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# Effects of Salinity Stress on Growth, Ions Partitioning and Yield of Some Cowpea (*Vigna unguiculata* L. Walp.) Cultivars

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**Abstract:** In this study, twenty one cowpea cultivars (*Vigna unguiculata* L. Walp.) were tested for their salt tolerance at different degrees of salinity; 0, 50, 100 and 200 mM of NaCl, in both the laboratory and field conditions. In the laboratory, $Na^+$, $K^+$, K/Na ratio, plant height, roots dry weights, stems and leaves were investigated. In the field conditions, yield components (weight of 1000 seeds, number of pods per plant, total chlorophyll and grains yield) were determined in harvesting phase. Results showed that $K^+$ concentration, K/Na ratio, seedlings height and total chlorophyll were significantly decreased by salt solutions, especially by 200 mM and the magnitude of reduction varied according to cultivars. $Na^+$ was significantly increased with increasing NaCl concentrations in all plant organs. Roots dry weights as well as stems and leaves decreased significantly in all cultivars with increasing salinity except in organs of Bambey 21 (V11), IT97K-556-4 (V3) and IT04K-332-1 (V10) cultivars. Under field conditions, the weight of 1000 seeds, the number of pods per plant and grains yield were affected by soil salinity at 50 mM of all cultivars except in Bambey 21, IT97K-556-4 and IT04K-332-1. The results obtained during vegetative growth and harvesting phase suggested that Bambey 21, IT97K-556-4 and IT04K-332-1 cultivars were relatively tolerant to salinity than others. Bambey 21, IT97K-556-4 and IT04K-332-1 cultivars could be grown in environments with varying salinity.

**Key words:** Cowpea, ionic distribution, plant organs, salt-tolerant

## INTRODUCTION

Cowpea (*Vigna unguiculata* L. Walp.) is an important food crop in west and Central Africa. The high protein content of cowpea (20 to 28%) makes it an important supply to the diet of many African people (Giami *et al*., 2001). Apart from their nutritional value cowpeas contribute to the soil nitrogen status through symbiotic $N_2$ fixation, thereby enhancing soil fertility (Martins *et al*., 2003). In addition, cowpea is considered to be less prone to drought damage and has a high yield potential especially when P fertilizers are applied (Jemo *et al*., 2006).

Salinity affects 7% of the world's land area for around 930 million ha (Munns, 2002). Salinity is one of the most serious factors limiting crops production, especially the sensitive ones (Zadeh and Naeini, 2007). Currently, high soil salinity affects the agricultural production in a large proportion in the world's territorial areas (Zhang and Hodson, 2001). Salinity reduces the ability of plants to take up water, leading to growth reduction as well as metabolic changes similar to those caused by the water stress (Munns, 2002). High salt concentration in root affects the growth and yield of many important crops (Alam *et al*., 2004; Taffouo *et al*., 2004). The salinity may reduce the crop yield by upsetting water and nutritional balance of plant (Khan *et al*., 2007). Water availability and nutrient uptake by plant roots is limited because of high osmotic potential and toxicity of $Na^+$ and $Cl^-$ ions (Al-Karaki, 1997). Thus, excessive uptake of Na and $Cl^-$ may lead to ionic disturbance of whole plants (Munns, 2002).

Agricultural soils have many types of salt ions. However, NaCl is usually the damaging and predominant salt (Turan *et al*., 2007a). Although, adaptation of plants to salinity is associated with osmotic adjustment (Turan *et al*., 2007b), they widely differ from the extend to which they accumulate inorganic ions (Munns, 1993). Osmotic regulators in plants include potassium, soluble sugar, proline and betaine (Le Rudulier, 2005). These molecules are important physiological indicator for evaluating osmotic adjustment ability (Zhu, 2002). The common methods of cultivation include the use of salt-tolerant cultivars, the soil and water reformation to meet the crops requirements and the use transgenic plants g6 (Puppala *et al*., 1999).

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In the soudanosahelian agro ecological area, the soil has a ferruginous nature. This zone covers a large part of Northern Cameroon and is considered to be fragile, with low levels of soil fertility due to very sandy structure. The most important processes of degradation are changes in salinity due to irrigation with brackish water (Mando *et al*., 2001). In order to overcome the adverse effects of salinity on growth and yield, the mineral fertilizers is generally used. However, the success of this practice is influenced by the degree of soil salinity. Identifying crop varieties that are able to grow and develop in saline medium is the one of the possible ways to address this constraint.

This research was carried out to evaluate the salt-tolerance at vegetative growth and harvesting stages of some cowpea cultivars and identification of salt tolerant ones.

