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Research Article

Influence of Sodium Chloride on germination, and Zinc, Copper, Zinc-Copper mixture on seedling performance of Dorke and Omankwa corn varieties

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Seed germination and seedling performance of Dorke and Omankwa corn varieties were investigated under varying salinity, copper and zinc concentrations. Sample analyses were done using AAS. Germination of both seeds decreased with increasing Sodium chloride. When NaCl was increased from 3 to 6ppm, the range of germination of Dorke seeds reduced from 33 - 20% while that of Omankwa seeds reduced from 20% to 13.3%. 85.5% germination in 60mMNaCl was the highest in Dorke and 72.2% germination in 90mMNaCl was the lowest. 87.8% germination in 30mMNaCl was the highest for Omankwa hybrid, 30% in 90mM being its lowest. Cu^{2+} accumulated more in the roots than shoot of both hybrids, while Zn^{2+} accumulated more in their shoots than the roots. Highest mean fresh weight of Dorke was recorded in moderate Cu^{2+} and Zn^{2+}. Also highest mean fresh weight of Omankwa hybrid occurred under low Cu^{2+} level and moderate Zn^{2+} levels, but was highest in higher levels of Zn^{2+} and Cu^{2+} mixture. From the study, farmers are advised against planting the two hybrids in alkaline soils and to apply Cu^{2+}/Zn^{2+} based fertilizers to improve photosynthetic activity and biomass.

Keywords: Germination, pollution, salinity, sodium chloride, copper, zinc.

INTRODUCTION

Modern civilization introduces a wide range of heavy metals to the soil through various anthropogenic activities such as unrestricted mining, municipal waste disposal practices and extensive use of agrochemicals that have resulted in the addition of large amounts of heavy metals at many places of the world (Ernst, 1996; Mullar *et al.,* 2000). Beyond a particular concentration, metals can prove to be toxic to plants and animals (Wu and Lin, 1990). Contamination of soil in cultivated fields with toxic heavy metals has emerged as a new threat to agriculture (Abba, 2014). Metal toxicity primarily depends on plant species (Vojtechova and Leblova, 1991). The apparent damage of plant tissues due to excessive amount of heavy metals in the growth medium can be used as an indicative of toxic effects of the metals (Mullar *et al*., 2000). Heavy metal tolerance is key to establishment of plants under any prevailing environment (Welbaum *et al*., 1998). If any element is lacking in the soil or not adequately balanced with other nutrients, growth suppression or even complete inhibition may result (Mengel *et al.*,2001). Copper and zinc are essential for normal plant growth, but at higher concentrations they become toxic and can interfere with numerous biological processes (Demirevska-Kepova *et al*., 2004; Mahmood *et al*., 2005).

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In plants, zinc is vital for normal growth and development but elevated or limited levels present in soils, would be toxic and can ultimately cause the death of plants (Broadley *et al*., 2007; Khalil and Jan, 2002). Also, seed pelleted with zinc sulfate ($ZnSO_4$) has produced significantly higher seed weights, seed weight/plant leading to seed yield increase over non-pelleted control (Masuthi *et al*., 2009). In a series of experiments, seed coated with commercially-available zinc Zn formulations effectively corrected zinc deficiencies and improved growth and grain yield of sunflower, maize, wheat, soybean and peanut (Singh, 2007), but at high concentrations the metals could become toxic to the plant. Leaf chlorosis, stunted growth, and stem and twig dieback are common deficiency symptoms of Copper (Osotsapar, 1999).

High salinity is a serious problem and a major limiting factor for crop production around the globe (Wahid *et al*., 2007). According to Ghoulam and Fares (2001)and Foolad *et al*. (1999), variation in salinity affects seed germination in several ways. Seed germination and early seedling growth are the most sensitive stages to salinity stress (Muhammad and Hussain, 2010). Germination and seedling establishment are critical phases in the life of a plant as they are the most vulnerable to injury, disease and water stress (Raven *et al*., 2005;Kitajima and Fenner, 2000). Salts are able to increase water potential, restricting the movement of water towards the seed surface (Polesskaya *et al.,* 2006; Houimli *et al*., 2008) and water imbibition is hindered which delays the germination (Almansouri *et al*., 2001). High soil salt content therefore reduces the rate of germination and total seed germination percentage (Sinha *et al*., 2004) as well as establishment of seedlings (Bybordi and Tabatabaei, 2009). Seeds of various corn hybrids also react differently to stress conditions (Velimir *et al.,* 2007). Khan *et al*. (2008) showed that differences in salt tolerance exist between species and also amongst genotypes within species (Khan *et al*., 2008). Thus the identification of genotypes could solve the problems of cultivation of crops in saline soils (Pervaiz *et al*., 2007).
This study was therefore carried out to determine copper and zinc tolerance in Dorke and Omankwa corn hybrids in Ghana and also to assess germination and seedling performance of the hybrids under salinity stress variation resulting from sodium chloride.

