Agro-morphological response of some groundnut genotypes (*Arachis hypogaea* L.) in water deficit conditions

TOUDOU DAOUDA Abdoul Karim¹, ATTA Sanoussi², INOUSSA Maman Maârouhi¹, HAMIDOU Falalou³ and BAKASSO Yacoubool¹

¹Faculté des Sciences et Techniques, Université Abdou Moumouni, BP 10662, Niamey, Niger.  
²Centre Régional AGRHYMET, BP 11011 Niamey, Niger.  
³International Crop Research Institute for the Semi-Arid Tropic (ICRISAT), BP 12404 Niamey, Niger.

Received 2 April, 2020; Accepted 2 May, 2020

Groundnut is a crop that can be grown under varied production conditions (in intercropping or rotation with cereals). In Niger, the production of groundnut is decreasing over the year due to drought and low soil nutrients. In this work, an agro-morphological evaluation of five groundnut genotypes (55-437, ICG12697, ICG4750, JL24 and ICG8751) under water deficit was carried out in order to identify the best performing genotypes for seed and forage production. Intermittent water deficit was imposed from the 53rd day after sowing, which was the beginning of pod filling. The other plants were well watered until harvest. The results showed that in water stress conditions all yield parameters (pod number, pod weight, seed number, seed weight, harvest index and pod filling rate) and vegetative parameters (aerial biomass and height) with the exception of the number of branches decreased. The principal component analysis revealed that genotypes with a good harvest index and high pod filling rate have good seed yield. Therefore, harvest index and filling rate can be used for the selection of genotypes under water stress conditions. The genotypes 55-437, ICG4750 and ICG12697 proved to be the best performers under water stress and well-watered conditions. These ones accumulate vegetative biomass as proportionate way to the production and filling of the seeds in contrast to JL24 and ICG8751, which tend to accumulate vegetative biomass to the detriment of the production and filling of pods.

**Key words:** Agromorphologic, yield, groundnut, water deficit, Niger.

**INTRODUCTION**

In Niger, the agricultural farming system is mainly rainfed. The dominant cropping system is the association of cereals and legume species with a predominance of millet, cowpeas, and groundnut. Groundnut (*Arachis hypogaea* L.) is the main legume crop grown after cowpeas. Cultivated in association or in rotation with millet, it is of socio-economic and ecological importance to small farmers.
However, its production is low, 302,524 tons in 2014 (RECA, 2015). One of the most limiting factors in agriculture is water deficit (FAO, 2014) due to the large inter-annual climate variations such as rainfall variations which cause drought (Himeno et al., 2009). Drought stress impacts plant growth at many different levels. At the physiological level water deficit is perceived in roots and results in turgor loss, reduced water potential and decreased stomata conductance (Zhang and Uwe, 2017). The impact of drought on groundnut yield depends on the intensity of water stress and the stage of its appearance. The reduction in pod production by water stress is higher in the flowering stage than during the pod filling stage (Haliliou, 2016). Among the most relevant mechanisms of drought tolerance in groundnut are root development and stomatal regulation (Haliliou, 2016), while others such as the accumulation of abscissic acid (ABA) or proline appear to present less of interest (Madhusudhan et al., 2002).

The short cycle groundnut (70 to 90 days) uses the drought escape mechanism, which is particularly effective in environment with frequent water deficit at the end of the cycle (Clavel et al., 2007). This mechanism allows them to avoid end-of-cycle dryness, which corresponds to the very sensitive pod filling stage in groundnut. Genotypic variations in seed yield under intermittent drought have been observed in groundnut (Haliliou, 2015). This work aimed to assess the effect of intermittent water stress at the end of the cycle on the yield of five groundnut genotypes in order to determine the most relevant traits in the expression of yield.

