

Sustainable Production of Groundnut (*Arachis hypogaea* L.) through Screening and Selection of Soil Salinity-Tolerant Genotypes

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ABSTRACT

Crop plants that are tolerant to soil salinity are needed for a sustainable food production in areas where there is salt build-up caused by irrigation practices. Ten groundnut (*Arachis hypogaea* L.) genotypes (ICGY-6M-5236, ICG-IS-11687, ICGY-5M-4746, ICG-IS-6646, ICG-IS- 3584, ICG49-85A, UGA-7-M, RRB12, RMP91 and RMP12) were screened in laboratory and field studies to identify those tolerant to soil salinity. Plants were irrigated with 0 (control), 25, 50, 100, 150 and 200 mM NaCl solution, prepared artificially from table salt. Germination rate and percentage germination decreased with increasing salinity. RRB12, RMP91 and RMP12 did not germinate up to 200 mM while others germinated with low percentages. Agronomic characters were significantly reduced by salinity above 50 mM NaCl. Biomass and growth decreased with increasing salinity. Mortality of 25-40 % was caused at 150 mM but only ICGY-5M-4746 and ICG-IS-6646 did survive at 200 mM with 52.17 and 55.16 %, respectively. Plants irrigated with saline water had lower yield than the control. However, ICGY-5M-4746 did not produce pods at 200 mM while ICG-IS-6646 produced pods without seeds at maturity. There was a large variation in germination, plant survival and yield among the genotypes. ICGY-5M-4746, ICG-IS-6646 and ICG-IS-3584 with high survival and yield under high salinity were identified as salt tolerant genotypes and recommended for planting in soil with salinity below 200 mM NaCl. The traits from the salt tolerant genotypes could be a source for developing salt tolerant variants for improvement in groundnut production.

Keywords: *Arachis hypogaea* , genotypes, soil salinity, germination, growth, survival, yield, tolerance.

1. INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is an annual plant belonging to Fabaceae family. It is grown in an area of about 26 million hectares (m ha) in more than 100 countries around the world under different agro-climatic conditions, and Nigeria is one of the major producing countries [1]. It was further reported that groundnut is the 13th most important food crop of the world, the world's 4th most important source of edible oil and 3rd most important source of vegetable protein. Its seeds contain high quality edible oil (50%), easily digestible protein (25%) and carbohydrate (20%). It has a total production of 36.1 million metric tons worldwide at an average productivity of 1.4 metric tons/ha. Globally, 50% of groundnut produced is used for oil extraction, 37% for confectionery use and 12% for seed purpose. Its haulms (vegetative plant part) also provide excellent hay for feeding livestock [1].

In arid and semi-arid regions of the world, [yield](#) [relies](#) largely on irrigation practices for crop production. Unfortunately, some of the water for irrigation purposes contain salt, which builds up in soil over a period of time. Soil salinization is a fast growing problem of agriculture, with about 23% of the world's cultivated land being saline, causing reduction in crop productivity and loss of arable land [2]. Soil salinity has been widely reported to negatively affect germination, growth and yield of many crop plants [3-6]. Unfortunately, this problem will continue as long as irrigation is being practiced, and it is expected that there would be about 30% arable land loss within the next 25 years due to salinity [2]. Therefore, selection of salt tolerant genotypes has become a necessity for sustainable crop production.

Meanwhile, it was reported that groundnut is one of the major oilseed crops, with the largest area in the world. Its area and production has reduced greatly, fluctuating between 6.0 – 8.5 m ha and 6.0 – 9.5 million tonnes, respectively, due to climatic variations, biotic influence and abiotic stresses [7]. Thus, it was proposed that soil salinity must have contributed to its reduced areas of cultivation and total productivity; hence selection of salt tolerant genotypes becomes a necessity to cope with its demand for food and industrial use. This selection will alleviate salinity stress and bring about more areas ~~for~~ suitable for groundnut cultivation. This research is aimed at selecting salt tolerant accessions by investigating germination, growth and yield performance of 10 groundnut genotypes from Nigeria.

