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Morphological and Physiological Responses of *Arachis hypogea* L. to Salinity and Irrigation Regimes in Screen House

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Authors' contributions

This work was carried out in collaboration among all authors. Author PTT conceived the research, and produced the experimental plan. Authors NCK, BCN and AJA implemented the research and collected field data. Author NCK did the laboratory analyses, while author PTT did the statistical analyses. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The K3237-80 groundnut variety from IRAD Nkolbisson is widely preferred in the Central African sub region for its sizable seeds and high yields, thus its contribution to livelihoods and food security. Apart from yield rating studies, responses to abiotic stress have not been done for this variety. The aim of this research was to investigate the responses of K3237-80 groundnut variety to salinity and water stress in screen house, in order to predict growth and yield performance under predicted conditions of soil salinity and rainfall variability.
Materials and Methods: The experimental design was a 4 by 3 factorial design. There were three levels of irrigation corresponding to 1100 mm, 2200 mm and 3300 mm crossed with four salinity levels of 0, 4, 8 and 12 ppt. Treatments were maintained till maturity and growth, yield and physiological parameters measured. Data were subjected to Factorial Analysis of Variance through the GLM approach, in the MINITAB Version 17 statistical package, followed by Spearman Rank Correlation and Factor analyses, all at α = 0.05.

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Results: It was found that this variety is mildly tolerant to salinity, as growth and yield decreased at salinity levels above 4 ppt. It is however resistant to irrigation water variability which explains why it does well in all five agroecological zones of Cameroon. Both salinity and irrigation treatments significantly influenced WUE, transpiration rate and TUE ($p<0.05$). Water use efficiency decreased from 3.23 g/l in plants irrigated with freshwater to 1.76 g/l in plants treated with water of 12 ppt salinity. Transpiration rate increased from 0.04 l/hr/plant at 0ppt to 0.06 l/hr/plant at higher salinities, while transpiration use efficiency correspondingly decreased significantly. Correlation analysis revealed that growth, yield and biomass parameters of *A. hypogea* are highly salinity-driven, while transpiration and water use efficiency are highly irrigation-dependent.
Conclusion: Therefore groundnut can be grown to maturity at salinity of up to 12 ppt, the trade-off is reduced growth and yield, caused by disruptions in photosynthesis and water relations.

Keywords: Salinity stress; deficit irrigation; transpiration use efficiency; water use efficiency; factor analysis.

1. INTRODUCTION

About 800 million people in the world are malnourished [1] and food production has to double in the next three decades to meet future needs [2,3]. Small holder food production in Cameroon is responsible for providing food security to both the rural and urban populations as well as significant export to the Sub Region. Major economic crops like *Theobroma cacao* L. (cocoa), *Coffea canephora* Pierre ex Froehner (coffee), *Hevea brasiliensis* Mull. Arg (rubber), and *Elaeis guineensis* Jacq. (oil palms) are essential to the country's GDP. However, food crops including *Zea mays* L. (maize), *Manihot esculenta* Crantz. (cassava), millet, sorghum, *Oryza sativa* L. (rice), and *Arachis hypogea* L. (groundnuts) among others constitute a major source of income and livelihood to the farmers.

Cameroon is the 13th world producer of groundnuts and its production has a world share of 1% [4]. Groundnut productivity in Cameroon is extremely low varying between 300 to 700 kg per ha. Groundnut is one of the cash rich crops that contributes greatly to Cameroon's economy. It constitutes a major source of income, especially for women. Groundnuts are a rich source of protein, and are consumed raw, soaked, fried, or roasted. Groundnut is also used in animal feed industries, and pharmaceutics; it has associated health benefits such as cancer prevention, control of diabetes, boost memory, stop hair loss, helps lose weight and promotes child growth [5].

