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Differential effect of NaCl and KCl salinity on dimorphic seeds of chicory (*Cichorium pumilum* L.) during germination and subsequent recovery

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Abstract

White and dark seeds of chicory were germinated in NaCl or KCl at 0, 30, 100 and 250 $mmol.L^{-1}$ for 7 days. The threshold salinity for germination capacity was 100 $mmol.L^{-1}$, beyond which NaCl exerted more toxic effect than KCl and white seeds had higher critical salinity (220 $mmol.L^{-1}$ NaCl and > 250 $mmol.L^{-1}$ KCl) than dark seeds (185 $mmol.L^{-1}$ NaCl and 200 $mmol.L^{-1}$ KCl). Germination speed was more salt-sensitive than germination capacity. High salinity delayed both onset and termination of germination. Embryo extension, particularly plumule growth, was more salt-sensitive than seed germination, with lower threshold salinity and complete cessation at high salinity. Upon release of salt stress, seeds readily recovered without lag; and recovery was better in dark seeds than in white seeds, from NaCl than from KCl and from high salt solutions than from low salt solutions. The depression of germination by high salt solutions of NaCl and KCl suggests an osmotic effect while the greater toxicity of NaCl than that of KCl suggests a specific ion effect. The osmotic effect dominates at high salinity with comparable effects of NaCl and KCl and maintenance of seed viability while the specific ion effect emerges at moderate salt levels with reduced seed viability and more toxicity of NaCl than of KCl. High salinity thus can be manipulated as a priming treatment, focusing germination in short time period with high speed.

Keywords: Chicory, NaCl, KCl, germination, dimorphism

Introduction

Accumulation of excessive soluble salts in the soil is a major constraint to utilization of large areas of land in agriculture. The toxic effect of salt is particularly evident on crop species which are commonly classified as glycophytes. The deleterious effect of salinity on plant performance can arise either from direct specific ion effects, osmotic stress or dehydration of plant tissue, indirect nutritional disturbances exemplified by the Na^+/Ca^{2+} and Na^+/K^+ antagonism as well as the Cl^-/NO_3^- antagonism and lastly through inducing an oxidative stress **(Gupta and Huang, 2014)**. Seed germination is an important and vulnerable stage in the life cycle of plants and determines seedling establishment and plant growth. It can be manipulated as a quick and preliminary test to look for salt-tolerant species and cultivars. The mechanisms of salt tolerance may differ during germination and vegetative growth and may be expressed to different extents in different mutants/strains of the same species **(Abogadallah *et al*., 2010)**.

The increasing demand on plant products to meet the explosion in human population necessitates devoting arable lands for cultivation of crop species and introducing more lands in use either by desalinization of soil or by manipulation of more salt tolerant wild species and marginal crops. Chicory (*Cichorium pumilum* L.) is a wild species of the family Asteraceae and is usually cultivated in Egypt in a limited scale as a marginal crop. *C. pumilum* is classified as a subspecies of the cultivated species *C. endivia* and is, therefore, considered to be the wild endive species **(Ghareeb *et al*., 2008).** The plant expresses seed dimorphism manifested as the production of dark and white seeds. Chicory exhibits some degree of salt tolerance, since it grows naturally as a weed inhabiting waste probably salt-affected lands. It has many nutritional and medicinal uses: as antioxidant, anti-viral, hepato-protectant/tonic, laxative, diuretic, antidiabetic, antiulcerogenic, anti-cancer and as anti-inflammatory supplement **(Shad *et al*., 2013; Dalar and Konczak, 2014)**.

The present work investigates the difference in salt tolerance between the white and dark seeds of chicory and aims to differentiate the osmotic component of salt stress from the specific ion component by germinating the two seed forms in isomolar solutions of NaCl and KCl. It is established that K is a macronutrient cation whereas Na is a toxic/beneficial non-nutrient cation. Nevertheless, can high levels of K (KCl salinity) exert the same toxic effect as NaCl salinity?

Materials and methods

Germination conditions

Seeds of chicory (*Cichorium pumilum* L.) were obtained from the local market (Egypt). Two seed forms can be distinguished in the natural population: dark and white seeds. The shape of both seed forms is nearly prismatic with comparable dimensions; but dark seeds are heavier than white seeds. Seeds of both forms were selected for size homogeneity and germinated in the dark in Petri dishes lined with filter paper saturated with NaCl or KCl solutions at 0, 30, 100 and 250 $mmol.L^{-1}$ at 25/17°C day/night. Germinated seeds were frequently transferred to new Petri dishes with filter papers saturated with the test solutions to prevent buildup of salt. Seeds were considered germinated upon emergence of radicle up to 2 mm and the number of germinated seeds was monitored at regular intervals for a period of 7 days.