2. MATERIALS AND METHOD

2.1 Groundnut genotypes

The ten genotypes were from different research centers within Nigeria. ICGY-5M-4746, ICG-IS-11687, ICGY-6M-5236, RRB12, RMP12 and RMP91 were from Zaria, ICG49-85A and UGA-7-M from UNAAB (University of Agriculture Abeokuta), while ICG-IS-6646 and ICG-IS-3584 were from UNILORIN (University of Ilorin).

2.2 Preparation of saline water

Concentrations of 25, 50, 100, 150 and 200 mM NaCl saline solutions were prepared in plastic kegs just before each treatment by dissolving weighed amount of commercially available salt in tap water to make the desired concentrations. One molar solution was prepared by dissolving 58.5 g (molar mass of NaCl) in water to make 1 litre. This quantity (58.5 g) was divided by 1000 to make 1 mM solution, and was subsequently multiplied by the desired value of mM and number of litres to be prepared, to account for the amount of salt to be dissolved in water.

2.3 Germination experiments

Twenty seeds of each genotype were placed on 2 layers of Whatman No. 1 filter papers soaked with the different saline solutions in petri dishes. Each treatment was replicated 3 times and arranged on laboratory bench at room temperature, in the Department of Plant Science and Biotechnology, Adekunle Ajasin University, Akungba Akoko, Ondo State Nigeria (7°37'N latitude, 5°44'E Longitude). The seeds were observed daily and germination was defined as emergence of radicle. The day of initiation of germination after sowing and the percentage of seeds that germinated at the end of the experiment were recorded.

2.4 Field preparation and experimental set up

The study was conducted at the experimental farm of Plant Science and Biotechnology Department, Adekunle Ajasin University, Akungba Akoko, Ondo State, Nigeria ($7^{\circ}37'N$ latitude, $5^{\circ}44'E$ Longitude and 100 m above the mean sea level). The soil had 5.60 pH, 6.19% clay, 4.29% silt, 89.7% sand, 2.89% C, 0.14% N, 9.02 mg/100 g P, 6.24 mg/100g Ca, 1.84 mg/100 g Mg, 0.34 mg/100 g Na, 0.23 mg/100 K, 0.20 mg/100 g H and 8.86 mg/100g CEC. The field was prepared manually, and seedlings of the different genotypes of *A. hypogaea* were raised following recommended agronomic practices. Each genotype was sown in single row plots, seeds spaced at 20 cm with inter-row spacing of 45 cm. Twenty days after seedling emergence, plants were thinned to one plant every 45 cm. The experiment was conducted in randomized block design (RBD) with 5 replications. Seedlings were irrigated with saline water with 0 (control), 25, 50, 100, 150 and 200 mM NaCl. Irrigation was done at the root zone of the plant to ensure that the relative level of soil salinity would be the primary cause of any observed effect rather than combined effect of soil and air-borne salinity. To prevent osmotic shock, plants were irrigated at the root zone by gradual 25 mM increments at 2-day intervals to reach the maximum salinity level of 200 mM NaCl after 14 days [8]. Survival, growth and yield of *A. hypogaea* at the different salinity levels were recorded after 12 weeks of treatment.

2.5 Survival and growth determination

Plant survival was monitored till the end of the experiment (12 weeks after treatment), which was equivalent to 114 days after sowing. Plant height was measured with meter rule. The leaves and primary branches on individual plants were counted. At maturity, pods were harvested and the vegetative plant parts were oven-dried and weighed.

2.6 Yield measurement

Fresh pods were sun dried at harvest. Number of pods per plant, number of seeds per pod, number of seeds per plant and 100 seed mass were recorded.

2.7 Statistical Analysis

Data were subjected to single factor ANOVA and means were separated with Tukey Honest Significant Difference (HSD) test using SPSS version 17.0 software (SPSS Inc., Chicago, IL, USA) at 95% level of significance.

3. RESULTS

The results indicated that salinity delayed germination and reduced germination percentage with large genotypic variations (Table 1). Salinity of 25-50 mM did not delay germination but higher concentrations delayed germination by 1-2 days depending on the genotype. Salinity considerably reduced percentage germination in the genotypes. However, RRB12, RMP91 and RMP12 did not germinate up to 200 mM, others germinated but with low percentages. Plant mortality increased with [an](#) increase in salinity in water used for irrigation (Table 1). Mortality varied with genotypes. Salinity below 60 mM did not cause mortality in any of the genotypes but higher level did, which increased with [an](#) increasing salinity. The lowest mortality of 24.14 and 24.56%

were obtained at 150 mM for ICGY-5M-4746 and ICG-IS-6646, respectively. In addition, only the two genotypes did survive at 200 mM with 52.17 and 55.16 %, respectively.

