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SOLUBLE CARBOHYDRATES CHANGES IN SEEDS OF THREE *SENNA* SPECIES GERMINATING UNDER THREE TYPES OF STRESS

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The present study aims to investigate the effects of osmotic water potential, (Ψ_s), temperature (T) and zinc (Zn) addition to the seed incubation medium to evaluate the effects of their interactions on the germination processes of seeds in three plant species of different ecological affiliation. These species were namely: *Senna alexandrina* Mill, *Senna italica* Mill (native to hot deserts) and *Senna occidentalis* (L.)Link (a wild mesophytic plant). Conversions of potentially water soluble (storage) carbon metabolites in storage organs of seeds into soluble forms and allocation into the embryonic axis which contribute to osmotic potential adjustment were studied. Addition of zinc improved the adjustment of radicles to water deficiency conditions through increasing the allocation of water soluble metabolites into the radicles and hence increasing the osmotic potentials of radicles. Also, zinc induced additional adaptation of the plants to extreme temperatures through increasing total osmotically active metabolic fractions in the radicle. The statistical analysis indicated that, the trifactorial interaction (Ψs x T x Zn) exhibited the major effect on the metabolic conversions in the three species.

***Key Words*: Soluble carbohydrates, *Senna* species, temperature, zinc, osmotic water potential**

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INTRODUCTION

A laboratory experiment on the separate effects of single factors is majority not indicative of their actual effect under field natural condition, ignoring the interactions among such factors acting together. Accordingly, treatment combinations of such factors are necessary to evaluate the effect of each factor and their interactions based on suitable experimental design [1]. The present work aimed to compare germination response of three *Senna* species, of different affiliations, to variation in temperature (T), reduced osmotic water potential (ψ_s) and zinc (Zn) concentration in the medium. The response is concerned with changes in hydrolysable carbohydrates (HC) and soluble sugars (SS) content of germinating seed organs , as components of osmotic adjustment to stress.

Metabolic activation is involved in the induction of germination in dormant seed. Environmental stresses lead to major alteration in carbohydrate metabolism [2,3]. The accumulated solutes in plants during water stress and contribute to active osmotic adjustment can be soluble carbohydrates, inorganic cations, organic acids or free amino acids [4,5]. High temperatures affect carbon metabolism not only by reducing photosynthesis but also by accelerating carbon losses. When temperature rises above the temperature compensation point (the temperature value at which the amount of CO_2 released by respiration equals the amount of fixed CO_2), more CO_2 is used as substrate for respiration than what photosynthesis can fix into carbohydrates [6]. Zinc deficiency is the most widespread micronutrient deficiency in the world [7]. During seed germination, Zn concentration of newly developed radicle and coleoptile is an extremely high, indicating critical physiological role of Zn during early seedling development [8].

MATERIALS AND METHODS

Seeds of three *Senna* species belonging to ecologically different habitats were investigated. These are: *Senna alexandrina* Mill (*Cassia senna*). *Sennaitalica* Mill. (*Cassia italica*) and *Senna occidentalis* (L.) Link. Preliminary germination tests performed before experimentation indicated a high germination percentage, reaching about 100% in these seeds; *Senna italica* seeds have naturally hard coats which therefore cause their dormancy. To induce germination in such case, special pretreatments were required, without which these seeds failed to attain the proper germination percentage. The mechanical scarification, by scratching the seed coats with the aid of abrasives, was found sufficient to ensure nearly 100% germination.

- **Adjustments of Incubation Temperatures:**

Incubators with air circulation which allow control of temperature between 15°C and 35°C were used in testing temperature effect on germination. The incubators were kept constantly dark during the period of incubation. The tests were run at: 15°C, 20°C, 25°C, 30°C and 35°C.