The experiment was factorial with three factors and four replications in a completely randomized design. The main factors were seed form with two levels (white and dark), type of salt with two levels (NaCl and KCl) and concentration of salt with five levels (0, 30, 100 and 250 $mmol.L^{-1}$). After approaching steady germination percentage, un-germinated seeds were transferred to distilled water and recovery from salt stress was monitored at time intervals up to 2 days.

Definitions, calculations and statistical analysis

Final cumulative germination percentage and final percentage recovery of germination from salinity were arcsine transformed before performing ANOVA to ensure homogeneity of variance. Data were statistically analyzed using SPSS version 22 and the effect of main factors and their interaction were assessed using three-way ANOVA. Mean separation was performed using the Duncan's multiple range test at $p < 0.05$.

The germination parameters were grouped into three categories (**El-Katony *et al*., 2015)**:

1. Germination capacity or germinability: is the final cumulative number of germinants as percentage of the total number of seeds.
2. Rate or speed of germination was estimated in terms of the following indices:
   a) Peak value (PV) is the maximum Mean daily germination.

Mean daily germination (MDG) =

$\frac{\text{cumulative germination \% at time } t_i}{t_i}$ (% d^{-1})

b) Timson index of germination velocity $= \frac{\Sigma G_i}{T}$ (% d^{-1})
Where G_i is the cumulative number of germinants at day i, and T is the total germination period.

a) Germination rate index (GRI) $= \Sigma \frac{g_i}{t_i}$ (% d^{-1})
Where g_i is the number of seeds newly germinated (or the daily germination percentage) at time t_i from sowing, not the cumulative germination%,

3. Germination times
   a) The first day of germination (FDG).
   b) The last day of germination (LDG).
   c) Time spread of germination (TSG) is the time elapsing between FDG and LDG.
   d) T_{10} or time to 10% germination is a measure of the lag period between imbibition and onset of germination.

The recovery percent from salinity stress was calculated as the number of newly germinated seeds after transfer to distilled water as a percentage of the number of seeds transferred (those non-germinated in the saline solution).

The threshold salinity of a specific process was defined as the highest salinity level leading to non-significant reduction; and the critical salinity as the salinity level leading to 50% reduction.

Results

Time course of germination of the two seed forms of chicory followed a typical pattern: with an initial lag, followed by a period of rapid increase in germination percentage and a tendency towards an asymptote at the end of germination period (Fig. 1). This pattern was however, modified to different extents according to the form of seed as well as type and level of salt. Irrespective of seed form and type of salt, germination percentage was not appreciably affected by salinity up to 100 mmol.L^{-1}; beyond which the reduction was more severe in NaCl than in KCl and in dark seeds than in white seeds. In addition to reducing germination capacity, salt stress also caused lag in germination; which was longer in NaCl than in KCl and in dark seeds than in white seeds.

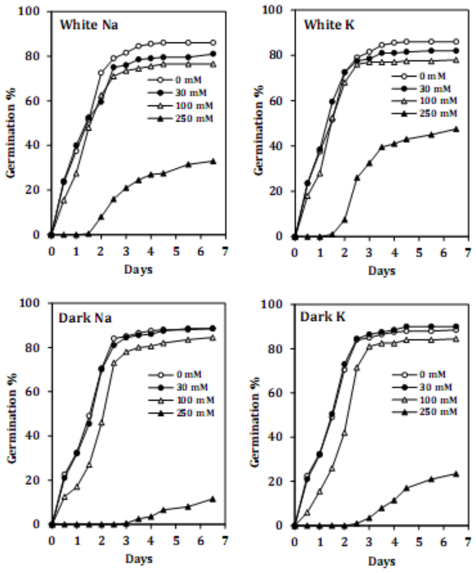

Figure 1. Time course of germination of white and dark seeds of chicory in response to salinity applied as NaCl or KCl. Each value is the mean of four replicates.

Salinity level was the most effective among the studied factors (having the highest F ratio), with a limited effect of seed form and mostly non-significant effect of type of salt. However, the germination capacity was exceptional in that it was subjected to greater influence of type of salt than of seed from (Table 1).