Despite the importance of groundnut, yield on farmers' fields in Cameroon remain low (0.3–7.0 t/ha) compared to over 3.0 t/ha obtained in countries such as China and Brazil. The low yield of groundnut could be attributed to several biotic and abiotic constraints [6,7]. The major biotic factors include early and late leaf spot diseases as well as groundnut rosette disease [6]. The abiotic constraints include poor soil fertility, erratic rainfall which results in intermittent drought and some anthropic causes like secondary salinization from fertilizers and other chemical products and poor irrigation water quality.

Salinity is one of the most important abiotic stresses, limiting crop production in arid and semi-arid regions, where soil salt content is naturally high and precipitation can be insufficient for leaching [7,8]. According to the FAO Land and Nutrition Management Service (2008), over 6% of the world's land is affected by secondary salinity to an extent that inhibits plant growth.

Climate change is equally adversely causing less water availability. This phenomenon is expected to continue and to intensify in these less developed countries that may lead to serious problems. For this reason there is increasing pressure to irrigate [9] but often, irrigation water levels have to be determined *a priori* to avoid inadequate levels that may affect crop production, or result in wastage of scarce freshwater resources. Plant response to soil salinity and drought would depend on crop species, variety, growth stage, and environmental factors. The capability to simulate changes in crop environment including water and salinity, which constitute constraints of productivity of tropical agricultural systems can be studied. For example, growth and yield reduction in potato with increasing salinity irrespective of irrigation levels has been reported in screen house [10] likewise reduction in growth and stimulation of early scenescensce in tomato under similar conditions [11]. Responses of groundnut to salinity and drought stress have

also been studied, for example [12–14]. Nevertheless, none of the studies investigated synergistic effects of both salinity and deficit irrigation on growth and yield of groundnuts. Also, groundnut varieties differ in their responses to salinity and water stress as has been shown by Kavas et al. [15]. Therefore varietal profiling of response to these stressors is essential. The K3237-80 groundnut variety from IRAD Nkolbisson is widely preferred for its sizable seeds and high yields. Apart from yield rating studies, responses to abiotic stress have not been done for this variety. The aim of this research was to investigate its responses to salinity and water stress in screen house, in order to predict growth and yield performance under predicted conditions of sediment salinity and rainfall variability.

2. MATERIALS AND METHODS

2.1 Study Site

This study was carried out in a screen house constructed at the Divisional Delegation for Agriculture and Rural Development for Meme, Kumba, Cameroon located at the geographical coordinates 4°38'N 9°27'E and 4.63°N 9.45°E and an elevation of 240 metres (790 ft) above sea level. The site is within Cameroon's Agro-ecological Zone IV with an annual rainfall of 2200 mm and an average annual temperature of 31°C (IRAD, unpublished data).

2.2 Experimental Design

The experimental design used was a 4 by 3 factorial design. There were two factors, namely, salinity and irrigation, with four salinity levels (S_1 = 0 parts per thousand (ppt), S_2 = 4 ppt, S_3 = 8 ppt and S_4 = 12ppt) obtained by dilution of seawater with freshwater. There were three irrigation regimes namely I_1 corresponding to 1100 mm, which represents a 50% deficit irrigation scenario for Kumba, for which each pot received 1.5 L of irrigation water per week; I_2 corresponding to 2200 mm per year, the mean annual rainfall for the region, for which plants received 3 L of irrigation water per week; and I_3 corresponding to 3300 mm which represents a 50% excess irrigation for Kumba, for which each pot was irrigated with 4.5 L of irrigation water. This gave a total of 12 treatments, each of which was replicated three times to give a total of 36 experimental units.

2.3 Characteristics of Planting Material

The groundnut variety studied was variety K3237-80 from IRAD Nkolbisson, treated with Seedrex (33% permethrin + 15% carbonderzine + 12% chlorothalonil). Seeds used were whole, free of weevils, and at planting, the germination rate was 99%.

