African Journal of Agricultural Research

Full Length Research Paper

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

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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.

Table 1. Origin and earliness of groundnut genotypes used.

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

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 (Halilou, 2016). Among the most relevant mechanisms of drought tolerance in groundnut are root development and stomatal regulation (Halilou, 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 (Halilou, 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.

Experimental conditions

The trial was conducted in pots during the 2016 rainy season (July-October) at the ICRISAT station in Sadoré (latitude 13° 15'N and longitude 2° 18'E.) located 45 km southwest of Niamey in Niger.

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 16 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 cockles 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:

$$IR = 1.65 \times \text{pod weight} / (\text{pod weight} \times 1.65 + \text{aerial biomass weight})$$

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

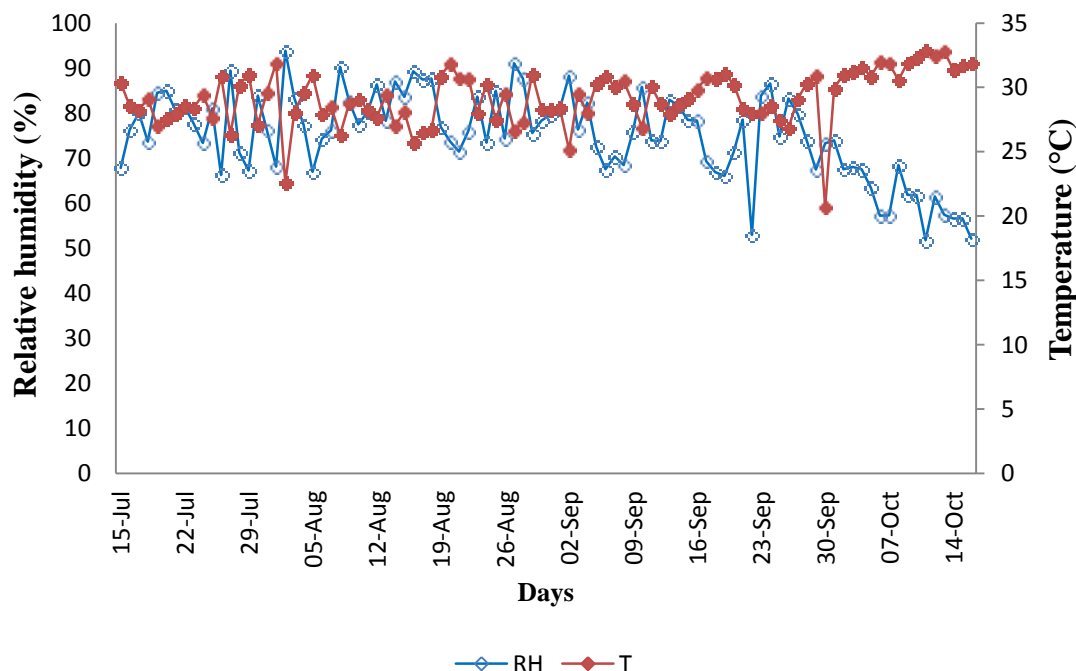The analysis of variance was carried out using the Minitab16

Figure 1. Variation in temperature (T) and relative humidity (RH) during the test period.

software. The separation of the means for the various measured parameters was carried out by the Tukey test at the threshold of α = 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).4