The final germination percentage (FG%) was non-significantly affected by moderate salinity (up to 100 mmol.L^{-1}); within this range it was comparable in NaCl and KCl but was significantly higher in the dark than in white seeds. The differential effect of seed form and type of salt became more evident at higher salt levels where the FG% was lowered to a greater extent in dark than in white seeds and in NaCl than in KCl. Thus, increasing salt level from 100 to 250 mmol.L^{-1} reduced the FG% of white seeds by 57% and 40% in NaCl and KCl respectively and that of dark seeds by 86% and 72% in NaCl and KCl respectively (Fig. 2a). Speed of germination in terms of the peak value (PV) had a low threshold salinity of 30 mmol.L^{-1}, within which it was higher in white than in dark seeds; but the differential effect of type of salt and form of seed was particularly evident at higher salt levels. As salinity level increased from 30 to 250 mmol.L^{-1} the reductions in PV amounted to 89% and 97% in white and dark seeds respectively in NaCl and to 80%

and 94% respectively in KCl (Fig. 2b). Similarly, in terms of Timson index and germination rate index (GRI) the speed of germination was, in general, higher in white than in dark seeds and in KCl than in NaCl; and it was reduced to a greater extent in dark seeds than in white seeds particularly under NaCl salinity (Fig.2c and 2d). GRI shared a common threshold salinity of 30 $mmol.L^{-1}$ in the two seed forms; however, it was reduced by 86% and 97% in white and dark seeds respectively as salt level increased from 30 to 250 $mmol.L^{-1}$ NaCl whereas the reductions under KCl salinity were 80% and 93% for white and dark seeds respectively (Fig. 2c). However, Timson index of white seeds exhibited greater threshold salinity (100 $mmol.L^{-1}$) than that of dark seeds (30 $mmol.L^{-1}$). Increasing salt level from 30 to 250 $mmol.L^{-1}$ lowered Timson index of dark seeds by 96% in NaCl and by 90% in KCl. In white seeds, increasing salt level from 100 to 250 $mmol.L^{-1}$ reduced Timson index by 73% in NaCl and by 61% in KCl (Fig. 2d).

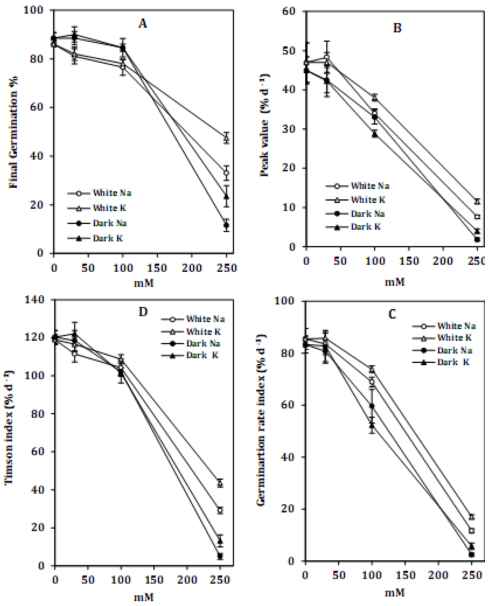

Figure 2. Final germination percentage (A), peak value (B), germination rate index (C), and Timson index of germination velocity (D) of white and dark seeds of chicory in response to salinity imposed either by using NaCl or KCl. Each value is the mean of 4 replicates ± SE.

Table 1. Three-way ANOVA showing the effect of the main factors (seed form, type of salt and level of salinity) on germination parameters of chicory seeds.

Variable and source of variation	df	F	P	Variable and source of variation	df	F	P
Germination capacity (deg.)				LDG			
Seed form	1	0.016	0.898	Seed form	1	5.533	0.023
Type of salt	1	6.515	0.014	Type of salt	1	0.885	0.351
Level of salinity	3	279.6	0.000	Level of salinity	3	12.23	0.000
PV				TSG			
Seed form	1	11.19	0.002	Seed form	1	1.936	0.170
Type of salt	1	0.146	0.704	Type of salt	1	0.598	0.443
Level of salinity	3	169.6	0.000	Level of salinity	3	1.100	0.358
GRI				Plumule length			
Seed form	1	19.21	0.000	Seed form	1	1.303	0.259
Type of salt	1	0.557	0.459	Type of salt	1	0.020	0.887
Level of salinity	3	404.7	0.000	Level of salinity	3	673.4	0.000
Timson index				Radicle length			
Seed form	1	11.26	0.002	Seed form	1	9.149	0.004
Type of salt	1	5.864	0.019	Type of salt	1	5.084	0.029
level of salinity	3	644.8	0.000	Level of salinity	3	207.6	0.000
FDG							
Seed form	1	43.20	0.000				
Type of salt	1	1.200	0.279				
Level of salinity	3	832.4	0.000				