2.4 Soil Collection, Potting and Pre-Planting Soil Analysis

Top soil was collected from the top 30 cm in a fallow area within the research site, well mixed and used to fill 36 plastic pots of volume 10 L each with a surface area of 530.9 cm^2. The pots were perforated uniformly with 10 holes below and 12 holes by the sides at regular intervals. The physic-chemical characteristics of the experimental soil have been reported in Tabot et al. (in Press).

2.5 Sowing And Application of Treatments

Five seeds were sown per pot, and two weeks later, thinned to 3 plants per pot. During these first two weeks, they were irrigated with freshwater to enable them establish adequately. Treatments commenced two weeks after transplanting. Plants in the three replicates of each treatment were irrigated with the respective volumes of irrigation water of corresponding salinity as described in Section 2.2. Irrigation water for each week was applied in three split applications. For one replicate of the treatments, the schedule of treatments is shown in Table 1.

2.6 Data Collection

Baseline data were collected two weeks after germination before application of treatments. Growth, yield and ecophysiological parameters were measured.

2.6.1 Growth parameters

Height of plants, number of leaves, leaf area and number of branches were measured weekly. Plant height was measured from the base to the crown of the plant using a meter tape graduated in millimetre. The total number of leaves was obtained by counting. Leaf area was measured using the method of tracing on graph paper graduated in mm [16]. The average leaf area of the traced leaves was then multiplied by the total

number of leaves on the plant to have the total leaf area available for photosynthesis. The total number of branches were also determined by counting.

2.6.2 Chlorophyll concentration

Uniform leaf discs measuring 1cm in diameter, were collected from intact leaves still attached, and placed in vials with 10 ml 95% ethanol in the cold room for 24 hours to extract. The absorbances were then read in a Cyanscan Spectrophotometer at 664.1 and 648.8 nm. Chlorophyll concentration was then calculated according to Lichtenthaler et al. (1984) as follows;

$$C_{a+b} = 5.24A_{664.2} + 22.24A_{648.6} \quad \text{(Eqn. 1)}$$

Where A = absorbance, C_a = chlorophyll a, C_b = chlorophyll b, C_{a+b} = total chlorophyll

2.6.3 Reproductive parameters (Biomass partitioning, fruit yield and harvest index)

At the start of measurements, an initial sample of 20 plants were harvested and weighed. They were separated into roots and shoots, then oven-dried separately at 60°C for 48 hours and re-weighed to obtain the dry mass, which was then averaged to get the initial dry mass per plant for each fraction. At the end of the experiment, two plants from each treatment were harvested, separated into roots and shoots, and washed in distilled water. They were then weighed separately to obtain the fresh mass, then oven-dried at 60°C for 48 hours and re-weighted to obtain the dry mass for each fraction. The mass of each fraction was then averaged to obtain the corresponding final dry mass per plant. A sample of fruits were equally weighed fresh, then oven-dried to constant mass at 60°C, then re-weighed to get the dry mass. This was used to establish a regression equation from which dry mass of all subsequent harvest was determined. The final biomass was a combination of root, shoot and fruit dry masses:

$$Biomass\ of\ plant\ (g) = root\ DM(g) + shoot\ DM(g) + fruit\ DM\ (g) \quad \text{(Eqn. 2)}$$

Where DM = dry mass

The number of fruits produced in each replicate were counted at the end of the experiment and averaged for the number of plants to obtain the number of fruits per plant. The fruits per plant were also weighed fresh to obtain the fruit mass. The harvest index was determined as the ratio of the economic to the biological yield:

$$HI = \frac{Economic\ yield(g)}{Biological\ yield\ (g)}\ that\ is, \frac{Fruit\ fresh\ mass(g)}{Plant\ Biomass(g)} \quad \text{(Eqn. 3)}$$