## MATERIALS AND METHODS

This research was conducted in laboratory and field conditions in Douala, Cameroon, between January to December, 2007. Twenty one cowpea cultivars (*Vigna unguiculata* L. Walp.) were used in this experiment: ten (IT97K-573-1-1: V1; IT97K-573-2-1: V2, IT97K-556-4: V3, IT98K-615-6-1: V4, IT99K-529-2: V5, IT00K-218-22: V6, IT03K-337-6: V7, IT04K-227-2: V8, IT04K-321-2: V9, IT04K-332-1: V10) were from International Institute of Tropical Agriculture (IITA, Ibadan); Four (Bambey 21: V11, Mouride: V12, Mougne: V13 and Melakh: V14) from Senegalese Institute of Agronomic Research (ISRA); two (Ife Brown: V15 and Vita-5: V16) from Agronomic Institute for Research and Development (IRAD, Dschang) and five (Garoua GG: V17, Garoua PG: V18, Mouola GG: V19, Mouola PG: V20 and Tsacre: V21) from the rural area of Cameroon. The experiment was conducted in the Faculty of Science, University of Douala under semi-controlled conditions (temperature: 26±3°C; light: 5000 lux during 12 h; relative humidity: 51-70%). The soil used consisting of sandy loam soil was from the University of Douala research farm with the physical and chemical characteristics described in Table 1. In order to investigate the response of 21 cowpea seedling cultivars to NaCl salinity, seeds were first sterilized in 7% sodium hypochlorite solution for 20 min and washed twice with sterile distilled water. The experimental design consisted of a completely randomized factorial design with three replicates. Seeds were pre-germinated in petri-dishes containing wet Watman No. 1 paper. Three days later, seedlings presenting their first couple of leaves were transferred in pot filled with 1000 g of sand previously cleaned and rinsed respectively in HCl and distilled water.

Table 1: Physiological and chemical characteristic of soil (0-20 cm of depth)

| Elements | Contents |
|---|---|
| Clay (%) | 14.20 |
| Coarse sand (%) | 27.90 |
| Fine sand (%) | 25.60 |
| Coarse silt (%) | 26.00 |
| Fine silt (%) | 5.40 |
| Carbon (%) | 0.28 |
| Nitrogen (%) | 0.80 |
| Ratio C/N | 0.35 |
| Assimilable phosphorous (ppm) | 4.83 |
| Exchangeable potassium (g $kg^{-1}$) | 0.33 |
| Exchangeable sodium (g $kg^{-1}$) | 0.14 |
| Exchangeable calcium (g $kg^{-1}$) | 0.40 |
| pH-water | 5.72 |

Otherwise, pots were filled with soil (1000 g) and NaCl solutions were added at 50, 100 and 200 mM concentration, respectively, before seeds were sown into the pots. Plants grown without NaCl addition served as control. Pots were supplied every three days with nutrient solution containing 0.4 mN of $KNO_3$, 0.2 mN of $KH_2PO_4$, 1.0 mN of $Ca_2NO_3$ and 0.4 mN of $MgSO_4$ (Wacquant, 1974). Plants were harvested six weeks later and parameter such as plant height of cowpea seedlings was assessed. Furthermore, leaves, stems and roots were separately dried at 85°C for 48 h and their dry weights determined.

For the analysis of $Na^+$ and $K^+$, three samples each of 50 mg of roots, stems and leaves dry materials were thoroughly grinded and homogenized into 20 mL HCl 1/10 for 24 h. Sodium and potassium concentrations were determined through flame photometer (Jenway).

After weighting the fresh material, plants were washed and 2.0 g of samples were taken for total chlorophyll determination. Total chlorophyll was extracted in 80% (v/v) aqueous acetone and absorption was measured in Thermospertronic He$\lambda$ios $\beta$ model spectrophotometer at 645 and 663 nm (Arnon, 1949).

In the field conditions, parameters such as weight of 1000 seeds, number of pods per plant, total chlorophyll and grains yield were assessed. The trials were conducted on the University of Douala research farm (4°01 N, 9°44 E, altitude: 13 m, total annual rainfall: 3597 mm, temperature: 27°C). The experimental design was a complete randomized block design with two treatments and three replicates. Plots were 10×10 m surfaced. The experimental plots were supplied with 50 mM NaCl and the control with simple distilled water (0 mM NaCl). The trials were carried out in pure culture without fertilization. Plants were watered once a week at a rate of 20 L $m^{-2}$.

Data are presented in term of Mean±SD. Multiple comparison of several means was set up using analysis of variance (ANOVA) and the post-hoc pairwise analysis was set up using the Student-Newman-Keuls procedure when the normality and equal variance conditions passed. Multiple comparisons of data noted in experimental groups *versus* those recorded in the single control group were set up using the Dunnett's procedure (Sigma stat software).

## RESULTS

### Growth parameters

**Dry weights of cowpea organs:** Plant growth was inhibited by soil salinity and roots, stems and leaves dry weights of cowpea cultivars (V1, V2, V4, V6, V7, V8, V9, V19 and V20) decreased significantly ($p<0.05$) at the lowest level of salinity (50 mM NaCl) with the increased amount of NaCl applied (Table 2-4). The growth inhibition effect of the salt was significantly noted at 100 mM NaCl on roots, stems and leaves dry weights of V5, V12, V13, V14, V15, V16, V17, V18 and V21 cultivars. At the highest salt concentration (200 mM NaCl), V3, V10 and V11 showed relatively higher tolerance than others (Table 2-4).