MATERIALS AND METHODS

Source and preparation of seeds of study corn hybrids

Seeds of the two corn varieties for study, Dorke and Omankwa, were obtained from the Crops Research Institute of the Centre for Scientific and Industrial Research at Fumesua, Ghana. To avoid fungal contamination, the seed samples were surface decontaminated in 10% calcium hypochlorite solution for 4 minutes. The samples were then washed thoroughly using distilled water before use. All experiments in this work were carried out by avoiding, as much as possible, contamination in order to prevent interaction between the metals studied and microorganisms.

Preparation of Copper, Zinc, Copper-Zinc mixture and Sodium Chloride Solutions

All the solutions were prepared using reagents of analytical grade and procedures of the Association of Official Seed Analysts (AOSA, 1992), with little modification. About 1.0 g each of solid copper sulfate ($CuSO_4$) and $ZnSO_4$ were dissolved in 25 mL beakers, mixed well and transferred to 1000 cm^3 beakers and toped up to the 1 Lmark with distilled water to make their respective stock solutions. 3, 6, 9 and 12 ppm concentrations of both solutions were then prepared by further dilution of the stock solutions. Mixed copper and zinc solutions were also prepared by adding equal volumes of the stock solutions into a volumetric flask and further diluted with distilled water to obtain 3, 6, 9 and 12ppm concentrations of mixed copper and zinc solutions.
Also, a stock solution of sodium chloride was prepared by dissolving 1.76g of sodium chloride pellets in a 25 mL beaker using small portions of distilled water and well stirred to ensure complete dissolution and mixing. This solution was then poured into a 1000mL volumetric flask, the beaker washed several times with distilled water into the volumetric flask and topped up to the 1000 mL mark with distilled water to make 1 M solution. Further dilution of the stock solution was carried out to obtain 30, 60, 90 and 120mM sodium chloride solutions.

Germination tests

9 cm diameter Petri dishes were washed with distilled water and lined with three pieces of filter paper for the germination study. Treatments comprised of a control using distilled water, and 3, 6, 9, and 12 ppm of copper and zinc solutions, and 0 (control), 30, 60, 90 and 120mM saline solution of sodium chloride. Each treatment was replicated. The filter paper beds were irrigated daily with 20mLof either distilled water or the respective solution of the elements. Each Petri dish received 15 seeds of either Dorke or Omankwa corn varieties. The emergence of radicle from the seed was used as index of germination, and a seed was considered germinated when the radicle pierces the integument.
The grains were observed for germination at the same time each day, for 7 days and the observations recorded. The percent germinations were then calculated. The experiment was conducted in the laboratories of the Department of Applied Biology, University for Development Studies, under conditions of 25/30^{o}C, 12 hours light /12 hours dark period.

Tests on seedling growth

The seedlings were allowed to grow for 12 days in the respective solutions. The Petri dishes were aerated

Table 1. Percent germination of Dorke and Omankwa seeds in varying concentrations of sodium chloride solution

Concentration of sodium chloride(mM)	Mean percent (%) germination	
	Dorke	Omankwa
0	97.8	91.1
30	84.4	87.8
60	85.5	77.8
90	72.2	30.0
120	84.5	67.8

during the course of seedling development by allowing air to blow over them. Seedlings were taken out from the solutions in the respective set ups after 12 days, washed carefully and weighed. Fresh weights of all the seedlings in duplicate treatments were recorded to determine average fresh weight per seedling.