2.6.4 Ecophysiological parameters

2.6.4.1 Water use efficiency (WUE)

The volume of water used for irrigation was recorded for the duration of the experiment. At the end of the experiment, the biomass was measured as previously explained. The water use efficiency represents the ratio of biomass accumulated per unit volume of irrigation water, according to [17]:

$$WUE = \left(\frac{g}{l}\right) = \frac{Total\ plant\ Biomass}{Total\ volume\ of\ irrigation\ water} \quad \text{(Eqn. 4)}$$

Table 1. Treatments applied according to a 3x4 factorial design of 3 irrigation levels (I1 to I3) and 4 salinity levels S1 to S4

Factors	Irrigation regimes		
Salinity (ppt)	I_1 (1100mm/yr) (50% deficit irrigation corresponding to 1.5 l/pot/week)	I_2 (2200mm/yr) (Normal irrigation corresponding to 3 l/pot/week)	I_3 (3300mm/yr) (50% excess irrigation corresponding to 4.5 l/pot/week)
S_1 (0 ppt)	S_1I_1 (1.5 l of 0ppt water)	S_1I_2 (3 l of 0ppt water)	S_1I_3 (4.5l of 0ppt water)
S_2 (4 ppt)	S_2I_1 (1.5 l of 4ppt water)	S_2I_2 (3 l of 4ppt water)	S_2I_3 (4.5 l of 4ppt water)
S_3 (8 ppt)	S_3I_1 (1.5 l of 8ppt water)	S_3I_2 (3 l of 8ppt water)	S_3I_3 (4.5 l of 8ppt water)
S_4 (12 ppt)	S_4I_1 (1.5 l of 12ppt water)	S_4I_2 (3 l of 12ppt water)	S_4I_3 (4.5l of 12ppt water)

2.6.4.2 Transpiration rate

To determine the volume of water transpired and the corresponding transpiration rate, the mass difference method was used, where each pot was placed in an intact transparent polythene bag and irrigated with its corresponding irrigation regime. The pots were then tied around the stems of the groundnut plants, so that the only possible avenue of water loss was through transpiration. The pots were weighed using a digital balance to get the initial mass (w1) at 8 am. At 1pm the pots were re-weighed to obtain the final mass (w2). The rate of transpiration was determined as follows:

$$TR(\frac{g}{hr}) = \frac{w1-w2}{t} \quad \text{(Eqn. 5)}$$

Where TR = Transpiration rate, w1 = initial mass of irrigated pot and plant, w2 = final mass of irrigated pot and plant, time (t) = 5 hours.

2.6.4.3 Transpiration use efficiency (TUE)

This measures the efficiency of water conservation relative to biological production and was determined by:

$$\text{TUE}\left(\frac{\text{g}}{\text{L}}\right) = \frac{\text{total plants biomass}}{\text{total amount of water lost by transpiration}} \quad \text{(Eqn. 6)}$$

2.6.4.4 RGR

The relative growth rate was calculated according to Tabot and Adams [18];

$$RGR = \frac{\ln w2 - lnw1}{t2-t1} \quad \text{(Eqn. 7)}$$

Where RGR = relative growth rate, ln = natural logarithm and t2-t1 = duration of measurement

2.6.4.5 Succulence

Succulence was measured as the ratio of the moisture content to the dry mass:

$$Succulence = \frac{Fm\ (g) - Dm(g)}{Dm(g)} \quad \text{(Eqn. 8)}$$

Where Fm = fresh mass of shoot, Dm = dry mass of shoot

2.6.4.6 SMF

The shoot mass fraction was calculated as a ratio of the mass of the shoot to the total plant biomass

$$SMF = \frac{Shoot\ mass\ (g)}{Total\ plant\ biomass\ (g)} \quad \text{(Eqn. 9)}$$

2.6.4.7 Root: Shoot ratio

The Root shoot ratio was determined as the fraction of the root dry mass to shoot dry mass:

$$Root{:}\,shoot\ ratio = \frac{root\ dry\ mass\ (g)}{Shoot\ dry\ mass\ (g)} \quad \text{(Eqn. 10)}$$

2.7 Data Analysis

Data were subjected to GLM ANOVA with interactions, in tandem with Tukey HSD test at α = .05, after tests for normality and homogeneity of variance. Data that were not normally distributed were Cox-Box transformed using the natural log function during analysis. Spearman rank correlation was done to determine data covariance and the relationship between parameters. Factor analysis based on data correlation was done to identify the spatial relationships and contribution of the different factors to the observed variability in the data. All analyses were done in the Minitab Version 17 statistical package (Minitab Inc., PA, USA) and where necessary, significance was determined at the 95% level (α = 0.05).

