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PHYSIOLOGICAL ASPECTS OF YIELD VARIATION AMONG SEVEN GROUNDNUT GENOTYPES CULTIVATED UNDER RAIN-FED CONDITIONS

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ABSTRACT

A field experiment was conducted at two locations, in North Kordofan under rainfed conditions for two consecutive seasons (2005/06 and 2006/07), to study the physiological aspects of yield variation among seven groundnuts (Araichis hypogaea L.), genotypes (Barberton, Sodiri, Gubiesh, ICGV89171, ICGV93296, ICGV86744 and ICGV92126). The parameters related to morpho-physiological traits were measured: growth rate (CGR), relative growth rate (RGR), specific leaf area (SLA), net assimilation rate (NAR), leaf area (LA), leaf area (LAI) and yield. The results of the combined analysis showed that there were no significant (p =0.05) differences among varieties for the measured morpho-physiological traits throughout the season. Mean seasonal pattern of these traits indicated that the maximum LAI, SLA, CGR, RGR and NAR were attained 65 days after planting. Significant varietal differences were observed for pod yield, hay yield, 100-seed weight and pod maturity. The highest pods yields of 551, 545 and 540 kg ha-1 were recorded by Barberton, ICGV89171 and Sodiri, respectively.

Contribution/Originality: This study is one of the very few studies which have investigated the effect of genotypes on growth and yield of groundnut related to morpho-physiological traits in the traditional rain-fed sector of North Kordofan, Sudan

1. INTRODUCTION

Peanuts or groundnut (*Arashis hypogaea L.)*, is an important oilseed crop grown in a wide range of countries over 22 million hectares in the tropical and sub-tropical parts of the world (Mohammed *et al.*, 2018); (El Naim and Eldouma, 2011). The total annual world production of the unshelled nuts amount to about 28 million tons. India, China and U.S.A produce almost 65% of the world production. Other major groundnut producing countries include Nigeria, Senegal, Sudan, Republic of Democratic of Congo and Indonesia. In Sudan, groundnut is an important oil and cash export crop. The area under cultivation the crop is about 0.8 million hectares with an estimated total production of 0.4 million ton (El Naim and Eldouma, 2011). The crop is grown under irrigation in the central clay plains and in the rainfed areas in the sandy soils of western Sudan (Ishag, 1986). About 80% of the area and two third of the national production come from the traditional rainfed sector of western Sudan. In North Kordofan, groundnut comes after sorghum in the area under cultivation. Barberton, Sodiri and Gubiesh, are widely grown cultivars characterized by early maturity, tolerance to drought stress and high pod yield. Several varieties and lines

are tested and evaluated by Elobeid Research Station in western Sudan (El Naim *et al*., 2011). Evaluation studies that carried out for these genotypes have considered only the final economic yield. Putative variations in crop yield among these genotypes may be related to physiological traits. Variability in physiological traits may lead to differences in growth and hence the final yield. The objective of this study is to analyze the growth and development of the recently released varieties and promising groundnut lines. It is hoped that this will assist plant breeders in development and selection of genotypes with higher yield potential.

2. MATERIAL AND METHODS

2.1. Study Area

This experiment was conducted under rainfed conditions for two consecutive seasons (2005/06-2006/07), at two locations in North Kordofan State, Sudan. The first location was Elobeid Research Station farm (12° -13° N, 3°-14° E), while the second location was Elkhor Elabied (22Km south of Elobeid city). General characteristics of the soil at the study locations and rainfall amount and distribution during the study period are presented in Table 1 and Table 2.

Table-1. Soil characteristics of the study area.

Property	Elobeid	Elkhor Elabied
Sand (%)	97	**88**
Clay (%)	2	**8**
Silt (%)	1	**4**
PH (H2O)	7.11	**7.31**
N (ppm)	0.021	0.03
P (ppm)	0.07	0.21

Source: Elobeid Agricultural Research Station (Soil lab).

Table-2. Rainfall (mm) amount and distribution during the experiment period.

Month	Elobeid		Elkhor Elabied	
	2005	**2006**	**2005**	**2006**
June	20	5	14.6	38.8
July	64.5	199.5	56.9	191.2
August	116	140.4	91.9	136.7
September	71.5	56.5	76.7	72.2
October	0	64.5	2.00	47.2
Total	277.4	465.9	242.1	485.7

Source: Elobeid Metrological station.