Salt tolerance tests

The germination response of the seeds to Sodium chloride salinity was assessed by counting and comparing the number of grains germinated in 30, 60, 90, and 120mM of the salt. Salt tolerance of each treatment was calculated as a ratio and expressed as a percentage using the following formula by Mujeeb-ur-Rahman (2008):

Salt tolerance= $\frac{Germinationinparticulartreatment}{Germinationorgrowt \quad hincontrol} \, x \, 100 \, \%$ -----(i)

Absorbed copper and zinc

Levels of copper and zinc in the roots and shoots of the seedlings were analyzed using a Themo Scientific ICE 3000 Series Atomic Absorption Spectrometer.
Collected parts of the seedlings from the various treatments were washed, crushed and vacuum-filtered through a 0.45µm membrane filter. Filtrates were digested using a mixed solution of nitric and hydrochloric acids in a ratio 1:3. 200 mL from each of the digested filtrates were acidified with nitric acid to a pH of 2 and aspirated directly with the AAS. The samples were shaken to thoroughly mix before injecting into the AAS. Concentrated nitric acid as well as copper and zinc standard solutions were used for calibrating the AAS.

The biological absorption coefficient (BAC) for the fresh weight of each sample was also determined using the following formula by Mahmood *et al*. (2005).

$BAC = \left| \frac{ppm \ (uptake \ ).100\%}{ppm \ (administered)} \right|$-----------------(ii)

Where; ppm (administered) is the metal concentration in the original solution and ppm (uptake) refers to amount of absorbed metal.

RESULTS

The results of investigations into the effects of sodium chloride on germination of the two corn varieties are presented in table 1. Also, results of influences by copper and zinc absorption are presented on Tables 2 and 3, whilst mean fresh weights of shoots and roots under varying levels of copper and zinc ions also presented on tables 4 and 5. Absorption coefficients are presented on tables 6 and 7.

Effects of varying concentrations of sodium chloride on the germination

Germination was highest in the controls of both corn varieties than in all the respective treatments. There is a clear reduction in the NaCl tolerance ability of the Omankwa hybrid with increasing concentration of NaCl up to 90mM (Table 1). Germination ability in Dorke was however very closely related in all the treatments, except at 90mMof salt in which a very low percent germination occurred. Generally, Dorke seeds had higher percent germination compared to Omankwa seeds under the same salt stress condition.

From table 1,the highest percent salt tolerance of Omankwa (87.8%) was realized in 30mM of NaCl solution. On the other hand, Dorke had its highest salt tolerance percent (85.5%) in 60mMNaCl. Increasing salt concentration was better tolerated by the Dorke hybrid at each concentration compared to that by the Omankwa hybrid (Table 1). Generally, germination reduced with increasing concentration of salt. However, the two hybrids rather had an increase in tolerance, hence germination at 120mM of salt concentration relative to 60mM.

Levels of Cu^{2+} and Zn^{2+} ions absorbed

Compared to Zn^{2+}, more$Cu^{2+}$was absorbed into the roots of both seedlings and the levels of absorbed metal increased with increasing concentration of the metal in the medium. Also more Cu^{2+} than Zn^{2+} was absorbed by both hybrids from the medium of Cu^{2+}/Zn^{2+} mixture.
The highest Zn^{2+}accumulation (0.41ppm) was in 6 ppm Zn^{2+}solution.

Table 2. Copper and Zinc content in roots of Dorke and Omankwa corn varieties of corn grown in varying concentrations of the elements

Solution	Concentrations (ppm)	Level of metal in seedling root (ppm)	
		Dorke	Omankwa
COPPER, Cu^{2+}	3	0.43	0.39
	6	0.46	0.43
	9	0.53	0.45
	12	0.64	0.57
ZINC, Zn^{2+}	3	0.28	0.23
	6	0.41	0.4
	9	0.21	0.17
	12	0.25	0.22
MIXED COPPER and ZINC (Cu^{2+} / Zn^{2+})	3	0.30 / 0.22	0.32 / 0.21
	6	0.33 / 0.26	0.32 / 0.27
	9	0.37 / 0.16	0.35 / 0.18
	12	0.42 / 0.24	0.38 / 0.26

Table 3. Copper and zinc content in shoots of Dorke and Omankwa varieties of corn grown in varying concentrations of the elements

Solution	Concentrations (ppm)	Level of metal in seedling shoot (ppm)	
		Dorke	Omankwa
COPPER, Cu^{2+}	3	0.31	0.28
	6	0.33	0.30
	9	0.30	0.29
	12	0.41	0.37
ZINC, Zn^{2+}	3	0.34	0.31
	6	0.52	0.48
	9	0.48	0.45
	12	0.43	0.42
MIXED COPPER and ZINC (Cu^{2+} / Zn^{2+})	3	0.22 / 0.31	0.21 / 0.29
	6	0.25 / 0.48	0.23 / 0.44
	9	0.28 / 0.43	0.30 / 0.41
	12	0.32 / 0.39	0.34 / 0.37

From the mixture of Zn^{2+} and Cu^{2+}metal solutions, relatively more $Cu^{2+}$was absorbed by seedling roots of Dorke compared to those of Omankwa, while more Zn^{2+} was absorbed by roots of Omankwa compared to Dorke. The amounts of each metal absorbed from the mixture of solutions were generally less than the respective amounts of the metals absorbed from the separate solutions of the metals (Table 2).