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

Plant height, number of leaves and leaf area varied significantly with both salinity and irrigation treatments ($p<0.05$ in all cases). Plant height decreased from 24.94 to 18.91 cm as salinity increased from 0 to 12 ppt while leaf area decreased from 2189 to 1441 cm^2 for plants treated with 0ppt and 12 ppt respectively (Table 2). With respect to irrigation treatments, plant heights did not vary significantly, but number of branches, leaves and leaf area increased as irrigation levels increased (Table 2).

Growth reduction in glycophytes under salt stress is the norm, as salinity induces an oxidative burst that elicits adaptive mechanisms. These mechanisms in part require the re-allocation of photosynthate towards stress tolerance and survival. This growth reduction with salinity increase has been shown for several species, for example in *Phaseolus acutifolius* A. Gray, *Vigna unguiculata* L. Walp., and *Phaseolus jiliformis* Bent [19]. In the related Bambara groundnut (*Vigna subterranea* (L) Verdc. , all growth parameters measured decreased as salinity increased [17]. On the other hand, growth parameters for these salinity levels were ameliorated under increasing irrigation levels. Water plays an essential role in all biochemical

and growth processes, and while *A. hypogea* plants did not display varying heights under irrigation treatments, other growth parameters such as leaf number, leaf area and branching increased as the volume of irrigation water increased. This is probably due to the fact that with adequate water, cell tugor is enhanced, and cell division and enlargement at the level of leaves and young stems is accelerated. The increasing leaf area at higher irrigation levels is essential for better photosynthesis and hence crop yields.

3.2 Yield Parameters

Salinity treatments significantly affected number of fruits and harvest index of groundnut ($p = 0.030$ and 0.007 respectively). Number of fruits decreased from 21.56 to 17.67 per plant as salinity increased from 0 to 12 ppt. This is the expected trend for glycophytes, because oxidative stress due to salinity obstructs the photosynthesis process that is responsible for overall crop production and reproduction; salinity stress also leads to membrane lipid peroxidation and specific ion toxicity. Our experiment showed a sustained decrease in leaf area such that effectively the physical apparatus for photosynthesis was reduced. All these require adaptive plant responses which make use of the already limited photosynthate to synthesise or up-regulate antioxidant systems for stress tolerance [20,21]. This has been shown for the eggplant [22] where increasing salinity in irrigation water decreased all yield parameters. On the other hand, HI increased from 0.71 in plants irrigated with freshwater to 1.2 in plants irrigated with water of 12 ppt salinity (Table 3). Fig. 1 shows that in spite of the salinity, all plants grew to produce pods but the salinity effect is clearly visible and intensifies as salinity increases. On the other hand, yield parameters were statistically similar for all irrigation levels (Table 3), probably because the levels of water reduction for the deficit irrigation (1100 mm per year) as well as the excess irrigation volume (3300 mm per year) were all within tolerant ranges for the crop. Indeed this explains why groundnut is grown in all agro ecological zones of Cameroon, which vary significantly in terms of rainfall distribution.