The reduction in yield due to stress was even more

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	ns	ns

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(%)
	55-437	35.25	7.75	53.50^a	95.25^a	35.65	28.8^a	7.73	36.33	81.27	75.08^a
	ICG12697	38.00	9.00	50.75^a	89.00^b	37.59	27.27^a	10.31	39.60	72.39	67.18^a
	ICG4750	36.75	8.50	39.50^b	76.25^c	37.27	28.42^a	9.63	38.47	72.53	67.09^a
	ICG8751	37.00	10.25	48.50^a	79.50^c	34.35	24.22^{ab}	9.54	39.26	70.68	62.86^{ab}
T0	JL24	35.65	11.00	38.50^b	56.75d	26.89	18.84^b	7.13	44.09	70.25	49.75^b
	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^b	50.75^a	17.89	13.49	3.70	22.16	74.99	50.33^a
	ICG12697	33.50	12	29.25^{ab}	49.25^a	22.70	13.58	4.63	25.88	73.03	46.44^{ab}
	ICG4750	34.25	13.25	32.75^a	58.00^a	17.61	16.55	5.08	27.33	75.08	49.50^{ab}
	ICG8751	35.50	13.5	19.00^c	33.50^b	18.72	10.05	5.03	29.89	62.76	35.21^b
	JL24	35.25	12	19.25^c	39.00^b	15.42	11.48	4.52	26.74	64.67	43.13^{ab}
	SE±	5.736	2.604	2.48	4.31	5.42	4.067	1.92	4.155	8.89	7.49
T1	Significance	ns	ns	***	***	0,74	ns	ns	ns	Ns	*
	Genotype	ns	ns	***	***	ns	ns	ns	*	**	**
	Treatement (T)	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; Fanes: Weight of aerial biomass; TR: Pod filling rate; IR: Pod harvest index.
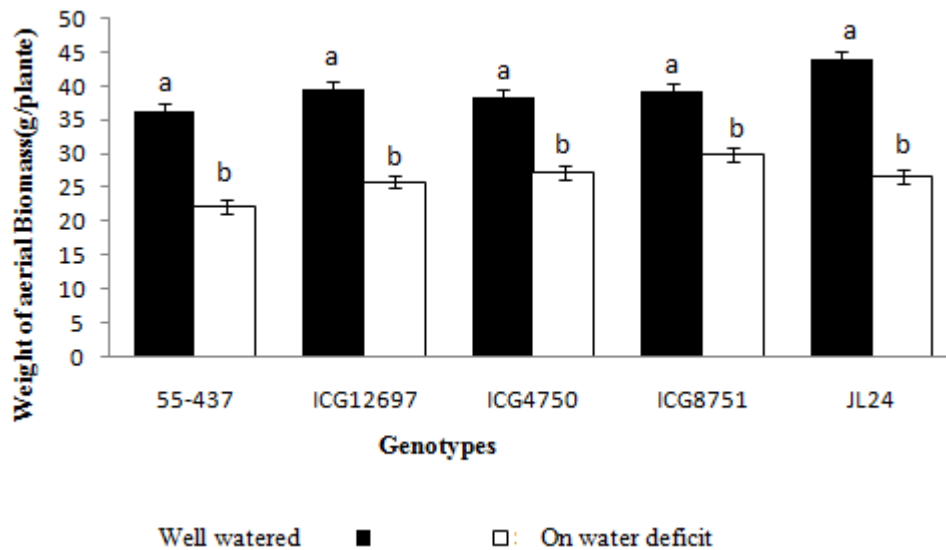
Figure 2. Comparison of the aerial biomass yield of five groundnut genotypes subjected to two water regimes (well-watered and under stress).
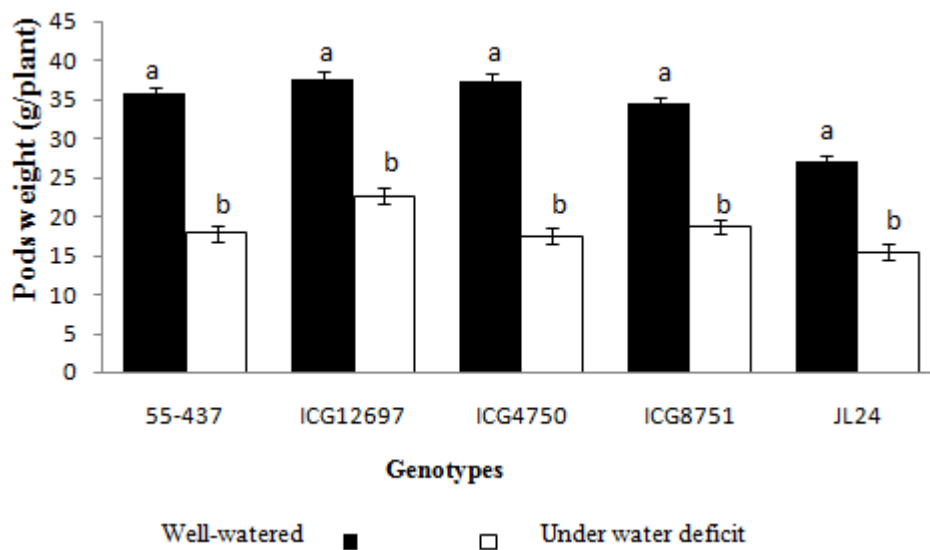