2.2. Plant Materials

Seven groundnut genotypes were used in the study. Names, botanical type, origin and seed sources of these genotypes are presented in Table 3. The treatments were arranged in a randomized complete block design (RCBD) with four replications. The experimental plot consisted of 6 rows, each was 5 meter long .Spacing was 60 cm between rows and 20 cm within the row, with two seeds per hole. Before sowing seeds were treated with fernisan-D at a rate of 3g/kg of seeds to prevent fungal diseases and insect damage. Sowing date was at (13/July- 25/July) in the first season and (10/July-15/July) in the second season. The experiments were weeded twice, after two weeks, and four weeks from sowing. The crop was harvested after 90 days in each location for each season. During the growing period, samples were taken at 15 days interval until harvest. The plants' samples were randomly taken from one meter a long one of the three eastern rows in the plot.

Table-3. General description of the tested genotypes.

Genotype	Branching pattern	Botanical type	Origin	Seed source
Sodiri	Sequential	Spanish	U SA	ARC, Elobeid
Barberton	Sequential	Spanish	India	ARC, Elobeid
Gubiesh	Sequential	Spanish	Sudan	ARC, Elobeid
ICGV92126	Alternate	Virginia	ICRISAT	ARC, Elobeid
ICGV86744	Sequential	Spanish	ICRISAT	ARC, Elobeid
ICGV89171	Sequential	Spanish	ICRISAT	ARC, Elobeid
ICGV93296	Sequential	Spanish	ICRISAT	ARC, Elobeid

*ACRISAT: International Crop Research Institute for the Semi Arid Tropic.

2.3. Morpho-Physiological Traits

These characters were measured according to formulas suggested by Osman (2003). Traits measured were:

1- Leaf area (LA): Leaves from one plant were collected and their area was measured by the leaf area meter (Model AM 101.001). Then, these leaves and the leaves of the all sampled plants were dried and weighed. Using area to weight ratio, the total leaf area was calculated and then leaf area index was determined.

3- Crop growth rate (CGR) :(g/day)

$$CGR = \frac{W2\_W1}{T2\_T1}$$

Where: W: Dry weight T: Time of sample

4- Relative growth rate (RGR): (g/g/day)

$$RGR = \frac{logw2\, log\, w1}{T2-T1}$$

Where: W: dry weight T: time of sample

5- Specific leaf area (SLA): (cm^2/g):

$$SLA = \frac{LA1+LA2}{W1+W2} \div 2$$

Where: LA: leaf area W: leaf weight

6- Net assimilation rate (NAR) ($g/dm^2/day$):

$$NAR = \frac{W2-W1}{LA2-LA1} \times \frac{LogLA2-logLA1}{T2-T1}$$

2.4. Yield and Its Components

1- Number of pods per plant.

2- Number of seeds per pod.

3- 100-seed weight.

4- Maturity (%): after 90 days from planting using the following formula:

$$maturity\ \% = \frac{\text{Mature pods/plant}}{\text{Number of pods/plant}} \times 100$$

5- Shelling (%):

$$shelling\ \% = \frac{\text{Seeds weight /plot}}{\text{Pods weight /plot}} \times 100$$

6- Pods yield/hectare (kg/ha):

$$Pods\ yields\ (kg/ha) = \frac{\text{Weight of pods (kg/plot)}}{\text{Harvest plot area (m2)}} \times 10000$$

7- For hay yield: the formula used the follows:

$$hay\ yield = \frac{\text{Weight of hay (kg)}}{\text{Harvest plot area (m2)}} \times 10000$$

8- Harvest index (%)

$$Harvest\ index = \frac{\text{Pod yield}}{\text{Hay yield} + \text{pod yield}} \times 100$$

2.5. Data Analysis

Single and combined analyses of variance (ANOVA) were carried out using MSTAT- C computer program. LSD was used to separate between means.