Table 2. Growth responses of groundnut to different levels of salinity and irrigation in screen house

Salinity (ppt)	Height (cm)	No. of of Branches	No. of leaves	Leaf area (cm^2)
0	24.94a	7.33a	188.3ab	2189a
4	20.82b	7.59a	201.1a	1923ab
8	20.02bc	7.02a	167.28b	1649bc
12	18.91c	7.32a	175.85ab	1441.1c
Irrigation (l/pot/week)				
1.5	20.60a	6.75b	166.21b	1621.1b
3	21.39a	7.65a	194.14a	1932a
4.5	21.53a	7.54a	189.08a	1848.1a

Values represent means. Means separated through GLM ANOVA with Tukey HSD test at α = 0.05. Means with the same letter within the column for each main effect are not significantly different

Table 3. Effects of salinity and irrigation on yield parameters of groundnuts in screen house

Salinity	No. of Flowers	No. of fruits	RS	HI
0	38a	21.56ab	59.71a	0.71b
4	38.78a	28.89a	85.9a	0.87ab
8	33.78a	17.33b	53.64a	1.29a
12	33.56a	17.67b	58a	1.20a
Irrigation				
1.5	35.42a	20.17a	64.6a	0.98a
3	34.42a	20.75a	63.18a	1.10a
4.5	38.25a	23.17a	65.14a	1.00a

Values represent means. Means separated through GLM ANOVA with Tukey HSD test at α = 0.05. Means with the same letter within the column for each main effect are not significantly different. RS = reproductive success; HI = Harvest index

Fig. 1. *Arachis hypogea* plants at harvest, arranged in order of increasing salinity

3.3 Biomass Partitioning

Fruit fresh mass was statistically similar across salinity and irrigation levels. Fruit dry mass ($p = 0.000$), shoot fresh mass ($p = 0.009$), root dry mass ($p = 0.015$) and overall plant biomass ($p = 0.003$) decreased significantly as salinity increased but root fresh mass increased instead (Table 4). The decrease in biomass fractions as salinity increases is explained by overall decrease in plant photosynthesis and metabolism under salt stress. When plants are stressed, the typical response is to re-allocate resources away from growth, to stress survival, which encompasses production of compatible osmolytes and other ROS scavenging mechanisms, as has been shown by Munns and Giliham [20]. This is consistent with findings by several authors [19,23]. There were no significant variations in these variables with changes in irrigation regimes, probably because of its wide tolerance of a broad range of rainfall regimes. While root fresh mass increased with salinity increase, this was not converted to fruit harvest, suggesting that this was an adaptation to better forage for water and nutrients under salt stress conditions. Considering Table 3 for Harvest index and Table 4 for overall biomass, we can conclude that during salt stress, plant vegetative growth in *A. hypogea* is suppressed in favour of reproduction (fruit yield) which is an adaptation to secure the next generation of plants.

3.4 Ecophysiological Parameters

Both salinity and irrigation treatments significantly influenced WUE, TR and TUE ($p<0.05$). In addition, salinity treatments significantly affected relative growth rate ($p = 0.001$), and shoot succulence ($p= 0.000$). Water use efficiency decreased from 3.23 g/l in plants irrigated with freshwater to 1.76 in plants treated with water of 12 ppt salinity. This is obvious because under salt stress, plant growth is reduced and hence biomass production per unit irrigation water. This has been reported for tomato [24] where salinity reduced WUE and hence overall crop growth and yield in a hydroponics system. Transpiration rate increased from 0.04 l/hr/plant at 0 ppt to 0.06 l/hr/plant at higher salinities, while transpiration use efficiency correspondingly decreased significantly (Table 5). This decrease is in part because of a reduction in leaf area and hence stomata available for transpiration, increased stomatal resistance for stress tolerance and reduction in water uptake [25,26]. Stomatal resistance refers to the closure of stomata when plants are under osmotic stress in order to reduce water loss by transpiration; this is especially important in salt tolerance because one of the consequences of salinity stress is decline in water uptake by plants. Hence stomatal resistance may help osmotically stressed plant cells to maintain tugor. Table 5 shows that RGR and succulence both decrease significantly as salinity increased from

0 to 12 ppt. The pattern is similar for irrigation effects on WUE, TR and TUE (Table 5), which once again confirms the reduction in photosynthesis, cell elongation and other processes for growth and development under salinity stress [25,27].