Times of germination were affected by salinity to different extents in the two seed forms of chicory (Table 2). The first day (FDG) and the last day (LDG) of germination were unaffected by increasing salinity up to 100 $mmol.L^{-1}$ and were maintained at about 0.5 and 4.6 d respectively regardless of seed form and type of salt. But, further increase in salinity up to 250 $mmol.L^{-1}$ lengthened FDG by about 2.6 and 3.5 folds in white and dark seeds respectively regardless of type of salt and increased LDG by an average of only 25% regardless of seed form and type of salt. As a consequence, the time spread of germination (TSG) was non-significantly affected by treatments and was maintained at an average of 5 d at all treatment combinations. The value of T_{10} was markedly longer in dark than in white seeds, particularly at high salinity. Also, in dark seeds the differential effect of type of salt was particularly evident where T_{10} of NaCl-treated seeds was twice that of KCl-treated seeds at the topmost salinity. T_{10} was slightly increased by increasing salinity up to 100 mmol.L^{-1} irrespective of seed form and type of salt, but further increase in salinity up to 250 mmol.L^{-1} increased T_{10} of white seeds by 6 folds as an average for NaCl and KCl and that of dark seeds by 14 and 4 times in NaCl and KCl respectively.

Table 2. Times of germination of white and dark seeds of chicory in response to salinity applied either as NaCl or KCl. Each value is the mean of 4 replicates ± SE. Means with common latter are not significantly different at $p \leq 0.05$. T_{10} was calculated using the mean germination percentages of the time course of germination curves; therefore, they are not followed by SE.

Salt type and level (mM)	FDG (d)	LDG (d)	TSG (d)	T_{10} (d)
		White seeds		
		NaCl		
0	0.5 ± 0.00^{a}	4.1 ± 0.13^{a}	4.6 ± 0.13^{ab}	0.20
30	0.5 ± 0.00^{a}	4.7 ± 0.60^{ab}	5.2 ± 0.60^{a}	0.20
100	0.5 ± 0.00^{a}	4.2 ± 0.14^{a}	4.7 ± 0.14^{ab}	0.32
250	1.9 ± 0.13^{b}	5.7 ± 0.25^{bc}	4.9 ± 0.24^{ab}	2.12
KCl				
0	0.5 ± 0.00^{a}	4.1 ± 0.13^{a}	4.6 ± 0.13^{abc}	0.20
30	0.5 ± 0.00^{a}	4.5 ± 0.35^{a}	5.0 ± 0.35^{ab}	0.22
100	0.5 ± 0.00^{a}	4.7 ± 0.60^{ab}	5.2 ± 0.60^{a}	0.28
250	1.8 ± 0.14^{b}	5.7 ± 0.48^{bc}	5.0 ± 0.46^{ab}	2.08
		Dark seeds		
		NaCl		
0	0.5 ± 0.00^{a}	4.7 ± 0.60^{a}	5.2 ± 0.60^{ab}	0.22
30	0.5 ± 0.00a	5.0 ± 0.29^{a}	5.5 ± 0.29^{ab}	0.24
100	0.6 ± 0.13^{a}	5.5 ± 0.41^{ab}	5.8 ± 0.52^{a}	0.40
250	2.5 ± 0.00^{b}	6.5 ± 0.00^{bc}	5.0 ± 0.00^{ab}	6.00
KCl				
0	0.5 ± 0.00^{a}	4.7 ± 0.60^{a}	5.2 ± 0.60^{a}	0.22
30	0.5 ± 0.00^{a}	4.4 ± 0.13^{a}	4.9 ± 0.13^{ab}	0.24
100	0.5 ± 0.00^{a}	4.9 ± 0.55^{a}	5.4 ± 0.55^{a}	0.70
250	2.5 ± 0.00^{b}	6.0 ± 0.29^{c}	4.5 ± 0.29^{ab}	3.80

Salinity exerted a drastic effect on extension of the emerging embryo (Fig. 3). Plumule length was comparable in the two seed forms and in the two types of salt. Mild salinity of 30 mmol.L^{-1} slightly increased plumule length; but further increase beyond this threshold and up to 250 mmol.L^{-1} led to almost complete cessation of plumule extension in the two seed forms, with more pronounced effect of NaCl than of KCl. Radicles were longer in dark seeds than in white seeds and under NaCl salinity than under KCl salinity. Increasing salinity from 0 to 250 mmol.L^{-1} progressively reduced radicle length by 86% and 95% in NaCl and KCl respectively in both seed forms.