Table 1: Germination performance and survival of groundnut (*Arachis hypogaea*) genotypes under salinity stress.

Groundnut genotype	Percentage germination						Days of initiation of germination						Plant percentage survival					
	0	25	50	100	150	200	0	25	50	100	150	200	0	25	50	100	150	200
ICG- IS-6646	100 ^a	100 ^a	100 ^a	90.34 ^a	68.86 ^b	48.88 ^b	3.12 ^a	3.04 ^a	3.3 ^a	4.06 ^{ab}	4.07 ^{ab}	4.05 ^{ab}	100	100	98.23	85.75	75.82	55.16
ICG- IS-3584	100 ^a	100 ^a	100 ^a	80.70 ^a	60.54 ^b	56.67 ^b	3.03 ^{ab}	3.06 ^{ab}	3.06 ^{ab}	4.00 ^a	4.04 ^a	4.00 ^a	100	100	85.74	74.23	60.02	-
ICGY-5M- 4746	100 ^a	100 ^a	100 ^a	89.55 ^a	64.33 ^b	31.71 ^c	3.11 ^b	3.11 ^b	3.05 ^b	5.04 ^a	5.00 ^a	5.00 ^a	100	100	97.57	81.34	72.44	52.17
ICG-IS- 11687	100 ^a	100 ^a	97.75 ^a	80.23 ^a	49.75 ^b	52.34 ^b	3.21 ^b	3.21 ^b	3.04 ^b	4.05 ^{abb}	5.00 ^a	6.03 ^a	100	100	86.84	72.20	60.20	-
ICG49-85A	100 ^a	100 ^a	92.28 ^a	81.45 ^a	50.34 ^b	27.14 ^c	3.21 ^b	3.21 ^b	3.07 ^b	5.06 ^{ab}	5.02 ^{ab}	6.00 ^a	100	100	87.33	73.00	52.00	-
ICGY-6M- 5236	100 ^a	100 ^a	96.32 ^a	84.74 ^a	51.35 ^b	23.47 ^c	3.10 ^b	3.00 ^b	3.20 ^b	5.00 ^a	5.07 ^a	5.03 ^a	100	100	85.46	75.23	54.04	-
UGA-7-M	100 ^a	100 ^a	92.33 ^a	81.80 ^a	52.12 ^b	32.86 ^{bc}	3.20 ^b	3.04 ^b	3.10 ^b	5.00 ^{ab}	5.00 ^{ab}	6.00 ^a	100	100	84.57	72.00	51.27	-
RRB12	100 ^a	100 ^a	91.25 ^a	83.46 ^a	48.60 ^b	-	3.13 ^b	3.32 ^b	3.05 ^b	4.00 ^a	5.00 ^a	-	100	100	81.38	72.92	50.35	-
RMP12	100 ^a	100 ^a	94.12 ^a	86.65 ^a	48.56 ^b	-	3.04 ^b	3.15 ^b	3.05 ^b	4.02 ^a	4.02 ^a	-	100	100	83.75	75.10	52.62	-
RMP91	100 ^a	100 ^a	92.04 ^a	84.56 ^a	45.90 ^b	-	3.21	3.13	3.06	4.05	5.11	-	100	100	80.88	74.08	53.64	-

In each variable, plants were irrigated with water of **0**= 0 mM NaCl (control), **25**= 25 mM NaCl, **50**= 50 mM NaCl, **100**= 100 mM NaCl, **150**= 150 mM NaCl, **200**= 200 mM NaCl. Each value is a mean of 3 replicates.

Plant height, number of leaves, number of nodes on primary stem, number of primary branches and biomass of vegetative parts were lower under salt stress than in control (Tables 2 and 3). The decrease in the growth parameters occurred in all the genotypes, with increase in the concentration of salt in water of irrigation. Data could not be taken for the genotypes at 200 mM as a result of complete mortality, except ICGY-5M-4746 and ICG-IS-6646 that survived.