There were strong negative correlations between salinity and plant height (ρ = -0.356, p = 0.000) and salinity and leaf area (ρ = -0.355, p = 0.000). Transpiration rate (ρ = 0.150, p = 0.027) correlated positively with salinity. Leaf area (ρ = 0.151, p = 0.042) and transpiration rate (ρ = 0.629, p = 0.000) correlated positively with irrigation regimes. Biomass (ρ = -0.547, p = 0.001), RGR (ρ = -0.584, p = 0.000), succulence (ρ = -0.660, p = 0.000), transpiration use efficiency (ρ = -0.508, p = 0.002) and water use efficiency (ρ = -0.412, p = 0.012) correlated negatively with salinity while harvest index (ρ = 0.528, p = 0.001) correlated positively with salinity regimes. Transpiration use efficiency (ρ = -0.589, p = 0.000) and water use efficiency (ρ = -0.646, p = 0.000) correlated negatively with irrigation regimes, while transpiration rate (ρ = 0.874, p = 0.000) correlated positively with irrigation regimes. Biomass was highly dependent on RGR (ρ = 0.954, p = 0.000), Transpiration use efficiency (ρ = 0.537, p = 0.001) and water use efficiency (ρ = 0.582, p = 0.000) and correlated negatively with harvest index (ρ = -0.493, p = 0.002) and root:shoot ratio (ρ = -0.561, p = 0.000). Fig. 2 shows the factor analysis of the correlation matrix, and spatial relationships between response variables and treatments. The first two factors explain 58.9% of the observed variation in the measured variables, and the correlations reflected in the spatial associations between treatments (Fig. 2).

These correlations reflect the already explained growth and physiological responses of *A. hypogea* to salinity and irrigation. Growth, yield and biomass parameters of *A. hypogea* are highly salinity-driven, decreasing as salt concentration in irrigation water increases and this is the norm for glycophytes. On the other hand, transpiration and water use efficiency are highly irrigation-dependent. Therefore while we could grow groundnuts to maturity at salinity of up to 12 ppt, the trade-off is reduced growth and yield, caused by disruptions in photosynthesis and water relations.