### MATERIALS AND METHODS

#### Plant material

Five groundnut genotypes were chosen for this experiment based on their response to drought (Table 1). The seeds used were made available to us by the International Research Institute for Crops of the Semi-Arid Tropics (ICRISAT) in Sadoré (Niger). All five genotypes have a 90-day development cycle.

| Name       | Origin  | Response to drought |
|------------|---------|---------------------|
| ICG 12697  | India   | Tolerant            |
| ICG 8751   | Perou   | Sensible            |
| JL 24      | India   | Sensible            |
| 55-437     | Senegal | Tolerant            |
| ICG 4750   | Paraguay| Tolerant            |

The experimental plants were grown in pots stored on tarpaulin support to prevent root contact with the soil. The trial was put in natural conditions of lighting, temperature, and humidity. The pots were filled with sandy soil deficient in phosphorus taken from the surface horizon (20 cm deep) of field 8°C at the Sadoré station. The 35 l plastic pots are filled with 34 kg of soil enriched with manure (30 g.kg⁻¹ soil). The bottom of each jar has been pre-drilled to let the water drip out. Sowing was carried out on July 15, 2016, at the rate of three seeds per pot followed by thinned to one plant per pot 15 days after sowing. During the imposition of stress, the plants were protected from rainwater by a mobile shed with a translucent roof. Climatic data (temperature and humidity) were recorded daily using a thermo hygrometer (Tiny tag Ultra 2 TGU-4500 Gemini Data loggers Ltd, Chichester, UK) installed next to the trial. During the trial, the average temperature was 29°C while the relative humidity was 75% (Figure 1).

#### Experimental device

The experimental design was a split plot in randomized blocks with four repetitions. Two factors were studied: the two-levels water regime and the five-levels genotypes. Each block is made up of 20 pots including 5 pots per repetition. Each water regime is applied to plants in the same block. The two levels of water regimes are: T0: well-watered; T1: suspend watering at pod filling stage 53 days after sowing (DAS) for 9 days.

#### Measured parameters

The following phenological stages were recorded: emergence, date of start of flowering, date of start of pod filling. These parameters were measured on all the pots for the two treatments. The stage was noted when 50% of the plants in the block have reached the stage. At maturity, the following parameters per plant were measured: total height, number of twigs, pods and seeds. After 8 days of drying in the greenhouse, the dry biomass of the tops, pods, seeds and cokes was determined.

The pod filling rate (TR) was calculated by the formula: TR = seed weight / pod weight.

The pod harvest index (IR) was calculated using the following formula:

\[
IR = 1.65 \times \frac{pod \ weight}{pod \ weight \times 1.65 \ + \ aerial \ biomass \ weight}
\]

The correction coefficient 1.65 was used to adjust for differences in the energy requirements of the peanut to produce the dry matter of the pods compared to the vegetative part (Duncan et al., 1978).

#### Data analysis

The analysis of variance was carried out using the Minitab16...
software. The separation of the means for the various measured parameters was carried out by the Tukey test at the threshold of $\alpha = 5\%$. The significance of the correlation between the parameters studied was verified using the Pearson correlation test. The principal component analysis (PCA) was carried out to choose the most relevant parameters, which allow the genotypes to be discriminated.

**RESULTS**

**Phenology**

All genotypes emerged on average after 5 days after sowing (DAS) (Table 2). There are no significant differences between the genotypes for the start of flowering and pod filling dates, which occurred, on average at 25 and 53 DAS, respectively.

**Influence of water deficit on growth parameters and groundnut yield**

The results show that when the plants are well watered (T0), there are no significant differences ($p > 0.05$) between the genotypes for the total height of the plant, the number of branches, the yield pods, empty pod, and aerial biomass as well as the pod filling rate (Table 3). However, significant differences exist between the genotypes for the other parameters. The Tukey test made it possible to separate the genotypes into two groups for the number of pods / plants: 55-437, ICG12697 and ICG8751 produced more pods than the other genotypes.

Genotype 55-437 produced the best number of seeds/plant (95.25 seeds / plant), followed by ICG12697 (89 seeds/plant), JL24 produced the lowest number of seeds (56.75 seeds / plant). This genotype also produced the lowest seed/plant weight (18.84 g) and pod harvest index (49.75%) compared to other genotypes that have similar values.