Table 2: Plant height, number of leaves and number of nodes on primary branches of groundnut (*Arachis hypogaea*) genotypes under salinity stress.

Groundnut genotype	Plant height (cm)						Number of leaves/plant						Number of nodes on primary stem					
	0	25	50	100	150	200	0	25	50	100	150	200	0	25	50	100	150	200
ICG- IS-6646	20.64 ^a	19.18 ^a	18.69 ^a	18.01 ^a	17.33 ^a	12.76 ^b	46.31 ^a	45.85 ^a	45.39 ^a	42.62 ^a	41.01 ^a	22.65 ^a	28.45 ^a	26.44 ^a	25.77 ^a	24.83 ^a	21.89 ^a	9.21 ^b
ICG- IS-3584	20.64 ^a	20.64 ^a	20.13 ^a	17.49 ^{ab}	15.46 ^{ab}	-	45.72 ^a	45.72 ^a	44.59 ^a	38.74 ^b	34.01 ^b	-	27.11 ^a	27.11 ^a	26.44 ^a	22.97 ^{ab}	20.30 ^{ab}	-
ICGY-5M-4746	19.65 ^a	18.63 ^a	18.35 ^a	17.24 ^a	15.85 ^a	12.15 ^b	46.23 ^a	46.00 ^a	44.63 ^a	42.57 ^a	39.82 ^{ab}	16.23 ^b	25.76 ^a	24.42 ^a	24.06 ^a	22.60 ^a	18.78 ^{ab}	7.43 ^b
ICG-IS-11687	19.69 ^a	18.51 ^a	18.04 ^a	16.62 ^{ab}	14.27 ^{ab}	-	41.00 ^a	40.60 ^a	37.99 ^a	35.98 ^a	25.73 ^b	-	25.81 ^a	24.26 ^a	23.65 ^a	21.79 ^a	18.70 ^b	-
ICG49-85A	19.71 ^a	19.42 ^a	19.12 ^a	18.39 ^a	9.12 ^b	-	44.45 ^a	41.79 ^a	40.72 ^a	40.99 ^a	31.94 ^b	-	27.97 ^a	27.55 ^a	27.14 ^b	26.09 ^b	12.94 ^c	-
ICGY-6M-5236	19.71 ^a	19.32 ^a	18.26 ^a	17.29 ^a	12.27 ^b	-	40.00 ^a	39.40 ^a	38.81 ^a	37.31 ^a	18.51 ^b	-	25.72 ^a	25.22 ^a	23.83 ^a	22.57 ^a	16.01 ^b	-
UGA-7-M	20.48 ^a	20.34 ^a	20.07 ^a	18.58 ^{ab}	11.66 ^b	-	45.55 ^a	45.25 ^a	44.65 ^a	43.44 ^a	25.34 ^b	-	28.14 ^a	27.95 ^a	27.58 ^a	25.53 ^a	16.03 ^b	-
RRB12	23.07 ^a	22.42 ^a	22.10 ^a	20.63 ^a	13.32 ^b	-	41.14 ^a	40.85 ^a	40.26 ^a	39.39 ^a	21.01 ^b	-	26.33 ^a	25.58 ^a	25.21 ^a	23.54 ^a	15.20 ^b	-
RMP12	22.19 ^a	21.76 ^a	19.60 ^a	18.44 ^a	8.93 ^b	-	41.14 ^a	40.34 ^a	36.33 ^b	36.60 ^b	18.97 ^c	-	24.75 ^a	24.27 ^a	21.86 ^a	20.57 ^a	9.96 ^b	-
RMP91	21.85 ^a	21.70 ^a	21.39 ^a	20.30 ^a	11.16 ^b	-	40.83 ^a	39.68 ^a	39.10 ^a	38.24 ^a	23.58 ^b	-	24.90 ^a	24.72 ^a	24.37 ^a	23.13 ^a	12.71 ^b	-

In each variable, plants were irrigated with water of 0= 0 mM NaCl (control), 25= 25 mM NaCl, 50= 50 mM NaCl, 100= 100 mM NaCl, 150= 150 mM NaCl, 200= 200 mM NaCl. For each parameter, means with the same letter(s)

[in superscript] in the same row are not significantly different at P = 0.05 (Tukey HSD).

