *A. hypogaea* ssp. *hypogaea* var. *hypogaea*
* = Genotypes which are improved germplasm or advanced breeding lines.

As broad sense heritability and expected GAM for CGR and PGR were highest under normal environment, the selection for these traits should be practiced in such an environment. Although the broad sense heritability for HI was the highest under normal growing environment, but its PCV and GCV were lowest. On the other hand, it had higher GCV and PCV under mid-season drought, but the heritability was lower than normal growing environment. Expected GAM for HI was the highest under mid-season drought followed by normal growing environment indicating a relatively greater progress in selection for this trait in the former environment. RWC was better selected under moisture stress as both heritability and expected GAM were higher under these environment; the end-of-season drought being the better. End-of-season drought was a good environment to select for SLN and PDM, as both heritability values and expected GAM were highest under this growing condition. For selection for SLA, both mid-season drought and normal growing environment were better than end-of-season drought.

The estimates of genetic parameters for yield and its components are presented in Table 3. GCV, PCV, heritability and GAM for pod yield were higher under mid-season drought and normal growing environment than end-of-season drought suggesting that the selection for pod yield should be carried out under the former conditions. Selection for shelling percentage under mid-season drought and for 100-kernel weight either under normal condition or end-of-season drought condition was preferred because of the higher values of the genetic parameters under such growing conditions. For number of mature pods per plant, GCV, heritability and GAM were highest under normal growing condition, the PCV was highest under mid-season drought conditions. For this trait also, selection under normal growing condition was preferred. End-of-season drought was the preferred environment for selection for sound mature kernel percentage because of the higher values of genetic parameters for this trait in that environment. Both normal growing and end-of-season drought conditions created more variability for oil content, but its heritability and GAM were highest under normal growing conditions. This suggested that preferred environment for selection for oil content should be normal growing conditions.

Correlations of pod yield with its components and physiological parameters did not present a consistent picture under three moisture regimes (Table 4 and 5). CGR, PGR, and SLN correlated positively and SLA negatively with pod yield under normal growing conditions. However, except for SLA, these correlations disappeared under mid-season drought conditions. Under end-of-season drought condition, SLN, PGR, 100-kernel weight and sound mature kernel percentage correlated positively with pod yield. From these results, it is evident that SLN and SLA at harvest can provide easily measurable indirect estimates of pod yield for selection in segregating populations in a normal growing environment in a breeding program. SLN and SLA have shown stability across environments (Nageswara Rao and Wright, 1994; Nageswara Rao *et al.*, 2001). PGR can also serve the purpose, but it is not an easily measurable trait. It would be useful to integrate SLN and SLA in a selection scheme for high pod yield in groundnut.

**Table 2 Estimates of variability parameters for physiological characters under three moisture regimes in groundnut**

| Character | Drought | GCV(%) | PCV(%) | Heritability | GAM (%) |
|---|---|---|---|---|---|
| Relative leaf water content at harvest | 1 | 3.61 | 5.54 | 42.37 | 4.86 |
| | 2 | 6.16 | 8.53 | 52.15 | 9.17 |
| | 3 | 9.59 | 13.51 | 50.38 | 14.02 |
| Specific leaf nitrogen content at harvest | 1 | 7.90 | 11.87 | 44.27 | 10.83 |
| | 2 | 9.88 | 20.28 | 23.76 | 9.92 |
| | 3 | 9.90 | 11.51 | 74.02 | 17.54 |
| Specific leaf area at harvest | 1 | 7.66 | 14.63 | 27.40 | 8.25 |
| | 2 | 6.06 | 10.05 | 36.32 | 7.52 |
| | 3 | 6.76 | 17.90 | 14.27 | 5.26 |
| Light interception at harvest | 1 | 11.25 | 14.83 | 57.48 | 17.57 |
| | 2 | 25.86 | 34.00 | 57.85 | 40.53 |
| | 3 | 4.82 | 13.30 | 13.16 | 3.61 |
| Crop growth rate | 1 | 15.60 | 21.33 | 53.47 | 23.55 |
| | 2 | 13.86 | 22.11 | 39.29 | 17.96 |
| | 3 | 12.93 | 23.59 | 30.17 | 14.60 |
| Pod growth rate | 1 | 14.25 | 21.09 | 45.70 | 19.84 |
| | 2 | 8.87 | 29.10 | 9.15 | 5.64 |
| | 3 | 7.26 | 25.28 | 8.03 | 4.33 |
| Partitioning of dry matter | 1 | 7.35 | 12.17 | 37.03 | 9.30 |
| | 2 | 7.92 | 18.17 | 19.23 | 7.20 |
| | 3 | 9.82 | 13.33 | 52.94 | 14.59 |
| Harvest index | 1 | 12.80 | 14.24 | 80.73 | 25.49 |
| | 2 | 18.82 | 23.03 | 66.79 | 30.95 |
| | 3 | 17.10 | 26.59 | 41.36 | 21.46 |