When plants were subjected to water stress (T1), the results indicate that there were no significant differences between the genotypes for the total height of the plant, the number of pod per plant, the yield of pods, seeds and hulls (Table 3). However, significant differences exist for the number of pods ($p < 0.01$). The best number was obtained for ICG12697 and ICG4750, with approximately 30 pods / plant and the lowest by ICG8751 and JL24 (19 pods / plant). The best number of seeds / plant was recorded for 55-437, ICG12697 and ICG4750 compared to genotypes ICG8751 and JL24. Stopping watering for 9 days resulted in an average reduction of 45.15% in the number of pods and 55% in the number of seeds compared to well-watered. Genotype 55-437 has the highest pod harvest index (50.33%) and ICG8751 the lowest (35.21%). The other genotypes (JL24, ICG4750 and ICG12697) have an intermediate index. The induction of water stress results in a variable reduction in haulm yield depending on the genotypes (Figure 2). This reduction was greater for 55-437 and JL24 (39%) and to some extent ICG12697 (35%). It was lower for ICG4750 (29%) and ICG8751 (24%) (Figure 3).

The reduction in yield due to stress was even more

![Figure 1. Variation in temperature (T) and relative humidity (RH) during the test period.](image-url)
Table 2. Phenological stages of genotypes studied (in number of days after sowing).

| Genotypes     | Emergence | Beginning of flowering | Beginning of pod filling |
|---------------|-----------|------------------------|--------------------------|
| 55-437        | 5.00      | 24.75                  | 52.75                    |
| ICG12697      | 5.13      | 24.88                  | 53.00                    |
| ICG4750       | 5.13      | 25.00                  | 52.13                    |
| ICG8751       | 5.13      | 25.75                  | 53.50                    |
| JL24          | 5.63      | 26.00                  | 53.75                    |
| SE±           | 0.32      | 1.12                   | 1.66                     |

Significance: ns = not significant.

Table 3. Total height of the plant, yield and its components per plant for five peanut genotypes well-watered (T0) and subjected to water deficit (T1).

| Treat | Genotypes     | Ht (cm) | NRm | Ngo | Ngr | Pgo (g) | Pgr (g) | Pcq (g) | P Fanes (g) | TR(%) | IR(%) |
|-------|---------------|---------|-----|-----|-----|---------|---------|---------|-------------|-------|-------|
| T0    | 55-437        | 35.25   | 7.75 | 53.50 | 95.25 | 35.65   | 28.8   | 7.73    | 36.33       | 81.27 | 75.08 |
|       | ICG12697      | 38.00   | 9.00 | 50.75 | 89.00 | 37.59   | 27.27  | 10.31   | 39.60       | 72.39 | 67.18 |
|       | ICG4750       | 36.75   | 8.50 | 39.50 | 76.25 | 37.27   | 28.42  | 9.63    | 38.47       | 72.53 | 67.09 |
|       | ICG8751       | 37.00   | 10.25| 48.50 | 79.50 | 34.35   | 24.22  | 9.54    | 39.60       | 70.68 | 62.86 |
|       | JL24          | 35.65   | 11.00| 38.50 | 56.75d| 26.89   | 18.84  | 7.13    | 44.09       | 70.25 | 49.75 |
|       | SE±           | 4.11    | 1.87 | 4.12 | 4.14 | 5.00 | 2.68 | 1.67 | 2.54 | 5.60 | 6.99 |
|       | Significance  | ns      | ns  | **  | *** | ns | ** | ns | ns | Ns | ** |
|       | 55-437        | 35.00   | 11  | 27.00 | 50.75 | 17.89  | 22.16  | 74.99   | 50.33       | 73.03 | 46.44 |
|       | ICG12697      | 33.50   | 12  | 29.25 | 49.25 | 22.70  | 13.58  | 4.63    | 25.88       | 70.68 | 62.86 |
| T1    | ICG4750       | 34.25   | 13.25| 32.75 | 58.00 | 17.61  | 16.55  | 5.08    | 27.33       | 75.08 | 49.50 |
|       | ICG8751       | 35.50   | 13.5| 19.00 | 32.50 | 18.72  | 10.05  | 5.03    | 29.89       | 62.76 | 35.21 |
|       | JL24          | 35.25   | 12  | 19.25 | 39.00 | 15.42  | 11.48  | 4.52    | 26.74       | 64.67 | 43.13 |
|       | SE±           | 5.736   | 2.604| 2.48 | 4.31 | 5.42    | 4.067  | 1.92    | 4.155       | 8.89  | 7.49  |
|       | Significance  | ns      | ns  | *** | *** | 0.74 | ns     | ns     | ns      | Ns  | *   |
|       | Genotype      | ns      | ns  | *** | *** | ns     | ns     | ns     | ns      | *   | **  |
|       | Treatment (T)  | ns      | ns  | *** | *** | ***    | ***    | ***    | ***     | Ns  | **  |
|       | Geno*T        | ns      | ns  | *** | *** | ns     | ns     | ns     | ns      | Ns  | ns  |