**Plant height:** Plant height of all cultivars was affected by salinity at 200 mM NaCl. Even at the lowest salt concentration (50 mM), plant height after 6 weeks of

Table 2: Effect of salinity on root dry weight (g/plant) of cowpea seedlings 6 weeks after salt application

| | Salinity (mM NaCl) | | | |
|---|---|---|---|---|
| Cultivars | 0 (control) | 50 | 100 | 200 |
| IT97K-573-1-1 | 0.29±0.05 | 0.19±0.07* | 0.18±0.06* | 0.16±0.03* |
| IT97K-573-2-1 | 0.37±0.08 | 0.25±0.05* | 0.22±0.02* | 0.19±0.09* |
| IT97K-556-4 | 0.65±0.03 | 0.67±0.03 | 0.65±0.040 | 0.64±0.05 |
| IT98K-615-6-1 | 0.61±0.04 | 0.45±0.01* | 0.43±0.06* | 0.42±0.05* |
| IT99K-529-2 | 0.43±0.01 | 0.41±0.04 | 0.30±0.05* | 0.18±0.04* |
| IT00K-218-22 | 0.39±0.01 | 0.30±0.07* | 0.27±0.04* | 0.24±0.06* |
| IT03K-337-6 | 0.45±0.06 | 0.31±0.09* | 0.21±0.04* | 0.11±0.03* |
| IT04K-227-2 | 0.70±0.07 | 0.57±0.03* | 0.53±0.02* | 0.42±0.04* |
| IT04K-321-2 | 0.69±0.02 | 0.54±0.04* | 0.45±0.07* | 0.42±0.02* |
| IT04K-332-1 | 0.70±0.03 | 0.72±0.05 | 0.71±0.020 | 0.69±0.07 |
| Bambey 21 | 0.81±0.02 | 0.80±0.04 | 0.79±0.010 | 0.78±0.03 |
| Mouride | 0.28±0.04 | 0.26±0.02 | 0.25±0.030 | 0.16±0.05* |
| Mougne | 0.38±0.06 | 0.39±0.03 | 0.28±0.08* | 0.26±0.01* |
| Melakh | 0.25±0.02 | 0.27±0.01 | 0.19±0.05* | 0.17±0.08* |
| Ife Brown | 0.55±0.04 | 0.52±0.05 | 0.42±0.02* | 0.39±0.06* |
| Vita-5 | 0.42±0.03 | 0.40±0.06 | 0.29±0.06* | 0.26±0.04* |
| Garoua GG | 0.59±0.08 | 0.55±0.03 | 0.42±0.02* | 0.39±0.01* |
| Garoua PG | 0.43±0.04 | 0.41±0.01 | 0.28±0.01* | 0.26±0.06* |
| Mouola GG | 0.29±0.03 | 0.19±0.02* | 0.16±0.01* | 0.15±0.02* |
| Mouola PG | 0.22±0.01 | 0.16±0.06* | 0.14±0.03* | 0.13±0.01* |
| Tsacre | 0.52±0.05 | 0.49±0.04 | 0.35±0.05* | 0.33±0.02* |

Values are expressed as Mean±SE. Based on Dunnett's test, values headed by *differ significantly ($p<0.05$)

Table 3: Effect of salinity on stem dry weight (g/plant) of cowpea seedlings 6 weeks after salt application

| | Salinity (mM NaCl) | | | |
|---|---|---|---|---|
| Cultivars | 0 (control) | 50 | 100 | 200 |
| IT97K-573-1-1 | 1.54±0.12 | 1.41±0.39* | 1.38±0.22* | 1.15±0.13* |
| IT97K-573-2-1 | 1.43±0.35 | 1.22±0.22* | 1.18±0.34* | 1.02±0.19* |
| IT97K-556-4 | 1.46±0.34 | 1.47±0.41 | 1.45±0.32 | 1.44±0.36 |
| IT98K-615-6-1 | 1.52±0.33 | 1.41±0.52* | 1.30±0.25* | 1.22±0.43* |
| IT99K-529-2 | 1.28±0.12 | 1.26± 0.31 | 1.15±0.24* | 105±0.09* |
| IT00K-218-22 | 1.32±0.35 | 1.22±0.08* | 1.20±0.04* | 1.14±0.05* |
| IT03K-337-6 | 1.69±0.24 | 1.51±0.42* | 1.45±0.12* | 1.42±0.23* |
| IT04K-227-2 | 1.44±0.20 | 1.26±0.33* | 1.20±0.11* | 116±0.07* |
| IT04K-321-2 | 1.53±0.45 | 1.40±0.26* | 1.35±0.12* | 1.24±0.17* |
| IT04K-332-1 | 1.51±0.19 | 1.52±0.22 | 1.49±0.34 | 1.51±0.25 |
| Bambey 21 | 1.87±0.41 | 1.90±0.35 | 1.91±0.24 | 1.88±.036 |
| Mouride | 1.66±0.12 | 1.61±0.07 | 1.48±0.06* | 1.45±0.01* |
| Mougne | 1.31±0.21 | 1.27±0.26 | 1.16±0.14* | 1.10±0.11* |
| Melakh | 0.93±0.06 | 0.89±0.05 | 0.77±0.02* | 0.69±0.01* |
| Ife Brown | 1.64±0.34 | 1.58±0.26 | 1.42±0.31* | 1.32±0.28* |
| Vita-5 | 1.65±0.33 | 1.67±0.24 | 1.49±0.14* | 1.31±0.09* |
| Garoua GG | 1.66±0.25 | 1.61±0.19 | 1.45±0.12* | 1.41±0.20* |
| Garoua PG | 1.07±0.35 | 0.99±0.06 | 0.89±0.05* | 0.83±0.05* |
| Mouola GG | 1.34±0.21 | 1.22±0.15* | 1.18±0.01* | 1.15±0.03* |
| Mouola PG | 0.87±0.04 | 0.71±0.07* | 0.62±0.02* | 0.53±0.04* |
| Tsacre | 1.02±0.41 | 0.98±0.08 | 0.76±0.06* | 0.67±0.03* |