- **Adjustments of Simulated Reduced Osmotic Water Potential, Ψ_s and Zinc Concentration (Zn):-**

The effect of decreased osmotic water potential on germination was simulated by using sodium chloride + calcium chloride solutions as substrate media for germinating seeds. Solutions having different water potentials, ψ_s , were prepared by dissolving certain amounts of sodium chloride (NaCl + calcium chloride ($CaCl_2$) in water, according to preconstructed calibration curves, keeping the sodium adsorption ratio (SAR) constant (1/8). Solutions having different water potentials with zinc (ψ_s+ Zn), were prepared by dissolving certain amounts of NaCl + $CaCl_2$ in zinc solution. The treatment solutions prepared thus are of certain levels of treatment combinations. Seeds were exposed to the following range of osmotic potentials: 0, -0.3, -0.7, -1.0, -1.5 MPa. For each species, another series of zinc solutions (0, 2, 5 and 8 ppm) at the same different levels of osmotic water potential. (ψ_s+ Zn) were prepared. The highest stress level for each seed kind represents the maximum tolerance limit (Least germination) as revealed by preliminary tests. Sets of 4 Petri-dishes were randomly assigned to each osmotic potential (ψ_s) level with or without zinc, then incubated at the specific temperatures as explained before. In order to have the data comparative under different conditions, incubation was terminated after 15 days of sowing, a period long enough to cover any delay of germination due to stress especially at low water potential levels or extreme temperature treatments.

For extraction, the radicle, hypocotyl and storage tissue were excised, washed rapidly in distilled water and rapidly dried between filter paper layers. The excised organs were then weighed, immediately crushed and extracted in 10 ml of ice-cold distilled water [9]. The extracts were kept in deep freeze until the time of analysis for water soluble carbon metabolites.

Determination of carbon metabolites:

Soluble sugars and hydrolysable carbohydrates were determined according to Dubois *et al*. [10] and Pucher *et al*. [11], respectively.

Statistical analysis:

The significance of the effects of single factors and their interactions were determined by analysis of variance. Based on the significance status, the magnitudes of the relative effect of each single factor and its interaction was determined by using the coefficient of determination (importance value, η^2), which is considered a test used to indicate the degree of control of each factor and its interaction on the tested parameters [12,13] as applied by El-Sharkawi and Springuel [14].

Results

Generally, soluble sugars were higher in *S. occidentalis* than that in case of both *S. alexandrina* and *S. italica*, whereas hydrolysable carbohydrates have maximum values in *S. alexandrina*.

1- *Senna alexandrina*

In *S. alexandrina*, it is noticed that low zinc concentration (2 ppm) induced an increase in soluble sugars content at temperatures 15°C and 25°C at osmotic water potentials 0 and -1.5 MPa, respectively. The soluble sugars reached a maximum value(41.0 mg.g^{-1}dry wt.) with Zn concentration 5 ppm at extreme temperature 35°C at moderate osmotic water potentials (-0.7 MPa). In the absence of zinc, there was an increase in soluble sugars content at 25°C with low osmotic water potential (-1.5 MPa) (Figure 1). The same was observed with high zinc concentration (8 ppm) but at high osmotic water potential (0 MPa).

It's quite obvious that, zinc addition helped in translocation of soluble sugars from storage tissue to the embryonic axis especially in radicle which showed the largest proportion at all temperatures tested (15-35°C). Under high water stress (-1.5 MPa), translocation of soluble sugars was greatly allocated toward the embryonic axis at both moderate Zn and temperature levels (Figure 2).