3. RESULTS AND DISCUSSION

3.1. Crop Growth Parameters

Seasonal and varietal variation of LA, LAI, SLA, CGR, RGR and NAR is presented in Tables 4 - 9. Leaf area increased rapidly up to 80 days from planting. Thereafter, it started to increase but at a slower rate. Non-significant differences were observed among genotypes in leaf area except at the early stage of development (20 days after planting). At this stage, the highest leaf area of about 74 cm^2 was attained by ICRISAT line ICGV89171 and the lowest of 61cm^2 by ICGV86744. The widely grown genotypes in the area i.e. Barberton, Sodiri and Gubiesh recorded a leaf area between 66 to 69 cm^2. In all genotypes, maximum leaf area was attained at 80 days after planting. It coincided with maximum dry matter production, indicating that dry matter production is highly influenced by the photosynthetic area. Similar results were reported by Maeda (Kvet *et al.*, 1971). He observed that the value of leaf area in Spanish types was 500 to1500 cm^2. In this study mean leaf area was from 68 to 1190cm^2 per plant by the end of the growing period. Across the season, no significant differences were observed among genotypes for LAI, CGR, RGR,SLA and NAR, mean seasonal pattern of these traits indicated that the maximum LAI and CGR were attained around 65 days after planting, whereas, NAR was kept consistently high up to the 65 days from planting where it started to decline. All these traits increased rapidly at the early period of growth reaching their maximum at around 65 days after planting and declined near harvest. Conversely, SLA and RGR were high at the beginning of the growth period and declined towards the end of crop maturity at 80 days after planting. Sanjeev (Maeda, 1971) studied Spanish and Virginia type varieties of groundnut using growth techniques.

Table-4. Leaf area (cm^2) of seven groundnut genotypes at 20, 35, 50, 65 and 80 days after planting.

	Days after planting				
Genotypes	**20**	**35**	**50**	**65**	**80**
Sodiri	66.4	220.5	659.8	952.4	1061.5
ICGV 89171	73.8	256.8	642.9	1154.7	1190.5
Barberton	68.6	235.9	605.2	1156.7	1268.7
ICGV 93296	73.5	213.3	465.1	1079.6	1187.1
Gubiesh	68.0	194.1	555.8	906.3	1174.4
ICGV 86744	60.8	227.9	619.8	1067.3	1137.8
ICGV 92126	65.5	224.4	553.0	1022.9	1324.2
Mean	68.1	224.7	585.9	1048.6	1192.0
SE ±	4.2149*	21.2067^{ns}	65.3096^{ns}	91.6197^{ns}	90.1248^{ns}

Source: Field experiment (2006/2007).

Table-5. Crop growth rate (g/day/plant) of seven groundnut genotypes at 35, 50, 65 and 80 days after planting.

	Days after planting			
Genotypes	**35**	**50**	**65**	**80**
Sodiri	0.100	0.358	0.476	0.435
ICGV 89171	0.113	0.320	0.719	0.348
Barberton	0.142	0.315	0.623	0.491
ICGV 93296	0.087	0.224	0.778	0.404
Gubiesh	0.091	0.418	0.465	0.639
ICGV 86744	0.111	0.299	0.588	0.455
ICGV 92126	0.103	0.272	0.592	0.592
Mean	0.107	0.315	0.606	0.481
SE ±	0.0237^{ns}	0.0517^{ns}	0.0875^{ns}	0.1110^{ns}

Source: Field experiment (2006/2007).

Table-6. Relative growth rate (g/g/day/plant) of seven groundnut genotypes at 35, 50, 65 and 80 days after planting.

	Days after planting			
Genotypes	***35***	***50***	***65***	***80***
Sodiri	0.033	0.032	0.021	0.011
ICGV 89171	0.034	0.031	0.026	0.010
Barberton	0.031	0.033	0.027	0.011
ICGV 93296	0.035	0.028	0.029	0.011
Gubish	0.031	0.037	0.018	0.012
ICGV 86744	0.037	0.030	0.026	0.011
ICGV 92126	0.033	0.029	0.024	0.016
Mean	0.033	0.031	0.025	0.012
SE ±	0.0029^{ns}	0.0028^{ns}	0.0026^{ns}	0.0024^{ns}

Source: Field experiment (2006/2007).

Table-7. Leaf area index of seven groundnut genotypes at 35, 50, 65 and 80 days after planting.

	Days after planting			
Genotypes	***35***	***50***	***65***	***80***
Sodiri	0.303	0.732	0.616	0.470
ICGV 89171	0.305	0.592	0.897	0.498
Barberton	0.279	0.685	1.05	0.387
ICGV 93296	0.233	0.404	1.03	0.377
Gubish	0.215	0.544	0.743	0.532
ICGV 86744	0.279	0.650	0.883	0.415
ICGV 92126	0.325	0.566	0.834	0.674
Mean	0.277	0.596	0.864	0.479
SE ±	0.0457^{ns}	0.1066^{ns}	0.1363^{ns}	0.1701^{ns}

Source: Field experiment (2006/2007).