Figure 3. Comparison of pod yield of five groundnut genotypes subjected to two water regimes (well watered and under stress).

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
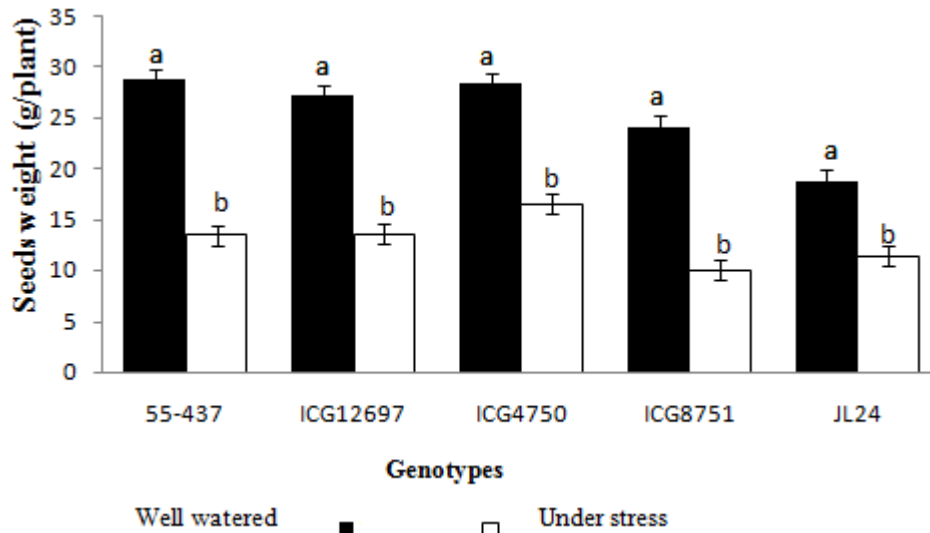
Figure 4. Comparison of the seed yield of five groundnut genotypes subjected to two water regimes (well watered and under stress).

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.

Eigenvalues and contributions of the characters to the axes of the principal component analysis for the two water regimes

The sum of the proportions of the eigenvalues of the axes of the PCA shows that the first two axes concentrate 91.8% of the information under well-watered conditions, and 86% for the plants under water deficit (Table 6). The first two axes can therefore guarantee precise analyzes. In non-limiting water supply conditions (Figure 5), axis 1 concentrates 67% of the information. It contrasts the vegetative parameters (aerial biomass and number of branches) with the yield parameters (Pgo, Ngr, Pgr, and IR). Axis 2 contrasts the height of plants and weight of empty pods with the pod filling rate. Axis 1 can be defined

as the parameters axis explaining the expression of yields and axis 2 for the growth parameters.

In water deficit conditions (Figure 6), axis 1 concentrates 58.8% of the information and opposes the yield parameters (Ngo, Ngr, Pgr, TR and IR) to certain vegetative parameters (aerial biomass yield and plant height). This axis can also be defined as the axis of the parameters participating in the expression of the yields. Axis 2 opposes the aerial biomass, the pod weight and the number of pod to the plant height. This axis can be defined as the axis of growth parameters.

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

Table 4. Correlation matrix between the parameters measured for plants normally supplied with water (T0).