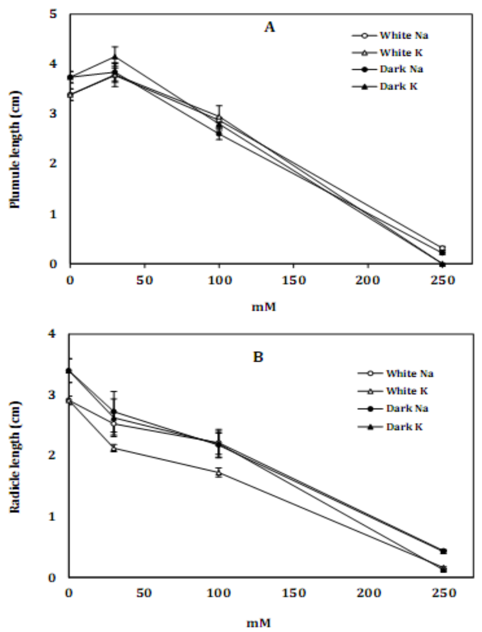

Figure 3. Plumule length (A) and radicle length (B) of white and dark seeds of chicory at the end of germination period (7 d) to salinity applied

either as NaCl or KCl. Each value is the mean of 4 replicates ± SE.

The time course of germination recovery from salinity stress followed similar pattern to that of the original germination test (Fig. 4); but with a short time span (only two days). Level of salinity was the most effective factor determining parameters of recovery from salt stress followed by seed form and type of salt which yielded non-significant F ratios in most of the parameters of recovery (Table 3).

Table 3. Three way ANOVA showing the effect of the main factors (seed form, type of salt and level of salinity) on parameters of recovery of chicory seeds from salt stress.

Variable and source of variation	df	F	P	Variable and source of variation	df	F	P
Final recovery (deg.)				**FDG**			
Seed form	1	63.68	0.000	Seed form	1	8.333	0.007
Type of salt	1	15.96	0.000	Type of salt	1	40.33	0.000
Level of salinity	1	3185	0.000	Level of salinity	1	72.33	0.000
PV				**LDG**			
Seed form	1	1.233	0.274	Seed form	1	28.85	0.000
Type of salt	1	0.001	0.980	Type of salt	1	24.05	0.000
Level of salinity	1	485.9	0.000	Level of salinity	1	81.87	0.000
GRI				**TSG**			
Seed form	1	0.184	0.670	Seed form	1	16.20	0.000
Type of salt	1	0.027	0.870	Type of salt	1	5.000	0.032
Level of salinity	1	1022	0.000	Level of salinity	1	34.40	0.000
Timson index							
Seed form	1	0.145	0.706				
Type of salt	1	0.060	0.808				
Level of salinity	1	1342	0.000				

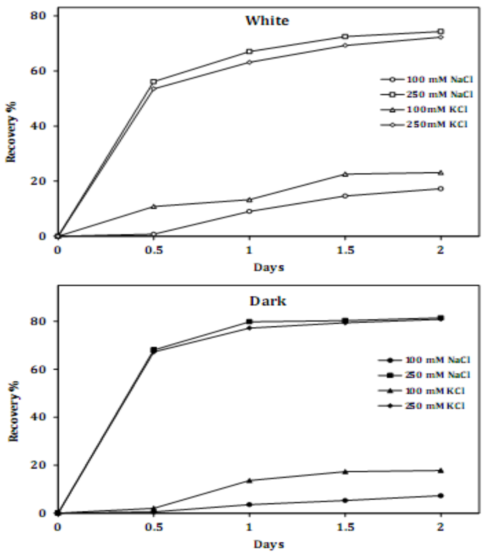

Figure 4. Time course of recovery of germination from salt stress of white and dark seeds of chicory. Seeds were germinated in NaCl or KCl for 7 days; non-germinated seeds were then transferred to distilled water and recovery of germination was monitored over a period of 2 days. Each value is the mean of four replicates

The magnitude of recovery from salt stress in addition to the different indices of speed of recovery (PV, GRI and Timson index) were markedly improved but T_{10} was reduced with the increase in salt pretreatment from 100 to 250 mmol.L^{-1} (Table 4). The magnitude of recovery and the different indices of speed of recovery from the topmost salinity (250 mmol.L^{-1}) were higher in dark than in white seeds and from NaCl than from KCl salinity; but the reverse was true at 100 mmol.L^{-1}. First day of recovery was indifferent in the two seed forms and the two types of salt but was appreciably reduced with the increase in salt pretreatment from 100 to 250 mmol.L^{-1}. Also, last day of recovery as well as time spread of recovery was non-significantly affected by seed from, type of salt and level of salt pretreatment.