Values are expressed as Mean±SE. Based on Dunnett's test, values headed by *differ significantly ($p<0.05$)

Table 4: Effect of salinity on leaf dry weight (g/plant) of cowpea seedlings 6 weeks after salt application

| | Salinity (mM NaCl) | | | |
|---|---|---|---|---|
| Cultivars | 0 (control) | 50 | 100 | 200 |
| IT97K-573-1-1 | 0.84±0.01 | 0.64±0.04* | 0.55±0.05* | 0.43±0.02* |
| IT97K-573-2-1 | 0.72±0.03 | 0.52±0.05* | 0.50±0.07* | 0.39±0.01* |
| IT97K-556-4 | 0.97±0.07 | 1.01±0.09 | 0.98±0.06 | 0.96±0.03 |
| IT98K-615-6-1 | 0.86±0.05 | 0.64±0.02* | 0.62±0.01* | 0.54±0.06* |
| IT99K-529-2 | 081±0.02 | 0.79±0.07 | 0.67±0.06* | 0.56±0.04* |
| IT00K-218-22 | 0.68±0.05 | 0.57±0.02* | 0.55±0.01* | 0.43±0.06* |
| IT03K-337-6 | 0.78±0.07 | 0.61±0.04* | 0.60±0.02* | 0.52±0.08* |
| IT04K-227-2 | 0.94±0.06 | 0.70±0.03* | 0.68±0.08* | 0.32±0.01* |
| IT04K-321-2 | 0.78±0.03 | 0.62±0.04* | 0.56±0.05* | 0.52±0.03* |
| IT04K-332-1 | 0.98±0.04 | 1.01±0.09 | 1.03±0.06 | 0.96±0.05 |
| Bambey 21 | 1.02±0.05 | 1.04±0.05 | 1.05±0.04 | 0.99±0.06 |
| Mouride | 0.69±0.04 | 0.71±0.01 | 0.54±0.03* | 0.30±0.02* |
| Mougne | 0.84±0.06 | 0.81±0.07 | 0.50±0.02* | 0.43±0.04* |
| Melakh | 0.55±0.04 | 0.60±0.02 | 0.47±0.01* | 0.12±0.03* |
| Ife Brown | 0.75±0.05 | 0.79±0.06 | 0.54±0.04* | 0.21±0.02* |
| Vita-5 | 0.82±0.08 | 0.78±0.06 | 0.50±0.04* | 0.23±0.01* |
| Garoua GG | 0.92±0.03 | 0.94±0.04 | 0.58±0.01* | 0.25±0.04* |
| Garoua PG | 0.61±0.05 | 0.68±0.03 | 0.38±0.02* | 0.17±0.05* |
| Mouola GG | 0.95±0.09 | 0.64±0.05* | 0.62±0.03* | 0.50±0.04* |
| Mouola PG | 0.66±0.05 | 0.44±0.03* | 0.40±0.04* | 0.21±0.03* |
| Tsacre | 0.85±0.02 | 0.88±0.05 | 0.69±0.03* | 0.52±0.06* |

Values are expressed as Mean±SE. Based on Dunnett's test, values headed by *differ significantly ($p < 0.05$)

Table 5: Effect of salinity on plant height (cm) of cowpea seedlings 6 weeks after salt application

| | Salinity (mM NaCl) | | | |
|---|---|---|---|---|
| Cultivars | 0 (control) | 50 | 100 | 200 |
| IT97K-573-1-1 | 35.26±1.67 | 26.15±1.04* | 24.20±1.14* | 16.25±1.17* |
| IT97K-573-2-1 | 58.81±1.34 | 42.54±2.84* | 40.23±2.67* | 34.18±1.47* |
| IT97K-556-4 | 32.10±3.82 | 31.75±2.95 | 24.52±2.74* | 21.25±2.45* |
| IT98K-615-6-1 | 38.56±1.45 | 22.36±3.22* | 14.02±1.12* | 10.17±1.03* |
| IT99K-529-2 | 47.85±3.32 | 44.41±2.67 | 19.12±4.01* | 17.12±2.57* |
| IT00K-218-22 | 37.70±1.81 | 20.87±2.84* | 17.62±3.04* | 15.36±1.72* |
| IT03K-337-6 | 48.81±4.21 | 31.45±3.52* | 34.93±1.95* | 29.22±3.01* |
| IT04K-227-2 | 39.50±2.35 | 25.6 ±0.48* | 20.74±1.75* | 17.10±1.05* |
| IT04K-321-2 | 43.30±1.23 | 27.24±2.42* | 25.82±1.39* | 15.35±1.13* |
| IT04K-332-1 | 41.50±1.94 | 40.61±2.03 | 30.32±2.92* | 20.45±3.27* |
| Bambey 21 | 54.42±3.21 | 56.45±1.45 | 52.32±4.10 | 35.63±2.68* |
| Mouride | 64.14±4.52 | 59.24±3.64 | 48.20±2.74* | 25.25±2.06* |
| Mougne | 42.40±2.20 | 39.81±3.40 | 29.34±1.91* | 21.31±2.16* |
| Melakh | 38.50±1.12 | 37.58±3.45 | 21.11±3.21* | 19.23±2.10* |
| Ife Brown | 36.79±2.88 | 37.10±3.72 | 25.15±3.21* | 22.18±1.56* |
| Vita-5 | 67.74±3.46 | 65.98±3.85 | 46.78±2.55* | 29.83±1.91* |
| Garoua GG | 44.55±2.14 | 39.56±2.63 | 27.32±1.11* | 23.13±2.03* |
| Garoua PG | 54.72±2.32 | 55.03±4.53 | 31.32±5.22* | 22.50±1.65* |
| Mouola GG | 87.55±2.12 | 49.75±1.62* | 39.75±1.40* | 43.27±1.80* |
| Mouola PG | 82.14±3.55 | 64.74±3.01* | 59.32±2.70* | 53.87±3.01* |
| Tsacre | 76.24±2.53 | 75.13±4.22 | 68.36±3.21* | 62.22±2.14* |