Table 3: Number of primary branches and biomass of vegetative parts of groundnut (*Arachis hypogaea*) genotypes under salinity stress.

Groundnut genotype	Number of primary branches						Biomass of vegetative parts (g)					
	0	25	50	100	150	200	0	25	50	100	150	200
ICG-	5.07	4.81	4.73	4.11	4.07	3.27	7.13	6.59	6.46	5.86	5.66	2.13
IS-6646												
ICG-IS-3584	5.26 ^a	5.23 ^a	5.08 ^a	4.84 ^{ab}	3.53 ^{ab}	-	7.42 ^a	7.42 ^a	7.24 ^a	6.29 ^a	5.85 ^{ab}	-
ICGY-5M-4746	5.10 ^a	5.05 ^a	4.73 ^a	4.53 ^a	4.20 ^a	3.02 ^b	5.06 ^a	4.77 ^a	4.70 ^a	4.42 ^a	3.90 ^a	1.67 ^b
ICG-IS-11687	5.04 ^a	4.96 ^a	4.89 ^a	4.89 ^a	2.33 ^b	-	5.45 ^a	5.19 ^a	5.05 ^a	4.66 ^{ab}	4.00 ^{ab}	-
ICG49-85A	5.41 ^a	5.09 ^a	5.02 ^a	4.86 ^{ab}	3.24 ^b	-	7.97 ^a	7.11 ^a	7.00 ^a	6.73 ^{ab}	4.25 ^b	-
ICGY-6M-5236	5.06 ^a	5.03 ^a	4.96 ^{ab}	4.83 ^{ab}	2.81 ^c	-	5.38 ^a	4.54 ^a	4.29 ^a	4.06 ^{ab}	3.13 ^b	-
UGA-7-M	5.23 ^a	5.19 ^a	5.12 ^a	5.01 ^a	2.67 ^b	-	8.04 ^a	7.44 ^a	7.00 ^a	6.80 ^{ab}	4.42 ^b	-
RRB12	5.50 ^a	5.39 ^a	4.93 ^{ab}	4.89 ^{ab}	2.54 ^b	-	4.46 ^a	3.95 ^{ab}	3.55 ^{ab}	3.40 ^{ab}	2.37 ^b	-
RMP12	5.71 ^a	5.60 ^a	5.12 ^a	5.08 ^a	2.63 ^b	-	4.47 ^a	4.12 ^a	3.68 ^{ab}	3.19 ^{ab}	1.42 ^b	-
RMP91	5.71 ^a	5.55 ^a	5.47 ^a	5.35 ^a	3.30 ^b	-	4.45 ^a	3.85 ^{ab}	3.49 ^{ab}	3.27 ^{ab}	2.03 ^b	-

In each variable, plants were irrigated with water of 0= 0 mM NaCl (control), 25= 25 mM NaCl, 50= 50 mM NaCl, 100= 100 mM NaCl, 150= 150 mM NaCl, 200= 200 mM NaCl.

For each parameter, means with the same letter(s) [in superscript] in the same row are not significantly different at P = 0.05 (Tukey HSD).

Generally, salinity negatively affected yield with yield parameters decreasing as salt concentration increased (Tables 4 and 5). The number of pods and related yield traits produced by *A. hypogaea* irrigated with saline water showed extreme variations among genotypes (Table 4). Of the 2 genotypes that survived at 200 mM, ICGY-5M-4746 did not produce pods while ICG-IS-6646 produced pods without seeds.

Table 4: Yield performance of groundnut (*Arachis hypogaea*) genotypes under salinity stress.