1= Normal condition; 2= Mid-season drought; 3= End-of-season drought

**Table 3 Estimates of variability parameters for yield and its components in groundnut**

| Character | Moisture regime | GCV (%) | PCV (%) | Heritability (%) | GAM (%) |
|---|---|---|---|---|---|
| No. of mature pods | 1 | 25.57 | 40.64 | 39.61 | 33.11 |
| | 2 | 25.24 | 58.48 | 18.65 | 22.50 |
| | 3 | 9.87 | 48.38 | 4.18 | 4.17 |
| Pod yield | 1 | 18.17 | 25.58 | 50.47 | 26.59 |
| | 2 | 17.25 | 23.96 | 51.85 | 25.60 |
| | 3 | 13.65 | 21.51 | 40.29 | 17.85 |
| Shelling percentage | 1 | 3.70 | 5.15 | 51.59 | 5.47 |
| | 2 | 8.85 | 9.70 | 83.29 | 16.64 |
| | 3 | 5.79 | 6.81 | 72.24 | 10.14 |
| 100 kernel weight | 1 | 15.79 | 17.77 | 78.98 | 28.90 |
| | 2 | 8.80 | 13.64 | 41.65 | 11.70 |
| | 3 | 17.84 | 19.98 | 79.77 | 32.83 |
| Sound mature kernel percentage | 1 | 4.16 | 8.67 | 22.96 | 4.10 |
| | 2 | 1.74 | 9.83 | 3.12 | 0.63 |
| | 3 | 7.92 | 13.35 | 35.20 | 9.69 |
| Oil percentage | 1 | 5.20 | 5.80 | 80.12 | 9.85 |
| | 2 | 3.66 | 4.57 | 64.04 | 6.21 |
| | 3 | 5.56 | 7.96 | 48.79 | 7.56 |

1= Normal condition 2 = Mid-season drought 3 = End-of-season drought

**Table 4 Correlation of yield and yield components**

| Character | Moisture Regime | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ |
|---|---|---|---|---|---|---|---|
| $X_1$ | 1 | 1.0 | 0.402 | -0.283 | -0.087 | 0.141 | 0.322 |
| | 2 | 1.0 | 0.361 | -0.144 | 0.135 | -0.049 | 0.224 |
| | 3 | 1.0 | 0.201 | -0.125 | 0.006 | -0.013 | 0.127 |
| $X_2$ | 1 | | 1.0 | 0.063 | 0.081 | 0.268 | -0.333 |
| | 2 | | 1.0 | 0.029 | 0.310 | -0.005 | -0.224 |
| | 3 | | 1.0 | -0.065 | 0.191 | -0.047 | 0.017 |
| $X_3$ | 1 | | | 1.0 | 0.327 | 0.439 | 0.381 |
| | 2 | | | 1.0 | 0.209 | 0.334 | 0.187 |
| | 3 | | | 1.0 | 0.423 | **0.455*** | **0.475*** |
| $X_4$ | 1 | | | | 1.0 | 0.250 | -0.031 |
| | 2 | | | | 1.0 | 0.109 | -0.039 |
| | 3 | | | | 1.0 | **0.455*** | **0.492*** |
| $X_5$ | 1 | | | | | 1.0 | 0.011 |
| | 2 | | | | | 1.0 | 0.078 |
| | 3 | | | | | 1.0 | 0.426 |
| $X_6$ | 1 | | | | | | 1.0 |
| | 2 | | | | | | 1.0 |
| | 3 | | | | | | 1.0 |