Values are expressed as Mean±SE. Based on Dunnett's test, values headed by *differ significantly ($p<0.05$)

treatment was significantly reduced compared to control, except for V3, V5, V10, V11, V12, V13, V14, V15, V16, V17, V18 and V21 cultivars (Table 5).

### Ions partitioning

**Sodium, potassium concentrations and K/Na ratio of cowpea organs:** Salinity affected ions concentrations of cowpea cultivars (Fig. 1, 2). Except to Na, K concentrations and K/Na ratio significantly decreased ($p<0.05$) in plant organs with increasing NaCl concentration. Na concentrations was increased with increasing salinity.

### Yield parameters

**Weight of 1000 seeds, number of pods per plant and grains yield of cowpea plants:** Weight of 1000 seeds, number of pods per plant and grains yield of all cowpea cultivars were also affected significantly by NaCl concentration, except for V3, V10 and V11 cultivars (Table 6).

**Total chlorophyll content of cowpea plants:** Total chlorophyll content of cowpea cultivars was also affected significantly ($p<0.05$) by NaCl concentration (Table 6). The NaCl addition in the soil decreased the total chlorophyll concentration in plants.

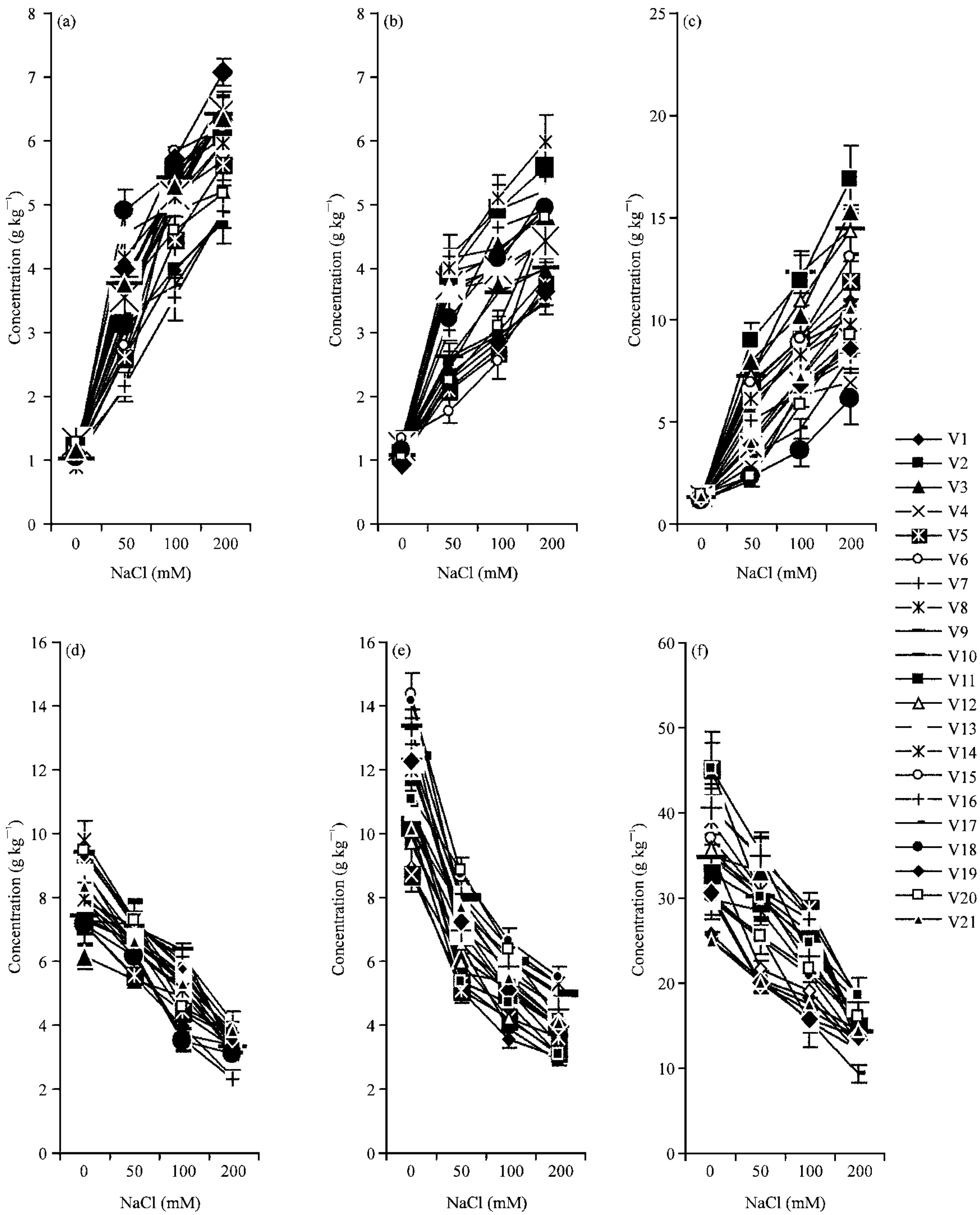


Fig. 1: Effects of NaCl (mM) on $Na^+$ and $K^+$ concentration (g $kg^{-1}$) in root, stem and leaves of twenty one cowpea cultivars grown under saline conditions. (a) $Na^+$ root, (b) $Na^+$ stem, (c) $Na^+$ leaves, (d) $K^+$ root, (e) $K^+$ stem and (f) $K^+$ leaves. V1: IT97K-573-1-1; V2: IT97K-573-2-1, V3: IT97K-556-4, V4: IT98K-615-6-1, V5: IT99K-529-2, V6: IT00K-218-22, V7: IT03K-337-6, V8: IT04K-227-2, V9: IT04K-321-2, V10: T04K-332-1, V11: Bambey 21, V12: Mouride, V13: Mougne, V14: Melakh, V15: Ife Brown, V16: Vita-5, V17: Garoua GG, V18: Garoua PG, V19: Mouola GG, V20: Mouola PG and V21: Tsacre

Table 6: Effect of salinity on yield components of cowpea cultivars in field conditions 12 weeks after salt application

| Cultivars | Salinity levels (mM NaCl) | weight of 1000 seed (g) | Number of pods per plant | Total chlorophyll (mg $g^{-1}$) Fresh weight | Grains yield (kg $ha^{-1}$) |
|---|---|---|---|---|---|
| IT97K-573-1-1 | 0 (control) | 235.3±15.1 | 21.6±1.4 | 8.89±1.10 | 3442.3±305.8 |
| | 50 | 148.5±10.3* | 10.6±1.1* | 4.32±0.92* | 1365.0±275.6* |
| IT97K-573-2-1 | 0 | 275.9±8.7 | 18.8±3.1 | 9.86±1.52 | 2658.5±250.9 |
| | 50 | 206.4±13.9* | 7.2±1.2* | 4.25±0.23* | 1677.9±152.7* |
| IT97K-556-4 | 0 | 259.2±18.1 | 25.4±3.5 | 7.94±1.12 | 3965.5±358.4 |