* *** = significant at the probability threshold of 0.05, 0.01 and 0.00 respectively; ns = not significant (p > 0.05). The figures bearing the same letter (s) in the same column are not significantly different at the threshold of p <0.05. Ht: Total height of the plant; NRm: Number of branches; Ngo: Number of pods; Ngr: Number of seeds; Pgo: Weight of pods; Pgr: Weight of seeds; Pcq: Weight of the empty pod; P Fanes: Weight of aerial biomass; TR: Pod filling rate; IR: Pod harvest index.
important for seeds and pods. The reduction in pod yield was around 50% for 55-437 and ICG4750, 46% for ICG8751, 43% for JL24 and 40% for ICG12697 (Figure 4). The reduction in seed yield (Figure 4) is greater than or equal to 50% for three genotypes: ICG8751 (59%), 55-437 (53%) and ICG12697 (50%). The reduction is around 40% for the other two genotypes (ICG8751 and JL24).

### Correlation between the measured parameters

Analysis of the correlation matrix under well water conditions (Table 3) shows significant negative correlations between some vegetative parameters and yield. Thus, the number of branches/plant (NB) was negatively and significantly correlated with the weight of seeds/plant ($r^2 = -0.94$) and the harvest index ($r^2 = -0.95$). Yield parameters such as, weight of seeds/plant (WS), number of seeds/plant (NS) and harvest index were negatively correlated with aerial biomass yield, $r^2 = -0.93$; $r^2 = -0.90$; $r^2 = -0.97$ respectively.

Apart from the negative correlations between the vegetative parameters and the yield parameters. There were positive correlations between the vegetative
Figure 4. Comparison of the seed yield of five groundnut genotypes subjected to two water regimes (well watered and under stress).

parameters on the one hand and between the yield parameters on the other hand.
Indeed the number of branch/plant (NB) was positively correlated with the aerial biomass yield \((r^2 = 0.89)\). A positive and significant correlation also exists between the weight of seeds/plant and the pod harvest index \((r^2 = 0.94)\) on the one hand and between the number of pods/plant and that of seeds/plant on the other hand \((r^2 = 0.89)\) (Table 4).

Under water stress conditions (Table 5), there is no significant correlation between the vegetative parameters and the yield parameters. However, there are significant positive correlations between the vegetative parameters on the one hand and the yield parameters on the other. Note that under water stress the correlation between the weight of seeds/plant and the pod harvest index is not significant.

**DISCUSSION**

The results of the study showed that yields decreased under water deficit conditions compared to the well-watered. There was no significant difference in seed yield for genotypes under water deficit conditions. Among the genotypes studied, 55-437, ICG12697, and ICG4750 gave the best seed yields under water deficit and well-watered conditions. These genotypes also gave the best seeds harvest index and seeds filling rates.