Table 4. Parameters of recovery from NaCl and KCl salinity of white and dark seeds of chicory. Seeds were germinated in NaCl or KCl for 7 days; then non-germinated seeds were transferred to distilled water and recovery of germination was monitored over a period of 2 Days. Each value is the mean of 4 replication + SE.

Germination parameter	mmol.L^{-1} NaCl				mmol.L^{-1} KCl			
	100	250	100	250	100	250	100	250
	White seeds		Dark seeds		White seeds		Dark seeds	
Final recovery %	17.2 ± 0.85	74.2 ± 1.65	7.25 ± 0.75	81.4 ± 1.25	23.1 ± 1.52	72.2 ± 2.02	17.7 ± 1.66	80.8 ± 2.63
PV (% d^{-1})	10.1 ± 0.79	112 ± 8.22	4.38 ± 0.24	136 ± 6.81	21.6 ± 2.32	107 ± 13.7	15.0 ± 1.67	134 ± 10.9
GRI (% d^{-1})	14.8 ± 1.39	127 ± 5.99	6.17 ± 0.39	148 ± 4.30	30.5 ± 2.22	122 ±1 0.3	18.3 ± 2.05	146 ± 8.67
Timson index (% d^{-1})	20.8 ± 1.58	134 ± 5.32	8.25 ± 0.32	154 ± 3.42	34.9 ± 2.31	129 +9.06	25.32 ± 2.31	152 ±7.85
FDG (d)	0.88 ± 0.13	0.50 ± 0.00	0.88 ± 0.13	0.50 ± 0.00	0.50 ± 0.00	0.50 ± 0.00	0.88 ± 0.13	0.50 ± 0.00
LDG (d)	2.00 ± 0.00	1.75 ± 0.14	1.75 ± 0.14	1.50 ± 0.29	1.63 ± 0.13	1.75 ± 0.14	1.50 ± 0.20	1.25 ± 0.25
TSG (d)	2.13 ± 0.13	2.25 ± 0.14	1.88 ± 0.13	2.00 ± 0.29	2.13 ± 0.13	2.25 ± 0.14	1.63 ± 0.24	1.75 ± 0.25
T_{10} (d)	1.06	0.09	∞	0.05	0.46	0.1	0.84	0.08

Discussion

The present results suggest that *C. pumilum* can be evaluated as salt-resistant during germination, since germination capacity exhibited a relatively high threshold salinity of 100 mmol.L^{-1} NaCl and KCl. The seed form × salt interaction on seed germination emerges more clearly at high salinity levels; where white seeds were more salt-resistant than dark seeds and NaCl was more toxic than KCl. Although dark seeds exhibited greater germination capacity within the threshold salinity, they experienced steeper reduction at higher salinity, exemplified by the lower critical salinity (185 mmol.L^{-1} NaCl and 200 mmol.L^{-1} KCl) than that of white seeds (220 mmol.L^{-1} NaCl and > 250 mmol.L^{-1} KCl). The relatively high salt tolerance of chicory can be further appreciated by comparing its threshold salinity (100 mmol.L^{-1} NaCl or KCl) with that of Egyptian clover (*Trifolium alexandrinum*) which was only 30 mmol.L^{-1} NaCl (**Saberi *et al*., 2013)**; particularly in view of the fact that in Egypt chicory grows naturally as a weed accompanying clover during winter.
In agreement with our findings of greater salt resistance of the white seeds of chicory than dark seeds, a pattern of better salt tolerance of light-colored (brown) seeds than dark (black) seeds has been encountered in *Suaeda moquinii* (**Khan *et al*., 2001)** and *Atriplex rosea* **(Khan *et al*., 2004).** These differences in salt tolerance of the two seed forms may contribute to the ability of the species to withstand stress conditions during germination and early seedling growth**.**
Salinity affected the different parameters of seed germination of chicory to different extents; with stronger effect on speed of germination than on germination capacity and of NaCl than of KCl. The threshold salinity for germination speed (30 mmol.L^{-1} NaCl for PV) was about one third that of the FGP (100 mmol.L^{-1} NaCl). In addition, the PV was subjected to steeper reductions at salinity levels beyond the threshold; manifested as lower critical salinity of 160 mmol.L^{-1} (as an average for the two seed forms and the two types of salt) compared with a critical salinity of 220 mmol.L^{-1} for FGP. The genotypic variability as well as the differential salt effects emerges again in considering speed of germination. The peak value of white seeds had a critical salinity of 175 mmol.L^{-1} (as an average for both NaCl and KCl), which was greater than that of dark seeds (145 mmol.L^{-1}). In addition, the PV was strongly inhibited by NaCl salinity with an average critical salinity for both seed forms of 150 mmol.L^{-1} NaCl than by KCl salinity which had higher average critical salinity of 165 mmol.L^{-1} KCl. A similar pattern can be traced quite clearly in the other measures of speed of germination such as GRI and Timson index. A stronger effect of salt stress on germination rate than