Lesser amounts of the metals were present in the shoots compared to that found in the roots. Also, more Cu^{2+} and Zn^{2+} were absorbed in roots of Dorke than Omankwa (Tables 2), and these were about proportional to the amount of each metal translocated to shoots of each hybrid (Table 3). 0.34, 0.52, 0.48 and 0.43ppm of Zn^{2+}ions were respectively translocated into shoots of Dorke (Table 3), with corresponding BACs of 0.11, 0.08, 0.05 and 0.04respectively(Table 7). The trend was almost the same as those of the same element in Omankwa shoots (Tables 3 and 7).The amount of Zn^{2+}detected in shoots of both species from the separate solutions was relatively higher compared

Table 4. Mean fresh weights of roots of Dorke and Omankwa seedlings germinated in varying concentrations of copper and zinc solutions

Medium	Concentrations (ppm)	Mean mass of fresh root (g)	
		Dorke	Omankwa
Distilled water	0	0.512± 0.048	0.513 ± 0.052
COPPER, Cu^{2+}	3	0.513± 0.044	0.663 ± 0.026
	6	0.588± 0.055	0.575± 0.073
	9	0.650± 0.033	0.488 ± 0.052
	12	0.563± 0.033	0.550 ± 0.046
ZINC, Zn^{2+}	3	0.444± 0.029	0.644± 0.024
	6	0.478± 0.022	0.622 ± 0.032
	9	0.467± 0.024	0.567± 0.041
	12	0.444± 0.024	0.578± 0.032
MIXED COPPER AND ZINC	3	0.513± 0.03	0.738± 0.026
	6	0.562± 0.046	0.753± 0.080
	9	0.675± 0.053	0.725± 0.072
	12	0.725± 0.037	0.758± 0.072

Table 5. Mean fresh weights of shoots of Dorke and Omankwa seedlings germinated in varying concentrations of copper and zinc solutions

Medium	Concentration (ppm)	Mean fresh weight of shoot (g)	
		Dorke	Omankwa
Distilled water	0	0.550± 0.027	0.663± 0.053
COPPER, Cu^{2+}	3	0.575± 0.041	0.712± 0.067
	6	0.650± 0.080	0.638± 0.063
	9	0.550± 0.060	0.675± 0.067
	12	0.600± 0.057	0.563± 0.026
ZINC, Zn^{2+}	3	0.456± 0.034	0.633± 0.091
	6	0.611± 0.059	0.511± 0.048
	9	0.478± 0.043	0.544± 0.053
	12	0.589± 0.031	0.644± 0.055
MIXED COPPER AND ZINC (Cu^{2+}& Zn^{2+})	3	0.750± 0.042	0.700± 0.042
	6	0.638± 0.102	0.863± 0.089
	9	`0.738± 0.050	0.638± 0.050
	12	0.650± 0.038	0.650± 0.063

to the detection in the composite solution of the ions(Table 3).

Mean fresh weight of the roots and shoots

In the separate ionic solutions, presence of Zn^{2+}appeared to have favoured root development in Omankwa whilst Cu^{2+} favoured root development in Dorke. The lowest mean weight of roots of Dorke was observed in 3ppm of $ZnSO_4$ while the lowest root weight of Omankwa was observed in 9ppm of $CuSO_4$. The highest mean root weights of both Dorke and Omankwa were observed in 12ppm of the mixed Cu^{2+} and Zn^{2+} solutions (Table 4).