Table-8. Specific leaf area (cm^2/g/plant) of seven groundnut genotypes at 35, 50, 65 and 80 days after planting.

	Days after planting			
Genotypes	***35***	***50***	***65***	***80***
Sodiri	182.2	183.1	176.6	170.7
ICGV 89171	190.7	190.5	179.4	175.7
Barberton	198.5	197.3	172.5	173.2
ICGV 93296	182.6	177.4	166.4	161.6
Gubish	176.8	172.8	163.2	166.3
ICGV 86744	182.7	188.2	180.5	170.7
ICGV 92126	172.2	173.5	172.9	175.8
Mean	183.7	183.3	173.1	170.6
SE ±	6.0727^{ns}	7.5035^{ns}	5.6102^{ns}	4.2385^{ns}

Source: Field experiment (2006/2007).

Table-9. Net assimilation rate (g/dm^2/day) of seven groundnut genotypes at 35, 50, 65 and 80 days after planting.

	Days after planting			
Genotypes	***35***	***50***	***65***	***80***
Sodiri	0.036	0.033	0.034	0.017
ICGV 89171	0.034	0.033	0.039	0.013
Barberton	0.033	0.034	0.035	0.020
ICGV 93296	0.031	0.031	0.040	0.022
Gubish	0.035	0.040	0.028	0.022
ICGV 86744	0.039	0.039	0.033	0.018
ICGV 92126	0.035	0.033	0.032	0.020
Mean	0.035	0.035	0.034	0.019
SE ±	0.0030^{ns}	0.0038^{ns}	0.0043^{ns}	0.0041^{ns}

Source: Field experiment (2006/2007).

Observation on LAI, GCR, RGR and NAR were taken at 30, 60, 90 (DAP) and at maturity. He observed that CGR increased as crop growth progressed and it was highest between 60 and 90 (DAP) in all studied cultivars except ALA1 and Kadiri 3 (Virginia type) where higher values were recorded between 90 (DAP) and maturity stage). RGR was highest in Kadiri 3 (Virginia type) between 60 and 90 DAP, whereas in ICGS 44 (Spanish type) between 30 and 60 days. NAR value was highest in Kadiri 3 variety between 90 DAP and maturity, and in AK 12 - 24 (Spanish type) between 60 and 90 DAP. They concluded that LAI, RGR, NAR and CGR significantly affected

pod yields in Chitra (Virginia type), had no definite trend in cultivars of the Spanish type. Kathirvelan and Kalaiselvan (Sanjeev and Arvind, 2000) studied growth characters and physiological parameters of four groundnut varieties. The results of their study indicated that the highest yielding varieties had the highest dry LAI, CGR, RGR and NAR. In contrast, Abdalla (1999) found a weak relationship between CGR and yield, yield and total dry matter and yield and leaf area index. He attributed this to poor and variable growth distribution between vegetative and reproductive components.

3.2. Primary and Secondary Branches

As shown in Table 10 and Table 11 numbers of primary branches were not significantly different among genotypes it seems plausible that number of primary branches are genetically determined. Secondary branches were significantly different. Primary branches showed a very slow rate of increase in their number during the growing period, while secondary branches increased at a higher rate. This might be ascribed to the fact that at later stages of crop growth where leaf area reaches its plateau, the plants tend to produce more secondary branches to enhance production of pegs and hence pods. Near the end of the growth period the highest number of secondary branches were recorded by ICRISAT line ICGV93296 and the lowest by ICGV89171.

Table-10. Number of primary branches per plant of seven groundnut genotypes at 20, 35, 50, 65 and 80 days after planting.

	Days after plant				
Genotypes	**20**	**35**	**50**	**65**	**80**
Sodiri	10.0	13.1	15.0	16.6	17.3
ICGV 89171	10.0	13.1	14.5	16.6	16.8
Barberton	9.56	13.1	14.1	16.3	17.9
ICGV 93296	10.3	13.5	14.1	16.7	18.3
Gubish	9.81	13.2	14.4	16.8	17.8
ICGV 86744	10.1	13.5	13.9	16.9	17.9
ICGV 92126	9.69	12.8	14.8	16.3	18.6
Mean	9.92	13.2	14.4	16.6	17.82
SE ±	0.2235^{ns}	0.3239^{ns}	0.3910^{ns}	0.4237^{ns}	0.4770^{ns}

Source: Field experiment (2006/2007).