Groundnut genotype	Number of pods/plant						Number of seeds/pod						Number of seeds/plant					
	0	25	50	100	150	200	0	25	50	100	150	200	0	25	50	100	150	200
ICG-IS-6646	18.12 ^a	16.23 ^a	13.04 ^b	11.45 ^b	9.10 ^{bc}	4.21 ^c	2.01 ^a	2.01 ^a	1.97 ^b	1.85 ^b	1.78 ^b	0.00 ^c	36.42 ^a	32.62 ^a	25.69 ^b	21.18 ^b	18.20 ^c	0.00 ^d
ICG-IS-3584	15.23 ^a	13.12 ^a	11.23 ^b	9.36 ^{bc}	5.20 ^c	-	2.03 ^a	2.03 ^a	1.98 ^b	1.72 ^b	1.51 ^b	-	30.92 ^a	26.63 ^b	22.24 ^b	16.10 ^c	8.85 ^d	-
ICGY-5M-4746	16.13 ^a	15.53 ^a	13.11 ^a	6.70 ^b	7.07 ^b	-	2.02 ^a	2.02 ^a	1.95 ^b	1.86 ^b	1.74 ^b	-	32.58 ^a	31.37 ^b	25.56 ^b	19.11 ^c	16.30 ^c	-
ICG-IS-11687	15.42 ^a	14.44 ^a	9.55 ^b	6.90 ^{bc}	4.18 ^{bc}	-	1.67 ^a	1.67 ^a	1.55 ^a	1.50 ^a	1.00 ^a	-	25.75 ^a	24.11 ^a	14.80 ^b	10.35 ^b	4.18 ^c	-
ICG49-85A	18.53 ^a	15.31 ^a	6.30 ^b	5.23 ^b	3.22 ^c	-	2.04 ^a	2.04 ^a	1.89 ^b	1.81 ^b	1.28 ^b	-	37.80 ^a	31.23 ^b	13.08 ^c	9.47 ^{cd}	4.12 ^d	-
ICGY-6M-5236	16.23 ^a	13.61 ^a	9.20 ^{ab}	4.48 ^b	3.11 ^c	-	1.34 ^a	1.32 ^a	1.30 ^a	1.30 ^a	0.62 ^b	-	21.75 ^a	17.97 ^b	12.50 ^c	5.82 ^d	1.93 ^e	-
UGA-7-M	18.11 ^a	13.45 ^{ab}	8.72 ^c	4.24 ^{cd}	2.20 ^d	-	1.51 ^a	1.50 ^a	1.48 ^a	1.44 ^a	0.84 ^b	-	27.35 ^a	20.18 ^b	12.91 ^c	6.11 ^d	1.85 ^e	-
RRB12	15.70 ^a	13.62 ^a	7.28 ^b	6.03 ^b	2.23 ^c	-	1.41 ^a	1.41 ^a	1.38 ^a	1.35 ^a	0.72 ^b	-	22.14 ^a	19.20 ^b	10.05 ^c	8.14 ^c	1.61 ^d	-
RMP12	16.10 ^a	14.14 ^a	6.67 ^b	5.03 ^b	3.08 ^c	-	1.54 ^a	1.53 ^a	1.38 ^a	1.37 ^a	0.71 ^b	-	24.79 ^a	21.63 ^a	9.20 ^b	6.89 ^{bc}	2.19 ^d	-
RMP91	15.04 ^a	13.09 ^a	7.75 ^b	3.05 ^c	1.06 ^d	-	1.42 ^a	1.42 ^a	1.40 ^a	1.39 ^a	0.82 ^b	-	21.36 ^a	18.59 ^b	10.85 ^c	4.24 ^d	1.87 ^e	-

In each variable, plants were irrigated with water of 0= 0 mM NaCl (control), 25= 25 mM NaCl, 50= 50 mM NaCl, 100= 100 mM NaCl, 150= 150 mM NaCl, 200= 200 mM NaCl. For each parameter, means with the same letter(s)

[in superscript] in the same row are not significantly different at P = 0.05 (Tukey HSD).

Table 5: 100 seed mass of groundnut (*Arachis hypogaea*) genotypes under salinity stress.