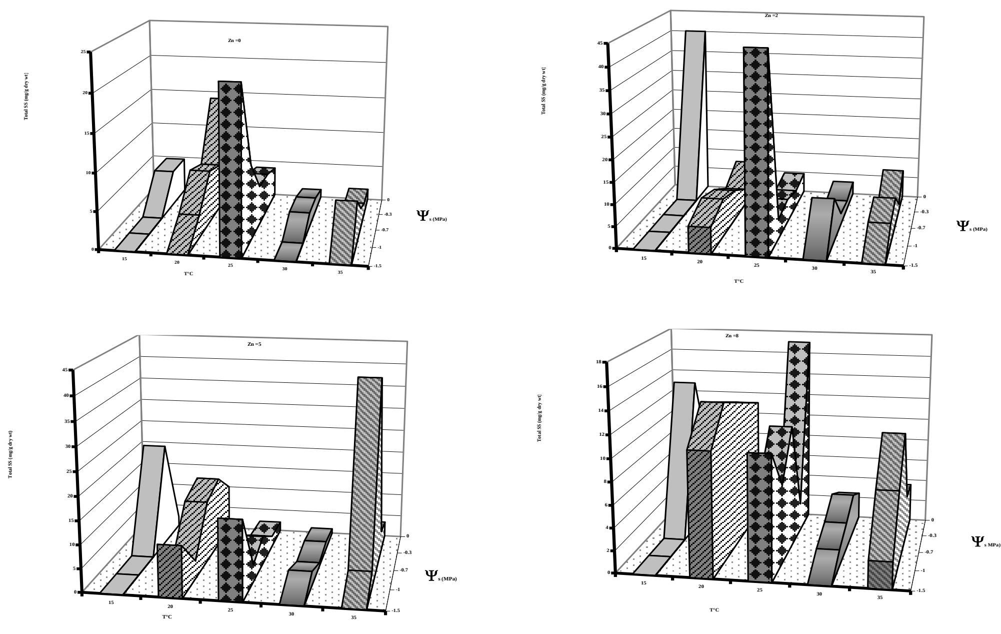
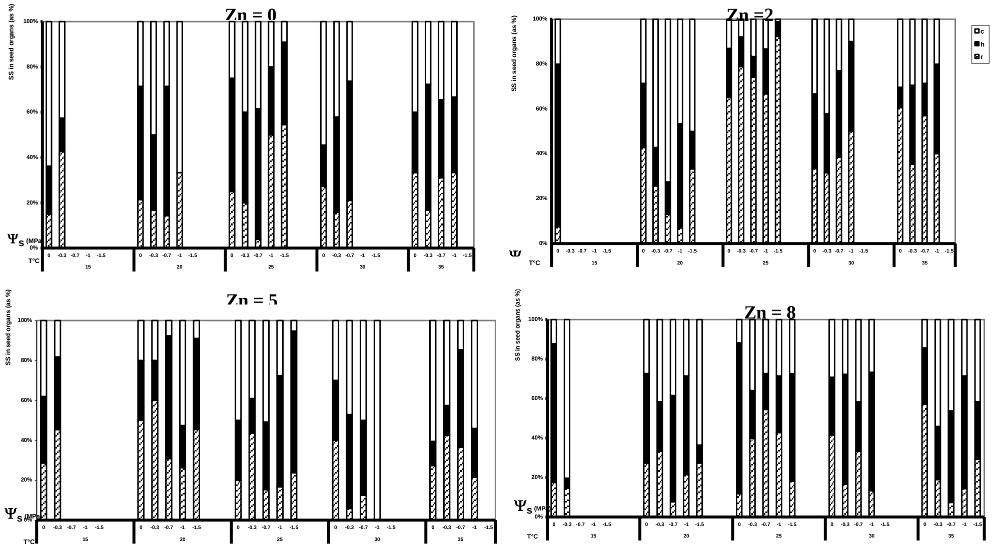


Figure (1): Total content of soluble sugars (SS) in germinating *Senna alexandrina* seeds at different osmotic water potentials (Ψ_s), temperatures (T) and zinc (Zn) concentrations.



r = radicle h = hypocotyl c = storage tissue

Figure (2): Relative distribution (as %) of soluble sugars (SS) in *Senna alexandrina* seed organs at different osmotic water potentials (Ψ_s), temperatures (T) and zinc (Zn) concentrations.