Paramèter	Ht	NRm	Ngo	Pgo	Ngr	Pgr	Pcq	Fanes	TR	IR
Ht	1									
NRm	0.05									
Ngo	0.13	-0.51	1							
Pgo	0.54	-0.78	0.52	1						
Ngr	0.20	-0.82	**0.89**	0.8	1.0					
Pgr	0.23	**-0.94**	0.54	**0.9**	0.9	1				
Pcq	**0.93**	-0.22	0.22	0.8	0.4	0.52	1			
Fanes	-0.01	**0.89**	-0.67	-0.8	**-0.9**	**-0.93**	-0.33	1		
TR	-0.52	-0.81	0.63	0.4	0.7	0.62	-0.30	-0.74	1	
Ir	0.01	**-0.95**	0.72	0.8	**0.9**	**0.94**	0.29	**-0.97**	0.82	1

In bold, significant values (except diagonal) at the alpha threshold = 0.050 (bilateral test); Ht: Total height of the plant; NRm: Number of Branchs / plant; Ngo: Number of pods / plant; Pgo: Weight of pods / plant; Ngr: Number of seeds / plant; Pgr: Weight of seeds / plant; Pcq: Empty pods weight/ plant; Fanes: Aerial biomass; TR: Pod filling rate, IR: Pod harvest index.

Table 5. Correlation matrix between the parameters measured for plants under stress (T1).

Paramèter	Ht	NRm	Ngo	Pgo	Ngr	Pgr	Pcq	Fanes	TR	IR
Ht	1									
NRm	0.10	1								
Ngo	-0.80	-0.08	1							
Pgo	-0.73	-0.01	0.40	1						
Ngr	-0.68	-0.22	**0.97**	0.18	1					
Pgr	-0.66	-0.05	**0.95**	0.12	**0.98**	1				
Pcq	-0.12	**0.95**	0.00	0.10	-0.15	0.02	1			
Fanes	0.21	**0.93**	-0.38	-0.02	-0.52	-0.36	**0.92**	1		
TR	-0.68	-0.40	**0.94**	0.32	**0.96**	**0.89**	-0.35	-0.68	1	
IR	-0.52	-0.58	0.78	0.00	**0.90**	0.84	-0.50	-0.79	**0.91**	1

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	0.288	0.063	**0.374**	0.247
Pgo	**0.346**	-0.263	0.122	0.244
Ngr	**0.373**	0.004	**0.39**	0.138
Pgr	**0.372**	-0.064	**0.359**	0.22
Pcq	0.17	**-0.569**	-0.167	**0.543**
Fanes	**-0.37**	-0.074	**-0.301**	**0.411**
TR	0.278	**0.435**	**0.406**	0.04
IR	**0.381**	0.103	**0.392**	-0.112

Bold values are significant for axis formation (≥ 0.3).
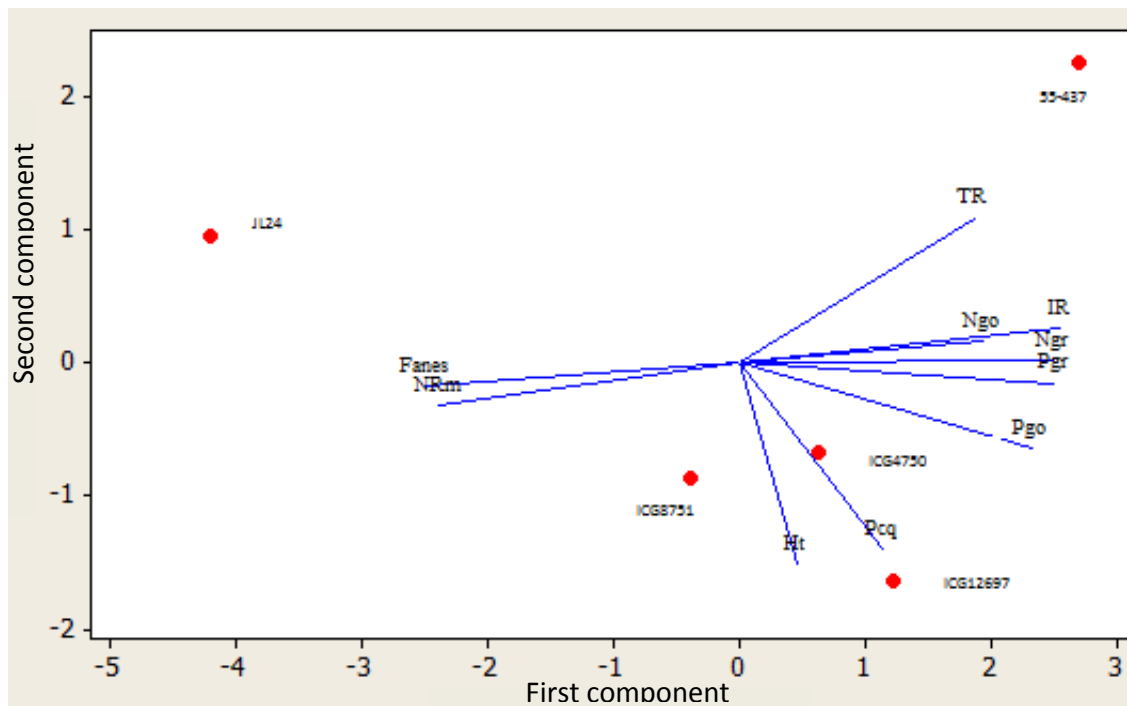
Figure 5. Double proportion diagram for plants under well watered conditions (T0).