Root weight of Dorke seedlings generally increased with increasing concentration of Cu^{2+} while that of Omankwa did not maintain a specific trend. In Zn^{2+} solutions, root weight of Dorke was higher in moderate (6ppm) concentrations of the metal but reduced at highest (12ppm) and lowest (3ppm) concentrations of the ions. The mass of the roots of Omankwa was highest in 3ppm of Zn^{2+}, but reduced in the highest Zn^{2+}concentration while the corresponding mean masses

Table 6. Absorption coefficients of copper and zinc in roots of Dorke and Omankwa hybrids

Metal	Concentration (ppm)	Biological absorption coefficient (BAC)	
		Dorke roots	Omankwa roots
Copper	3	0.14	0.13
	6	0.08	0.07
	9	0.06	0.05
	12	0.05	0.05
Zinc	3	0.09	0.089
	6	0.07	0.07
	9	0.02	0.02
	12	0.02	0.02

Table 7. Absorption coefficients of copper and zinc in shoots of Dorke and Omankwa hybrids

Metal	Concentration (ppm)	Biological absorption coefficient (BAC)	
		Dorke shoots	Omankwa shoots
Copper	3	0.09	0.09
	6	0.06	0.05
	9	0.03	0.03
	12	0.03	0.03
Zinc	3	0.11	0.1
	6	0.08	0.08
	9	0.05	0.05
	12	0.04	0.04

in Cu^{2+} did not maintain a uniform trend (Table 4).

The highest mean mass of shoot of Dorke and Omankwa (Table 5) were observed in 3ppm and 6ppm respectively for the mixed metal solutions. In the separate solutions, the least mean weight of shoot of Dorke in $ZnSO_4$ was observed in 3ppm, while that of Omankwa in $ZnSO_4$was observed in 6ppm. In the Cu^{2+} solution, the highest mean mass of shoot of Dorke was in 6ppm and the least mean mass in the 9ppm (Table 5). In copper solution, the highest mean shoot mass of Omankwa was in 3ppm and the least in 12ppm. In the Zn^{2+}solution, the highest mean shoot mass of Omankwa was in 12ppm and the least in 6ppm. Also, the highest mean shoot mass of Dorke was realized in 6ppm and the least in 9ppm as indicated in table 5.

The biological absorption coefficient (BAC)

The metal content in roots of Dorke seedlings corresponding to germination in the presence of 3, 6, 9, and 12 ppm of Cu^{2+} solution had linear increment of fresh weight from 0.43 to 0.64ppm (Table 2)with a corresponding BAC as shown in table 6. Also from Table 2, shoots accumulated 0.31,0.33, 0.30 and 0.41ppm Cu^{2+} from 3, 6, 9 and 12 ppm respectively and the calculated BAC is presented in table 6.
BAC calculated using values from tables 4 and 5 for the two hybrids show that more Cu^{2+} was stored in roots than Zn^{2+}, while more Zn^{2+} was translocated into shoots than Cu^{2+}. Comparing the BAC values (Table 6 and 7) of both metals absorbed by shoots of Dorke seedlings and that of Omankwa, more Zn^{2+} was absorbed in the shoots of both hybrids than Cu.

DISCUSSION

There are variations in level of tolerance of Dorke and Omankwa hybrids of corn to increasing sodium chloride solution treatments during the early growth stages. The salt tolerance, assessed as growth performance was comparatively better in Dorke hybrid than in Omankwa (Table 1). High salt stress is known to disturb osmotic and ionic homeostasis that limit the availability of water to the seeds and ultimately cause slow and poor germination (Gupta *et al.,* 1993). The genetic potential for salt tolerance was indicated by the ability of a seed to germinate under salt stress because seedling establishment and survival are highly sensitive to soil salinity (Cordeiro *et al.,* 2014). It was found that increasing levels of salinity stress from 30mM salt solution negatively affected germination. There is gradual decrease in percentage seed germination hence a decrease in the salt tolerance with increasing concentration of NaCl especially in Omankwa. At a higher concentration of salt (90mM), germination of Omankwa and Dorke was respectively reduced to 25.6 % and 61.1 %compared to germination in the absence of added salt. At that salt concentration, germination of Omankwa was at its lowest. Dorke therefore appear to withstand salt stress better than Omankwa.

Abiotic stresses are able to alter the levels of plant growth hormones leading to decrease in plant growth (Gupta *et al.,* 1993). Studies of seedling salinity tolerance has been used by many researchers to select salinity tolerant breeds of plants (Ashraf *et al.,* 1986; Ashraf and McNeilly, 1990; Al-Khatib *et al.,* 1993; Kebebew and McNeilly, 1994) because the response of seedlings to salinity reflects enhanced salinity resilience in the adult plant. It has also been reported that early seedling response to salinity could reflect potential grain yield at maturity (Maiti *et al.,* 1996).The screening of seedlings therefore provides a method of selection for breeding, assuming that variability at the seedling stage is genetically based. In the current study, higher salinity tolerance of Dorke hybrid corn may therefore translate into an equally higher yield at maturity.