on germination percentage has been reported by **Atak *et al*. (2006)** for 3 triticale cultivars.

The adverse effect of NaCl salinity relative to KCl salinity on germination of chicory points to a specific ion effect. **Tavili and Biniaz (2009)** reported a differential salt effect on germination of *Hordeum vulgare*, with stronger inhibition by 180 mmol.L^{-1} KCl than by isomolar concentration of NaCl, but the reverse was evident at higher salt levels. Although K^+ and Ca^{2+} are essential macronutrients, they might exert a toxic effect on plant growth and development when their concentrations approach the limits of salinity; where their toxicity might in some cases exceed that of Na^+ (**Tavili and Biniaz, 2009; Sali *et al.*, 2015)**. However, the osmotic component of salt stress cannot be excluded; and it seems that the mechanism of salt injury differs in halophytes and glycophytes; with the stress is fulfilled mainly through osmotic effect in halophytes and through a specific ion toxicity along with an osmotic effect in glycophytes (**Dodd and Donovan, 1999).**

In addition to affecting magnitude and speed of germination of chicory seeds, salinity also affected times of germination differentially in white and dark seeds. Salinity above a threshold level delayed both onset and termination of germination with limited changes in TSG. The differential timing of germination of chicory seeds under stress according to seed form might afford a way to adapt to stress conditions. In this regard, **Khan *et al.* (2004)** demonstrated that seed heteromorphism provides *Atriplex rosea* with alternative strategies for survival in saline habitats by varying the germination times of the brown and black seeds, thus ensuring successful establishment of the population. Delay in seed germination under salt stress has been demonstrated in sunflower **(Wu *et al*., 2015)** and *Medicago arborea* **(Amel and Zoheir, 2016)**. It seems that both timing and speed of germination are more affected by salinity than germination capacity. In this regard, the delay in onset of germination of wheat **(El-Hendawy *et al.*, 2011**) and the increase in TSG of *Abelmoschus esculentus* **(Miryam *et al.*, 2015)** by salinity was associated with non-significant effect on the final germination percentage.

Embryo growth, like speed of germination, exhibited a threshold salinity of 30 mmol.L^{-1}, about one third that of germination capacity; and was subjected to severe reduction at high salinity particularly plumule growth under NaCl salinity, which was completely ceased at the topmost salinity (250 mmol.L^{-1}). This signifies that extension of the embryonic axis of chicory is more salt-sensitive than the mere emergence of the embryo and that plumule growth is more salt-sensitive than radicle growth. Similarly, salinity reduced growth of plumule and radicle of wheat **(El-Hendawy *et al.*, 2011)** without effect on germination percentage. The differential effect of salt stress on radicle and plumule growth is reflected in altered root/shoot ratio either on the basis of weight or length. A greater reduction in shoot growth than in root growth under salt stress has been reported in wheat (**El-Hendawy *et al.*, 2011).**

The ready and comparable recovery of chicory seeds from strong NaCl and KCl solutions suggests that the effect of high salinity on germination arises mainly from osmotic effect; and also that the high salt treatment can be manipulated as a priming treatment, leading to focusing of germination within short time. Ready and/or complete recovery of germination has been demonstrated after release of salt stress **(El-Katony *et al.*, 2015).** The priming effect of salt pretreatment has been demonstrated in the seeds of several species where the rate of germination at recovery exceeded that of controls**.** This priming effect of salt pretreatment is related to promotion of the protective enzymes (superoxide dismutase, peroxidase and catalase) as well as to increases in compatible solutes such as proline, and soluble sugar **(Kazemi and Eskandari, 2012).**