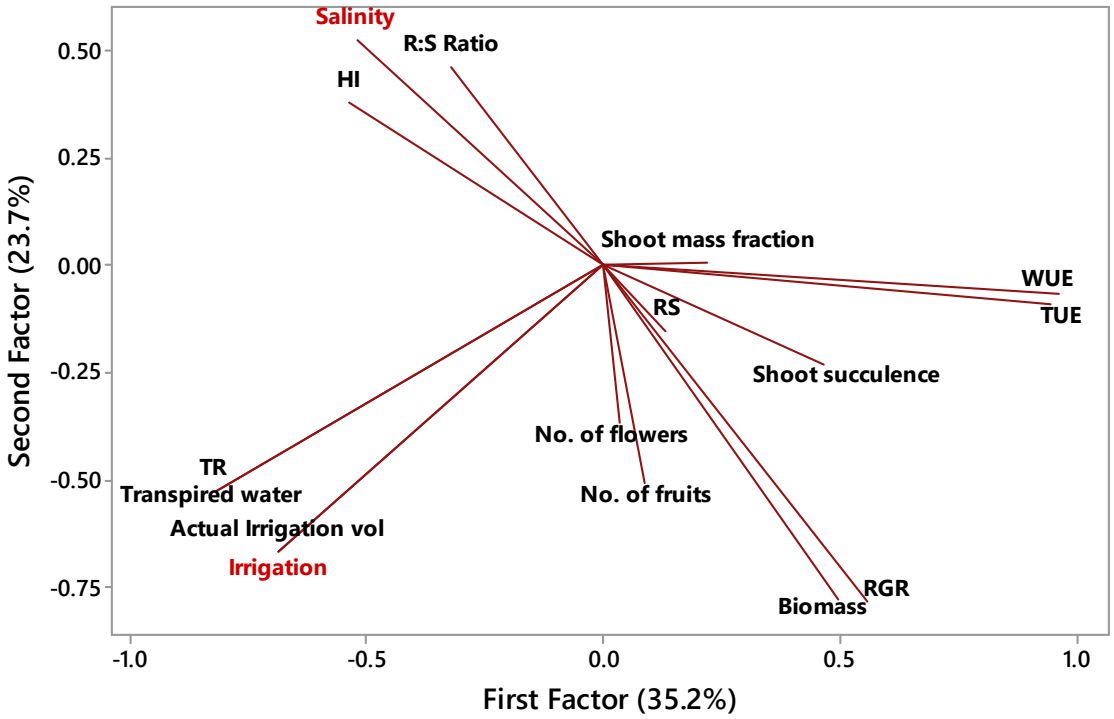

Fig. 2. Factor analysis plot showing spatially the correlations between the response and treatments variables

Table 4. Effect of salinity and irrigation on biomass partitioning in groundnut

Salinity (ppt)	Fruit FM (g)	Fruits DM (g)	Shoot FM (g)	Shoot DM (g)	Root FM (g)	Root DM (g)	Biomass (g)
0	23.33a	13.67ab	51.67a	18.11a	5.44a	3ab	34.78a
4	29.44a	14.78a	49.44a	17.11a	7.33a	3.33a	35.22a
8	26.67a	8.56bc	28.89ab	11.33a	6.56a	1.89b	21.78ab
12	22.22a	5.44c	18.33b	9.78a	7.67a	2.78ab	18b
Irrigation (l//pot/week)							
1.5	23.33a	8.92a	35.42a	12.75a	6.67a	3.04a	24.71
3	26.25a	10.25a	37.5a	14.33a	6.17a	2.63a	27.21
4.5	26.67a	12.67a	38.33a	15.17a	7.42a	2.58a	30.42

Values represent means. Means separated through GLM ANOVA with Tukey HSD test at α = 0.05. Means with the same letter within the column for each main effect are not significantly different. FM = fresh mass; DM = Dry mass

Table 5. Effects of salinity and irrigation on ecophysiological parameters of groundnut grown in screen house

Salinity (ppt)	WUE (g/l)	TR (l/hr)	TUE (g/l)	RGR (g/g/week)	Succulence	SMF	R:S ratio
0	3.23a	0.04b	349a	0.54ab	1.98a	0.50a	0.22a
4	3.35a	0.06a	189.9ab	0.54a	1.92a	0.47a	0.22a
8	2.43ab	0.06a	142.7bc	0.47bc	1.53ab	0.50a	0.20a
12	1.76b	0.06a	100.1c	0.45c	0.93b	0.54a	0.27a
Irrigation (l/pot/week)							
1.5	4.12a	0.02a	351.70a	0.49a	1.76a	0.51a	0.25a
3	2.27b	0.05b	140.50b	0.50a	1.49a	0.51a	0.22a
4.5	1.69b	0.09c	94.10b	0.51a	1.51a	0.49a	0.22a

Values represent means. Means separated through GLM ANOVA with Tukey HSD test at α = 0.05. Means with the same letter within the column for each main effect are not significantly different. WUE = water use efficiency; TR = transpiration rate; TUE = transpiration use efficiency; RGR = relative growth rate; SMF = shoot mass fraction; R:S ratio = root:shoot ratio

4. CONCLUSION

Arachis hypogea is moderately tolerant of salinity stress and highly tolerant to wide variations in irrigation water volume in greenhouse conditions. The strategies for stress tolerance include increased stomatal resistance and resource re-allocation to roots or better nutrient and water foraging. This groundnut variety can therefore be valorised in cropping systems for food sustainability.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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