Our results also show that the number of pods is more affected by water stress than the number of seeds. These results corroborate those of Nassar et al. (2018) on 20 peanut genotypes. According to Sharma and Sivakumar (1991), the decrease in the number of pods/plant under water stress is due to the compaction of the soil, which affects their development. Dahanayake et al. (2015) explain this reduction by the abortion of flowers, or due to abortion of newly formed seed (Vurayai et al., 2011).

There was a significant correlation in the harvest index for the seed weight of the well-watered plants, and not
significant for the plants under water deficit. However, there was no significant correlation between the harvest index and the pod weight for the two treatments. Our results were in contradiction with those of Halilou (2016) who found a strong correlation between the harvest index and the pod yield. Our results were explained by the fact that some genotypes (ICG8751 and JL24) under water deficit and well-watered conditions tend to produce more biomass than pod. Groundnut yields cannot be explained by pod weight alone, but by seed size and pod filling rate. Otherwise, the ability of plants to transfer assimilates from the vegetative system to pods (Bennett et al., 2012).
Table 6. Eigenvalues and contributions of the characters to the axes of the principal component analysis for the two treatments.

|                  | Treatment T0 |                  | Treatment T1 |                  |
|------------------|--------------|------------------|--------------|------------------|
|                  | Axis1 | Axis2 | Axis1 | Axis2 |
| Eigenvalues      | 6.69   | 2.47  | 5.87  | 2.72  |
| Proportion (%)   | 67     | 24.8  | 58.8  | 27.2  |
| Accumulation (%) | 67     | 91.8  | 58.8  | 86    |
| Correlation between variables and axes | | | | |
| Ht               | 0.068  | -0.614 | -0.28 | -0.29 |
| NRm              | -0.355 | -0.13  | -0.204 | 0.495 |
| Ngo              | 0.346  | 0.063  | 0.122  | 0.244 |
| Ngr              | 0.373  | 0.004  | 0.39   | 0.138 |
| Pgo              | 0.372  | 0.064  | 0.359  | 0.22  |
| Pgr              | 0.17   | -0.569 | -0.167 | 0.543 |
| Pcq              | -0.37  | -0.074 | -0.301 | 0.411 |
| Fanes            | 0.278  | 0.435  | 0.406  | 0.04  |
| TR               | 0.381  | 0.103  | 0.392  | -0.112 |

Bold values are significant for axis formation (≥ 0.3).

In well-watered conditions, significant negative correlations were observed between the vegetative parameters (aerial biomass, Ht, NRm) with the yield parameters (Ngo, Pgo, Ngr, Pgr, IR). This means that when the water is not limited, the genotypes develop more aerial biomass. But there is an inter-genotypes difference. According to Gigih et al. (2018), there is a genotypic difference in plant grown under the same environmental conditions. ICG1269 has a very high height and empty pod weight and a relatively low pod...
filling rate unlike 55-437 and ICG4750. This means that at ICG12697, the pod filling time is relatively longer compared to 55-437 and ICG4750.

Nevertheless, when water is limited, plants slow down their growth by reducing the biomass in favor of pod filling. According to Gigih et al. (2018) under normal condition, groundnut plants are more focused on pod propagation to encourage more pods production. Under conditions that causes less pod formation, the plant focuses on seed enlargement. All genotype increase the number (NRm) of branches but the biomass and yield parameters at harvest reduced, due to leaves lost. These results corroborate with those of Mukhtar et al. (2014) who showed that the yield component of groundnut where affected by time and intensity of defoliation. Zhang and Uwe (2017) revealed that drought stress that occurs during plant growth will affect the plant growth. It may decrease plant yield during harvest. JL24 and ICG8751 produced fewer seeds compared to the other genotypes (55-437, ICG4750 and ICG12697). This low productivity is due to their strong vegetative growth, which would have accelerated the use of water and the decrease in soil water reserves, leading to more severe water stress in its latter.