Nevertheless, the specific ion effect emerges when considering recovery of seeds from low salt levels (100 mmol.L^{-1}) which was generally lower than from strong solutions; but with stronger toxicity of NaCl relative to KCl. This in contrast to the recovery from strong salt solutions (250 mmol.L^{-1}) which was higher in dark than in white seeds and from NaCl than from KCl. The very negative water potential of the strong salt solutions might restrict entry of salt ions into seeds, thus keeping the seeds quiescent and ready for recovery while the relatively high water potential of the low salt solutions permits entry of salt ions into the seed which might injure the embryo of the non-germinated seeds with consequently low recovery upon release of stress. Thus, it can be claimed that the osmotic effect of salinity predominates at high salt levels while the specific ion effects are expected at low salt levels.

In conclusion: Chicory (*Cichorium pumilum*) - a wild species exhibiting seed dimorphism- might be considered as salt-resistant during germination; with greater resistance of white seeds than of dark seeds and more toxic effect of NaCl than KCl. The stronger toxicity of NaCl relative to KCl was particularly evident in the salt-resistant white seeds than in the dark seeds. Germination speed and embryo growth were more salt-sensitive than germination capacity; and plumule growth was more salt-sensitive than radicle growth. The osmotic effect of salinity on germination dominates at high salt levels while the specific ion effect emerges at low salt levels. High salinity acts as a priming treatment, focusing germination in short time with high speed.

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الملخص العربي

عنوان البحث: التأثير التفاضلى لملوحة كلوريد الصوديوم وكلوريد البوتاسيوم على بذور السريس ثنائية التشكل أثناء الانبات والشفاء اللاحق

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تم انبات بذور السريس البيضاء والداكنة تحت تأثير تركيز 0، 30، 100، 250 مللى مول/لتر من كلوريد الصوديوم وكلوريد البوتاسيوم لمدة سبعة أيام. تحملت إنباتية البذور عتبة ملوحة مقدارها 100 مللى مول/لتر والتى بعدها اتضح جليا التأثير الاكثر سمية لكلوريد الصوديوم مقارنة بكلوريد البوتاسيوم والمقاومة الملحية الأعلى نسبيا للبذور البيضاء مقارنة بالبذور الداكنة؛ إذ بلغت الملوحة الحرجة للبذور البيضاء 220 مللى مول/لتر كلوريد صوديوم وأكثر من 250 مللى مول /لتر كلوريد بوتاسيوم بينما بلغت قيمتها للبذور الداكنة 185 مللى مول/لتر كلوريد صوديوم و200 مللى مول/لتر كلوريد بوتاسيوم. كانت سرعة الانبات أكثر تأثرا بالملوحة من نسبة الانبات. أدت الملوحة العالية الى تأخير بدء وانهاء الانبات. كان نمو الجنين -خاصة الريشة - أكثر تأثرا بالملوحة من نسبة الانبات حيث تميز نمو الجنين بعتبة ملوحة أقل وبالتوقف شبه التام فى الملوحة العالية. بمجرد زوال الاجهاد الملحى تعافت البذور بنشاط ملحوظ وأنبتت بدون تلكوء؛ وكان التعافى أوضح فى البذور الداكنة منه فى البذور البيضاء ومن ملوحة كلوريد الصوديوم أفضل من ملوحة كلوريد البوتاسيوم ومن الملوحة العالية أفضل من الملوحة المعتدلة. يقترح الانخفاض العام فى الانبات فى التركيزات الملحية العالية سواء تلك الناتجة عن كلوريد الصوديوم أو كلوريد البوتاسيوم تأثيرا أسموزيا للإجهاد الملحى بينما يدل الانخفاض الأكثر حدة الناتج عن كلوريد الصوديوم مقارنة بتأثير كلوريد البوتاسيوم بتأثير نوعى للملح. ويبدو أن التأثير الأسموزى يسود فى الملوحة العالية حيث يتساوى تأثير كل من كلوريد الصوديوم و كلوريد البوتاسيوم مع الاحتفاظ بالبذور حية لتتعافى بصورة متقاربة من الملحين فيما بعد؛ بينما يتضح التاثير النوعى للملح عند الملوحة المعتدلة والتى تهدد حيوية البذور بتأثير أقوى لكلوريد الصوديوم مقارنة بكلوريد البوتاسيوم. بناء على ذلك يمكن توظيف الملوحة العالية كمعاملة منبهة للانبات حيث تؤدى الى تسريع الإنبات وتركيزه فى فترة زمنية قصيرة.