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
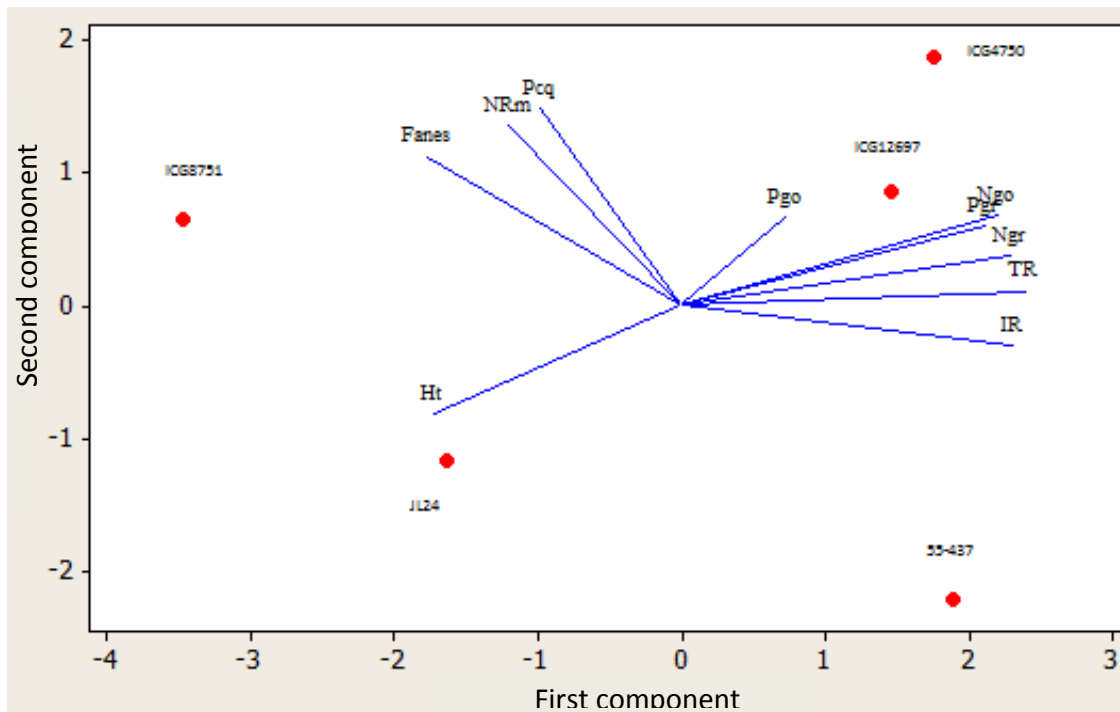
Figure 6. Double proportion diagram for plants under water deficit (T1).

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.

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