* = significant at 0.05 P ** = significant at 0.01 P

1= Normal condition
2 = Mid-season drought
3 = End-of-season drought
$X_1$ - No. of mature pods
$X_3$-100 kernel weight
$X_5$- Oil percentage
$X_2$- Shelling percentage
$X_4$- Sound mature kernel percentage
$X_6$- Pod yield (g/plot)

**Table 5 Correlation among physiological characters and with yield**

| Character | Moisture regime | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ |
|---|---|---|---|---|---|---|---|---|---|---|
| $X_1$ | 1 | 1.0 | -0.132 | -0.075 | 0.326 | -0.040 | -0.152 | -0.203 | 0.031 | 0.071 |
| | 2 | 1.0 | -0.227 | -0.137 | -0.293 | 0.013 | -0.123 | -0.252 | 0.002 | 0.394 |
| | 3 | 1.0 | 0.137 | -0.281 | 0.216 | -0.066 | -0.185 | -0.214 | 0.126 | -0.164 |
| $X_2$ | 1 | | 1.0 | -0.282 | 0.109 | 0.301 | **0.452*** | 0.225 | -0.268 | **0.588**** |
| | 2 | | 1.0 | -0.277 | 0.114 | -0.053 | 0.076 | 0.230 | 0.067 | 0.105 |
| | 3 | | 1.0 | -0.208 | -0.159 | 0.031 | 0.153 | 0.240 | 0.035 | **0.444*** |
| $X_3$ | 1 | | | 1.0 | -0.178 | -0.278 | -0.271 | -0.067 | 0.202 | **-0.520*** |
| | 2 | | | 1.0 | -0.054 | -0.191 | -0.143 | 0.007 | 0.154 | **-0.494*** |
| | 3 | | | 1.0 | 0.040 | -0.115 | -0.021 | 0.172 | 0.073 | -0.140 |
| $X_4$ | 1 | | | | 1.0 | -0.063 | -0.008 | 0.057 | 0.065 | 0.190 |
| | 2 | | | | 1.0 | 0.348 | 0.199 | -0.158 | -0.412 | -0.375 |
| | 3 | | | | 1.0 | 0.134 | -0.010 | -0.301 | -0.163 | 0.036 |
| $X_5$ | 1 | | | | | 1.0 | **0.847**** | -0.333 | **-0.979**** | **0.622**** |
| | 2 | | | | | 1.0 | **0.823**** | -0.025 | **-0.966**** | 0.280 |
| | 3 | | | | | 1.0 | **0.854**** | -0.158 | **-0.964**** | 0.279 |
| $X_6$ | 1 | | | | | | 1.0 | 0.209 | **-0.811**** | **0.686**** |
| | 2 | | | | | | 1.0 | **0.568**** | **-0.785**** | 0.360 |
| | 3 | | | | | | 1.0 | 0.371 | **-0.812**** | **0.555*** |
| $X_7$ | 1 | | | | | | | 1.0 | 0.370 | 0.026 |
| | 2 | | | | | | | 1.0 | 0.002 | 0.135 |
| | 3 | | | | | | | 1.0 | 0.182 | 0.298 |
| $X_8$ | 1 | | | | | | | | 1.0 | 0.039 |
| | 2 | | | | | | | | 1.0 | 0.217 |
| | 3 | | | | | | | | 1.0 | 0.094 |
| $X_9$ | 1 | | | | | | | | | 1.0 |
| | 2 | | | | | | | | | 1.0 |
| | 3 | | | | | | | | | 1.0 |

* = significant at 0.05 P ** = significant at 0.01 P

1= Normal condition
2 = Mid-season drought
3 = End-of-season drought
$X_1$- Relative leaf water content at harvest
$X_3$- Specific leaf area at harvest
$X_5$- Crop growth rate
$X_7$ – Partitioning of dry matter to pods
$X_2$- Specific leaf nitrogen content at harvest
$X_4$- Light interception
$X_6$ –Pod growth rate
$X_8$ – Harvest index
$X_9$- pod yield

Among yield components, oil percentage was positively correlated with 100-kernel weight and sound mature kernel percentage only under end-of-season drought. Among physiological characters, crop growth rate was positively correlated with pod growth rate in all the three moisture conditions, similarly harvest index was negatively associated with crop and pod growth rate in all the three moisture conditions, indicating the stability of their association across the moisture regimes. Pod growth rate was positively associated with specific leaf nitrogen content only under normal condition and with partitioning of dry matter only under mid-season drought.

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