Groundnut genotype	100 seed weight (g)					
	0	25	50	100	150	200
ICG-IS-6646	42.17 ^a	42.17 ^a	44.05 ^a	34.65 ^b	33.46 ^b	-
ICG-IS-3584	42.34 ^a	42.34 ^a	42.13 ^a	35.87 ^b	33.37 ^b	-
ICGY-5M-4746	41.74 ^a	41.74 ^a	41.15 ^a	36.45 ^b	32.14 ^b	-
ICG-IS-11687	38.46 ^a	38.46 ^a	35.43 ^a	28.20 ^{ab}	16.55 ^b	-
ICG49-85A	37.68 ^a	37.68 ^a	36.41 ^a	29.28 ^{ab}	20.11 ^b	-
ICGY-6M-5236	38.18 ^a	38.18 ^a	36.57 ^a	28.84 ^{ab}	12.57 ^c	-
UGA-7-M	37.66 ^a	37.66 ^a	32.78 ^a	27.20 ^b	20.69 ^b	-
RRB12	36.76 ^a	35.82 ^a	29.22 ^b	28.04 ^b	18.85 ^c	-
RMP12	36.74 ^a	36.29 ^a	31.81 ^a	25.31 ^a	16.13 ^c	-
RMP91	37.14 ^a	37.14 ^a	31.41 ^a	25.91 ^b	16.51 ^c	-

In each variable, plants were irrigated with water or 0= 0 mM NaCl (control), 25= 25 mM NaCl, 50= 50 mM NaCl, 100= 100 mM NaCl, 150= 150 mM NaCl, 200= 200 mM NaCl. For each

parameter, means with the same letter(s) [in superscript] in the same row are not significantly different at P = 0.05 (Tukey HSD).

4 DISCUSSION

Reduction in percentage germination and delay in germination at high salt concentration in this study is in line with many previous results. Seed germination of most non-halophytes may be inhibited by 0.5% salt [9]. Sodium chloride (NaCl) at osmotic tension of 0.0625 and 0.125 MPa did not have significant effects on germination of *Sesamum indicum*, but higher osmotic tensions of 0.250 and 0.500 MPa significantly reduced the percentage germination compared to the control. The few seeds that germinated at 0.500 MPa were weak and chlorotic and did not proceed with radicle elongation and shoot development [10]. Negative effect of salinity on germination was also observed in guar [11]. Salinity influences seed germination primarily by lowering the osmotic potential of the soil solution sufficiently to retard water absorption by seeds [12]. Destruction and weakness of embryo by salt toxicity [13] must have been responsible for the delay and a reduction in percentage germination recorded in this study.

Salinity caused accumulation of salt in the root zone and hence, its effect started with [an](#) imbibition of seed as soon as it came in contact with saline water. The tolerance is a relative term depending mainly upon the intensity of salinity and relative performance of genotypes. Soil salinity has been earlier reported to cause death in several plants; *Secale cereale* [5], *Hordeum vulgare* [14] and *Coriandrum sativum* [15]. Growth reduction under salinity stress has been reported in *Triticum dicoccum farrum* [5], *Oryza sativa* [3], *Vigna subterranea* [16] and *Coriandrum sativum* [15]. Many nutrients have essential roles in the process of cell division and cell extension and those would cease soon after the supply were halted, especially in tissues with little nutrient storage [17]. The growth reduction in *A. hypogaea* can therefore be attributed to disturbed/imbalance nutrition. Plant height was also reduced by salinity in *Nigella sativa* [18], which was attributed to suppression of internode growth. Decrease in plant height might be due to [a](#) reduced photosynthesis, which in turn limited the supply of carbohydrate needed for growth [17]. Growth decrease might have resulted from reduced turgor in expanding tissues caused by reduced water potential in root growth medium [2, 19]. A decrease in the number of leaves under salt stress was due to leaf abscission, senescence and defoliation, coupled with an inhibition of lateral branches bearing the leaves, caused by Na⁺ and Cl⁻ toxicity [20]. Expectedly, a decrease in plant parts culminated in reduced biomass. Soil salinity has been shown to negatively affect yield in *Brassica napus* [21], *Hordeum vulgare* [14] and a local variety of *Arachis hypogaea* [22]. A decrease in pod number was associated with an increase in ABA and pollen death. Pod size was reduced, leading to a decrease in the number of seeds. It was reported that, the significant decrease of yield components under salt stress in cowpea was partly related to a significant reduction of foliar chlorophyll contents, more than 50% essential for fruit production. A decrease in the number of leaves limited surface area available for light interception for photosynthetic activities, with consequential effect on growth and productivity [4, 22].

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Comment [K1]: more recent data should be cited

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