Similar results on varying performance of different crops under salinity stress conditions were reported in tomato by Mohammad *et al.* (1998), in cotton by Meloni *et al.* (2001), and in wheat by Sarwar and Ashraf (2003). Salt tolerance by Dorke could be due to its genetic variability to persevere under salinity conditions and/or a probable less uptake of NaCl by its roots. Reports indicate that some crops, even within the same species, could have adaptive character towards saline environments as have been reported by Khan *et al.* (2008) in sorghum, and Ashraf *et al.* (1991, 1998) in wheat and rice. Our results compare well with those cited in Zoheir *et al.* (2013). Observations made were also in conformity with those of Uniyaland Nautiyal, (1998).We observed that root growth was sensitive to high salt concentrations and affected by increasing salinity (Table 4). Rooting behaviour provides useful information regarding the salt tolerant potential of plants. In a study by Cramer *et al.* (1988) and Ashraf *et al.* (2005) it was reported that roots were rapidly reduced or prevented by salinity.

After the germination however, increasing presence of Cu^{2+} in the culture medium had much more influence on shoot and root growth (Tables 4 and 5). The mean weights of roots were generally higher in tests than in the control. In presence of Cu^{2+}, both Dorke and Omankwa hybrids had greater mean fresh weight. But in presence of Zn^{2+}, only Dorke had a greater mean fresh weight compared to the control. Though the mean fresh weights of both species were greater in mixed Cu^{2+} and Zn^{2+}, the Omankwa species separately had a greater weight. The trend of fresh mean weight of fresh roots reflected also in the shoots of both species.
This suggests some inhibitory mechanism resulting in the reduced translocation of Cu^{2+} from root to shoot (Nishizono *et al.,* 1989). As shown in tables 2 and 3, Zn^{2+} was more diffusible than Cu^{2+} which tended to accumulate in the roots of seedlings of both hybrids. Stefani *et al.,* (1991) identified similar pattern of distribution of heavy metals in *Juncusacutus* seedlings. Also, findings in the current work agree with the work reported by Chatterjee and Chatterjee, (2000), who indicated similar effects of cobalt, chromium and copper on cauliflower. Zn^{2+} uptake appeared to have been more feasible in lower concentration of the metal ions in the treatments. Seeds use their own mineral reserves during germination and this process was not influenced by the presence of metal ions (Stefani *et al.,* 1991). In a later experiment, Mahmood *et al.,* 2005 indicated that increasing concentrations of $Zn^{2+}$and Cu^{2+} did not influence germination. Thus germination of seeds of these hybrids of *Z. mays* seeds may not have been influenced by the presence of Cu^{2+} and Zn^{2+} in the environment. Results of the current study are also consistent with results of earlier work on other species such as *Triticumvulgare* and *Avena sativa* (Fiussello, 1973) as well as in arboreal *Piceaerubens*, and *Abiesbalsamica* (Scherbatskoy *et al.,* 1987). Based on the foregoing, Dorke and Omankwa may therefore not have extensive challenges when cultivation under situations where water and soil suffer from Cu^{2+} and Zn^{2+} pollution.

CONCLUSION

Through laboratory experiments, percentage germination and salt tolerance parameters have been successfully used in the screening of germination and growth of Dorke and Omankwa corn hybrids under salinity stress conditions and some metal pollution. The present study has shown that increasing concentration of sodium chloride in the environment of seeds of Dorke and Omankwa decreases germination and the ability of seedlings to develop roots and shoots. Hence Dorke and Omankwa corn varieties may not be suitable for cultivation in saline soils.
Also the assessment of biomass accumulation in presence of Cu^{2+} and Zn^{2+}indicated that the mass of developed roots and shoots of Omankwa hybrid were generally more than that of Dorke. However, the metal accumulation in the roots and shoots of Dorke were generally more than that in Omankwa. Copper accumulated more in the roots than in the shoots of both hybrids, and zinc accumulated more in the shoots than in the roots.
The amount of zinc and copper absorbed in both shoots and roots of seedlings of the two hybrids were reduced under competitive presence of either metal. Translocation of Zn^{2+} took place in preference to Cu^{2+}under competitive presence of both ions. Under the competitive presence of Zn^{2+}, Cu^{2+} accumulated more in the roots while zinc accumulated more in the shoots.

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