Table-11. Number of secondary branches per plant of seven groundnut genotypes at 20, 35, 50, 65 and 80 days after planting.

	Days after plant				
Genotypes	**20**	**35**	**50**	**65**	**80**
Sodiri	9.58	21.1	31.0	36.7	39.8
ICGV 89171	9.69	23.7	30.8	39.3	39.0
Barberton	7.75	22.7	26.3	36.5	45.1
ICGV 93296	11.59	28.6	29.1	42.5	57.0
Gubish	8.00	20.7	25.8	34.0	41.3
ICGV 86744	9.67	23.0	26.4	36.9	39.8
ICGV 92126	11.344	21.9	30.9	39.4	54.8
Mean	9.66	23.1	28.6	37.9	45.3
SE ±	0.7901*	1.7124*	2.0295^{ns}	2.3715^{ns}	2.6426*

Source: Field experiment (2006/2007).

3.3. Yield and its Components

Yield and yield components of the tested genotypes are shown in Table 12. Significant ($p \leq 0.05$) varietal differences were observed for pod yield, hay yield, 100- seed weight and maturity, while differences in the number of pods per plant, seeds per pod, shelling percentage and harvest index were not significant. The highest pod yield of 551, 545 and 540 kg/ ha was recorded by Barberton, ICGV89171 and Sodiri respectively. The lowest yield of 376 kg/ ha was recorded by ICRISAT line ICGV93296. Barberton cultivar recorded the best hay yield followed by the ICRISAT lines. Sodiri and Gubiesh, the released cultivars recorded a high hay yield of more than 900 kg/ ha. Hundred seed weight of all genotypes, except ICGV93296, ranged between 35 and 38 g. ICGV93296 recorded a 100 seed weight of 41g. The widely grown cultivars i.e. Barberton, Sodiri and Gubiesh recorded almost similar 100 seed weight. Differences in the number of pods per plant, the number of seeds/pod and shelling out-turn were

slight. Maturity among genotypes ranged from 81 to 86%. The highest maturity was recorded by Barberton, while the lowest was recorded by ICRISAT line ICGV93296. Differences in harvest index were slight and not significant. Harvest index of all genotypes ranged between 31 and 35 %. The highest and lowest harvest indices were reported by ICRISAT lines. Studies carried out by Abdalla (Kathirvelan and Kalaiselvan, 2006) showed that the mean pod yield of ICRISAT lines was 500 kg/ha and 570 kg/ha for the released varieties, shelling percentage was 65 % in ICRISAT lines and 68 % for the released varieties, hay yield was 2000 kg/ha for ICRISAT lines and 1950 kg/ha for the released varieties, hundred seed weight ranged from 32 to 37 % in ICRISAT lines and 32 for the released cultivars.

Table-12. Yield and yield components of the seven groundnut genotypes.

Genotypes	Pods/ plant	Seeds/ pod	100 seed weight (g)	Shelling (%)	Harvest index (%)	Pod yield (kg\ha)	Hay yield (kg\ha)	Maturity (%)
Sodiri	23.3	1.78	34.9	59.1	34.4	540	914	84.3
ICGV 89171	19.5	1.78	36.6	58.1	35.1	545	1017	85.8
Barberton	22.7	1.73	34.9	59.1	32.9	551	1072	85.9
ICGV 93296	25.3	1.78	41.3	56.3	31.0	376	768	81.0
Gubish	22.5	1.75	34.8	57.3	33.8	506	953	84.0
ICGV 86744	22.7	1.80	36.6	56.9	34.4	518	979	85.6
ICGV 92126	21.9	1.79	37.9	59.2	32.5	432	836	80.8
Mean	22.6	1.78	36.7	58.0	33.4	495	934	83.9
SE ±	2.0^{ns}	0.025^{ns}	0.59*	2.2^{ns}	1.02^{ns}	30.1*	63.7*	1.35*

Source: Field experiment (2006/2007).

4. CONCLUSION

The results of this study indicated significant varietal variations in pod yield, hay yield, 100-seed weight and maturity. However the Barberton, ICGV89171 and Sodiri cultivars gave the highest pod yield and assumed to better for rain-fed of North Kordofan of Sudan hence the Barberton and Sodri already exist in this environment, so further research studies need to recommend the cultivation of ICGV89171 cultivar in the field with further profound field investigation at the different environments.

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