In *S. alexandrina*, (Figure 3), in the absence of zinc, hydrolysable carbohydrates (HC) reached a maximum peak (101.0mg.g^{-1}dry weight) at the highest temperature 35^{o}C with low osmotic water potential (-1.0 MPa). Zn concentrations 2 – 5 ppm induced the increase of hydrolysable carbohydrates at temperature 25^{o}C with osmotic water potential -1.5 & -0.7 MPa, respectively. Apparently, high zinc concentration (8 ppm) induced an increase in hydrolysable carbohydrates at a wide range of temperatures (15, 20 and 25^{o}C).

The relative distribution of hydrolysable carbohydrates indicated that both radicle and hypocotyl competed for hydrolysable carbohydrates sort out of storage tissue both in absence and presence of zinc at all temperatures and osmotic water potentials. Exceptionally, at zinc concentration 5 ppm with osmotic water potential -0.3 MPa the storage tissue retained a larger share than the embryonic axis at temperature 35^{o}C. In general, the hydrolysable carbohydrates in the embryonic axis gradually decreased with the increase in water stress (Figure 4).

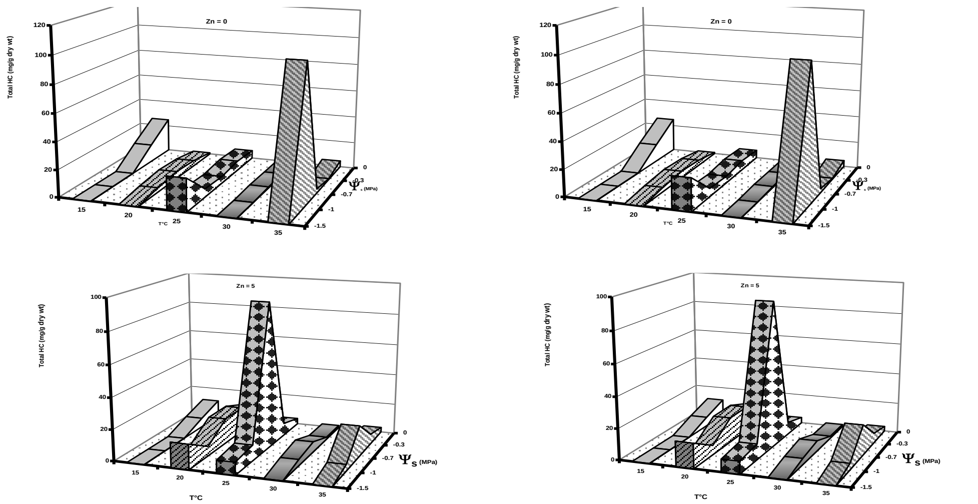
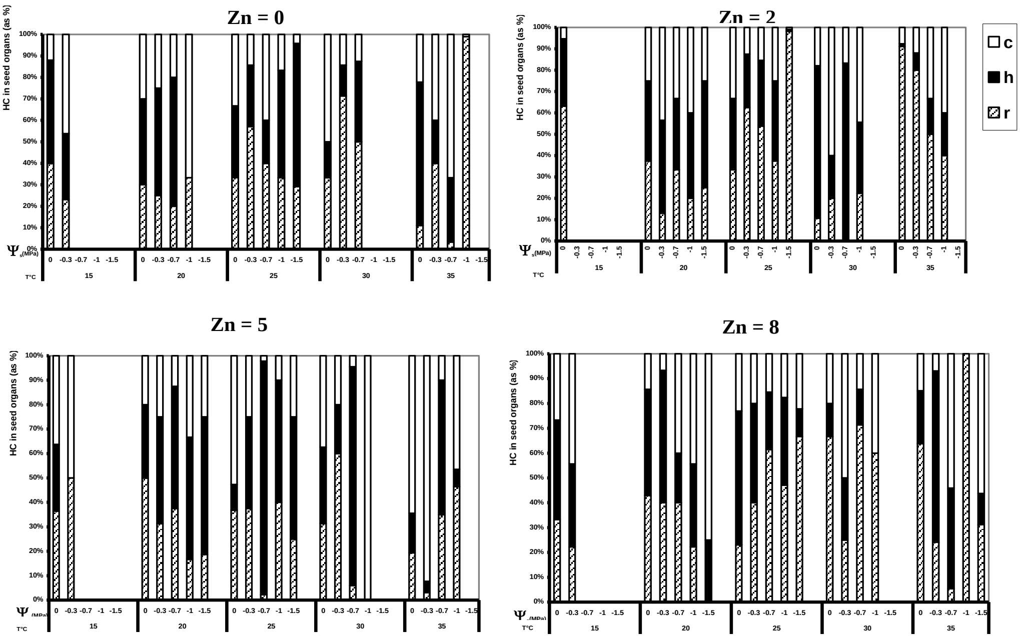