| | 50 | 275.2±7.2 | 27.6±2.7 | 6.55±0.25* | 3984.8±342.1 |
| IT98K-615-6-1 | 0 | 275.2±12.5 | 17.3±2.2 | 3.12±0.17 | 2656.7±198.2 |
| | 50 | 211.6±11.6* | 8.6±1.5* | 1.98±0.13* | 1623.2±124.3* |
| IT99K-529-2 | 0 | 155.1±9.5 | 18.2±2.1 | 5.61±0.85 | 2186.3±165.8 |
| | 50 | 126.8±12.1* | 10.6±3.1* | 2.75±0.34* | 1115.6±175.6* |
| IT00K-218-22 | 0 | 144.4±15.0 | 23.1±2.4 | 6.52±0.75 | 2358.4±125.7 |
| | 50 | 100.5±5.8* | 12.5±1.9* | 3.13±0.33* | 1285.1±136.4* |
| IT03K-337-6 | 0 | 278.7±14.8 | 20.9±2.0 | 4.15±0.25 | 2875.3±184.3 |
| | 50 | 215.8±16.4* | 9.8±1.3* | 2.05±0.11* | 1634.7±143.7* |
| IT04K-227-2 | 0 | 286.9±19.6 | 14.7±2.1 | 5.30±0.95 | 2594.5±384.9 |
| | 50 | 203.4±15.3* | 5.6±1.2* | 2.56±0.23* | 1125.1±122.5* |
| IT04K-321-2 | 0 | 289.3±21.2 | 20.3±2.5 | 5.86±0.88 | 2632.9±356.8 |
| | 50 | 202.6±19.3* | 13.4±1.7* | 2.65±0.35* | 1531.2±325.4* |
| IT04K-332-1 | 0 | 334.4±24.3 | 24.2±3.4 | 6.25±0.22 | 2894.6±138.2 |
| | 50 | 325.3±22.1 | 25.4±1.6 | 5.01±0.31* | 2911.5±122.6 |
| Bambey 21 | 0 | 375.2±18.6 | 28.9±2.7 | 4.89±0.66 | 3568.4±372.5 |
| | 50 | 390.1±15.8 | 30.6±3.3 | 4.05±0.23* | 3575.8±365.8 |
| Mouride | 0 | 272.5±15.6 | 16.6±2.5 | 4.95±0.55 | 2880.6±134.7 |
| | 50 | 170.3±12.8* | 7.8±1.4* | 3.39±0.14* | 1253.4±105.6* |
| Mougne | 0 | 286.6±18.4 | 19.3±1.1 | 5.03±0.67 | 2525.1±256.2 |
| | 50 | 210.8±14.3* | 6.2±0.7* | 4.45±0.22* | 1734.9±115.8* |
| Melakh | 0 | 161.8±10.2 | 14.2±3.6 | 6.22±0.96 | 2342.3±286.1 |
| | 50 | 105.4±8.9* | 4.3±0.8* | 4.96±0.24* | 2125.5±267.9* |
| Ife Brown | 0 | 175.8±12.3 | 23.6±3.1 | 3.97±0.31 | 2715.7±342.7 |
| | 50 | 109.3±14.6* | 15.8±2.5* | 2.95±0.41* | 2051.9±166.3* |
| Vita-5 | 0 | 195.9±15.6 | 21.7±2.1 | 4.99±0.11 | 1984.7±168.5 |
| | 50 | 118.4±13.8* | 13.4±1.9* | 3.55±0.34* | 1105.8±142.8* |
| Garoua GG | 0 | 272.9±19.9 | 16.5±3.2 | 7.25±1.02 | 2697.1±394.2 |
| | 50 | 204.5±12.3* | 8.2±1.1* | 5.33±0.64* | 2050.3±253.4* |
| Garoua PG | 0 | 190.7±15.6 | 15.5±3.6 | 6.45±0.85 | 2321.4±207.6 |
| | 50 | 101.9±9.8* | 8.1±0.5* | 4.87±0.26* | 1555.1±195.3* |
| Mouola GG | 0 | 305.5±21.6 | 22.6±2.6 | 5.25±0.33 | 2675.2±245.5 |
| | 50 | 211.3±13.2* | 9.4±2.2* | 2.42±0.29* | 1426.7±261.1* |
| Mouola PG | 0 | 162.7±9.8 | 18.6±3.2 | 4.36±0.42 | 2572.3±382.9 |
| | 50 | 101.6±7.5* | 9.2±1.6* | 2.01±0.21* | 1203.9±156.8* |
| Tsacre | 0 | 373.8±21.7 | 23.4±4.1 | 8.26±1.08 | 2998.2±345.3 |
| | 50 | 314.2±19.4* | 15.7±2.8* | 6.85±0.67* | 2342.8±277.5* |