Conclusion

The study of the water deficit on the agro-morphological responses of the genotypes studied made it possible to identify the best performers according to the objectives and production conditions. Indeed, for an objective of seed production in rain-fed culture in Niger, the genotypes ICG4750 and 55-437 can be proposed because of their high productivity under water deficit conditions and well-watered. JL24 can be proposed for irrigated crops, in particular for the production of biomass and for better integration of livestock farming in a context where fodder resources are becoming increasingly scarce.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Clavel D, Bradat P, Khalfaoui JL, Drame NK, Diop ND, Diouf O, Zuly-Fodil Y (2007). Adaptation à la sécheresse et création variétale : le cas de l’arachide en zone sahélienne. Deuxième partie: une approche pluridisciplinaire pour la création variétale. Oéagineux, Corps Gras, Lipides 14(3):293-308.

Dahanyake N, Ranawake AL, Senadhipathy DD (2015). Effects of water stress on the growth and reproduction black gram (vigna mungo L.), Tropical Agricultural Research and Extension 17(1):45-48.

Duncan W, McCloud D, MacGraw R, Boote K (1978). Physiological aspects of peanut yield improvement. Crop Science 18(6):1015-1020.

Bennett E, Jeremy A, Roberts, Carol W (2012). Manipulating resource allocation in plants. Journal of Experimental Botany 63(9):3391–3400.

FAO (2014). The state of world fisheries and aquaculture 2014, Food and Agriculture Organization of the United Nations (FAO), Rome 223 pp.
Gigih IP, Ropolia, Anaggaeni (2018). Selection of Bangka local groundnut (Arachis hypogaea L.) germplasm tolerant to drought stress. Advances in Engineering Research 167:183-187. https://dx.doi.org/10.2991/icoma-18.2019.39
Hallou O, Hamidou F, Boulama KT, Saadou M, Vincent V (2015). Water use, transpiration efficiency and yield in cowpea (Vigna unguiculata Walp L.) and peanut (Arachis hypogaea) across water regimes. Crop and Pasture Science 66:715-728.
Halilou O (2016). Effet de la sécheresse sur la reproduction et réponses physiologiques de l’arachide (Arachis hypogaea L.) et le niébé (Vigna unguiculata L. Walp.). Thèse doctorat, Université de Niamey 206 p.
Himeno K, Inoue N, Kurauchi N, Ito O, Nishikawa Y, Kobayashi Y (2009). Les céréales au Niger. Accent sur le mil et le sorgho. JAICAF (Association pour la Collaboration Internationale en matière d’Agriculture et de Forêts du Japon). P. 109.
Madhusudhan KV, Giridarakumar S, Ranganayakulu GS, Reddy PC, Sudhakar C (2002). Effect of water stress on some physiological responses in two groundnut (Arachis hypogaea L.) cultivars with contrasting drought tolerance. Journal of Plant Biology 29:199-202.
Mukhtar AA, Falaki AM, Ahmad A, Jaliya MM, Abdoulkarim B(2014). Response of groundnut (Arachis hypogaea L.) varieties to varying defoliation intensities. Proceedings of the 4th ISOFAR Scientific Conference pp. 921-924.
RECA (2015). Résultats définitifs de la champagne agricole d’hivernage 2014 et perspectives alimentaires 2014-2015. P. 32.
Sharma PS, Sivakumar MVK (1991). Penetrometer soil resistance, pod number and yield of peanuts as influenced by drought stress. Indian Journal of Plant Physiology 34:147-152.
Vurayai R, Emongor V, Moseki B (2011). Effect of water stress imposed at different growth and development stages on morphological traits and yield of bambara groundnuts (vigna subterranean L. Verde). American Journal of Plant Physiology 6(1):17-27.
Zhang B (2015). Micro.RNA: a new target for improving plant tolerant to abiotic stress. Journal of Experimental Botany 66:1749-1761.
Zhang H, Uwe S (2017). Differences and commodities of plant responses to single and combined stress. The Plant Journal 90:839-855.