Values are expressed as Mean±SE. Based on Dunnett's test, values headed by *differ significantly ($p < 0.05$)

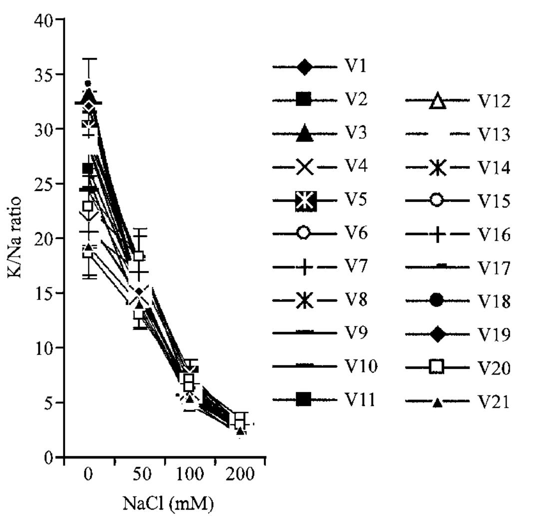


Fig. 2: Effect of NaCl on ratio of cowpea seedling 6 weeks after salt application

## DISCUSSION

Salinity is currently one of the most severe abiotic factors limiting agricultural production. In arid and semi-arid lands, the plants are subjected through their life cycle to salt stress; some of these plants can tolerate this stress in different ways depending on plant species. An interesting finding of the present study is that increasing NaCl concentration in the rooting media significantly ($p<0.05$) reduced the roots, stems and leaves dry weights of cowpea cultivars (V1, V2, V4, V6 V7, V8, V9, V19, V20) at the lowest level of salinity (50 mM NaCl) (Table 2-4). They can be considered as salt-sensitive cultivars whose tolerance level ranges from 0 to 50 mM NaCl (Levitt, 1980).

This is in agreement with the results obtained by Khan *et al.* (1998) and Taffouo *et al.* (2004). According to Munns (2002), salinity reduces the ability of plants to take up water and this quickly causes reduction in growth rate, along with a suite of metabolic changes. There are two growth phases response to salinity (Munns, 1993): The first phase of growth reduction is quickly apparent and is due to the salt outside the roots. It is essentially a water stress or osmotic phase for which there is surprisingly little genotypic variation. The growth reduction is presumably regulated by hormonal signals coming from the roots. Then, there is a second phase of growth reduction which take time to develop and results from internal injury. It is due to salts accumulating in transpiring leaves at the excessive levels, exceeding the ability of the cells to compartmentalize salts in the vacuole. This will inhibit growth of the younger leaves by reducing the supply of carbohydrates to the growing cells. The growth inhibition effect of the salt was significantly noted at 100 mM NaCl on roots, stems and leaves dry weights of V5, V12, V13, V14 V15, V16, V17, V18 and V21 cultivars. Adverse effects of increasing NaCl concentration were more pronounced on leaves than on stems and roots, indicating that roots growth were less affected by salinity (Greenway and Munns, 1980). Similar observation were reported by Taffouo *et al.* (2004, 2006) on three moderately tolerant glycophytes (*Vigna unguiculata*, *Mucuna poggei* and *Gossypium hirsutum*). At higher salt levels (200 mM NaCl ), V3, V10 and V11 had a relatively higher tolerance than others (Table 2-4). Similar results were observed in *Ceriops roxburghiana* (halophyte) and at some salt-tolerant genotypes of *Lycopersicon esculentum* in saline medium (Rajest Arumugam and Venkatesalu, 1998; Agong *et al.*, 2003).

The present study also showed that salinity greatly reduced plant height of all the cultivars at 200 mM NaCl. Similar outcome were obtained earlier by Greenway and Munns (1980), Brun (1988), Saadallaha *et al.* (2001a, b) and Khadri *et al.* (2001). Even at the lowest salinity treatment (50 mM), plant height after 6 weeks of salinization were significantly reduced compared to control, except for V3, V5, V10, V11, V12, V13, V14, V15, V16, V17, V18 and V21 cultivars (Table 5). The growth inhibition effect of the salt was not significantly noted at 100 mM NaCl on plant height of Bambey 21. According to Rajest Arumugam and Venkatesalu (1998) and Alam *et al.* (2004), the plant height decreased in salinized plots would be of several reasons: Firstly, salinity reduced plant photosynthesis, which in turn limited the supply of carbohydrate needed for growth. Secondly, the salinity reduced root and shoot growth by reducing turgor in expanding tissues resulting from lowered water potential in root growth medium. A disturbance in mineral supply, either an excess or a deficiency, induced by changes in concentrations of specific ions in the growth medium, might directly affected growth (Slama, 1986; Tattini *et al.*, 1995; Suarez *et al.*, 1998). Arshad and Rashid (2001) reported that the effects of salinity of different concentrations on morphology of canola were due to the widespread effects of salt stress on plant cells functions, including the functions of different enzymes, metabolism of the cell. The ionic toxicity of the salinity would be due to the replacement of potassium by sodium through biochemical interactions as well as structural changes, lack of protein functions as a result of uptake of the ions of $Cl^-$ and $Na^+$ and interference of the interactions between amino acids (Zhu, 2002).

NaCl exhibited controversial effects on ions concentrations of cowpea cultivars. Salt treatments increased significantly ($p<0.05$) $Na^+$ concentrations in plant organs, whereas potassium concentration and K/Na ratio of plants were significantly decreased. There is an overwhelming amount of evidence to indicate that NaCl induced salinity increases $Na^+$ uptake by plants (Taffouo *et al.*, 2004; Al-Khateeb, 2006; Taffouo *et al.*, 2006; Turan *et al.*, 2007a). Results showed that $K^+$ uptake and transport to the leaves of cowpea cultivars were significantly reduced with increasing salinity. This could be attributed to the competition of $Na^+$ with the uptake of $K^+$, resulting in a K/Na antagonism (Larcher, 1978; Al-Khateeb, 2006; Turan *et al.*, 2007b).

The result of the present study showed that the weight of 1000 seeds, the number of pods per plant and the grains yield of all cowpea cultivars were also affected significantly ($p<0.05$) by salinity except for V3, V10 and V11. Other researchers have also reported reduction of number of canola (*Brassica napus*) seeds, number of flowers as well as weight loss for its 1000 seeds under saline condition (Zadeh and Naeini, 2007). The significant decrease of yield components observed under salt stress in cowpea salt-sensitive cultivars would be partly related to a significant reduction of the foliar chlorophyll contents (more than 50%) and $K^+$ concentrations in saline medium. According to Heller (1995), chlorophyll is an essential element for photosynthesis and potassium plays an important roles in photosynthesis, proteins synthesis, translocation of assimilates as well as increasing growth plant and yield.

Salinity decreased the chlorophyll content of cowpea leaves. It is attributed to a salt-induced weakening of protein-pigment-lipid complex (Strogonove *et al.*, 1970) or increased chlorophyllase (EC: 3.1.1.14) enzyme activities (Stivesev *et al.*, 1973). The decreased in chlorophyll content under salt stress is a commonly reported phenomenon and in various studies, because of its adverse effects on membrane stability (Ashraf and Bhatti, 2000; Hajer *et al*., 2006). Our results confirm those noted by El-Iklil *et al*. (2002) and Turan *et al*. (2007a) who showed that the foliar chlorophyll contents were reduced under salt stress.

The lowest salt concentration (50 mM NaCl) greatly reduces growth and yield components in V1, V2, V4, V6, V7, V8, V9, V19 and V20 cowpea cultivars. They can be considered as salt-sensitive cultivars whereas in moderately salt-tolerant cultivars (V5, V12, V13, V14, V15, V16, V17, V18 and V21), the growth and yield components significantly reduce at 100 mM NaCl. The results obtained during vegetative growth and harvesting phase suggested that V3, V10 and V11 cultivars were relatively tolerant to salinity than others. V3, V10 and V11 cultivars showed better growth seedlings and yield parameters in this conditions revealing a greater adaptability of these cultivars under salinity stress. They could be cultivated in environments with varying salinity.

Results also show that $K^+$ concentration, K/Na ratio, plant height of seedlings and total chlorophyll were all significantly decreased by salt solutions, especially by 200 mM and the magnitude of reduction varied between cultivars.

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