Figure (3): Total content of hydrolysable carbohydrates (HC) in germinating *Senna alexandrina* seeds at different osmotic water potentials (Ψ_s), temperatures (T) and zinc (Zn) concentrations.



r = radicle h = hypocotyl c = storage tissue

Figure (4): Relative distribution (as %) of hydrolysable carbohydrates (HC) in *Senna alexandrina* seed organs at different osmotic water potentials (Ψ_s), temperatures (T) and zinc (Zn) concentrations.

All single factors and their interactions had highly significant effect on soluble sugars content (except zinc in case of hypocotyls) and hydrolysable carbohydrates content in seedling organs (Tables 1&2). In all organs, the interaction (Ψ_s x T x Zn) exhibited the major effect and the interaction (Ψ_s x T) showed the sub-dominant role.

2- *Senna italica*

In *S. italica*, (Figure 5), there was a remarkable increase in soluble sugars content at low temperature (15^{o}C) with all zinc concentrations and at high stress levels. This increase in soluble sugars tended to a maximum (52.0 mg.g^{-1} dry weight) in the absence of Zn. Besides, high zinc concentration (8 ppm) induced an increase in soluble sugars content at 35^{o}C with relatively low and high osmotic water potentials (-1.5 and 0 MPa, respectively). While, at 25^{o}C an increase in soluble sugars was found under high water stress and relatively low Zn concentration.

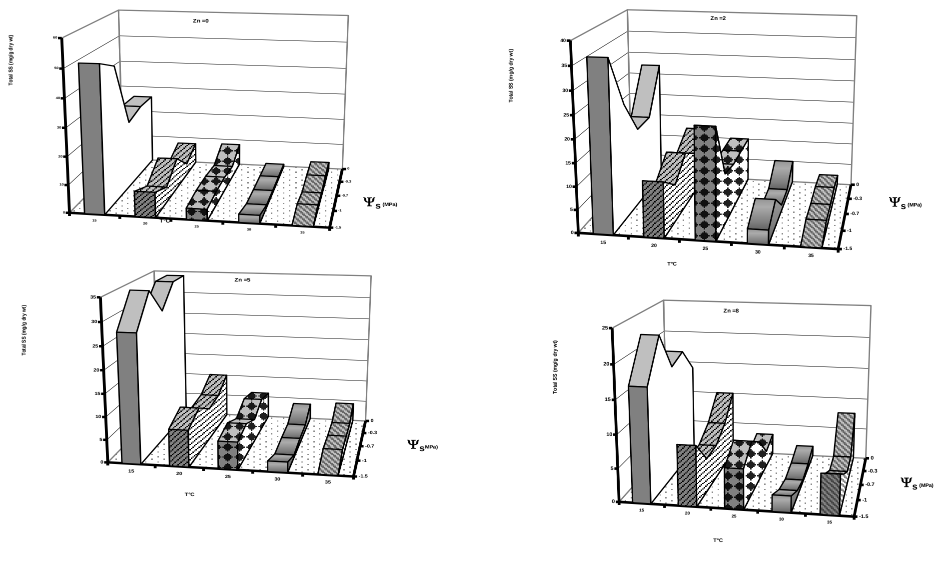
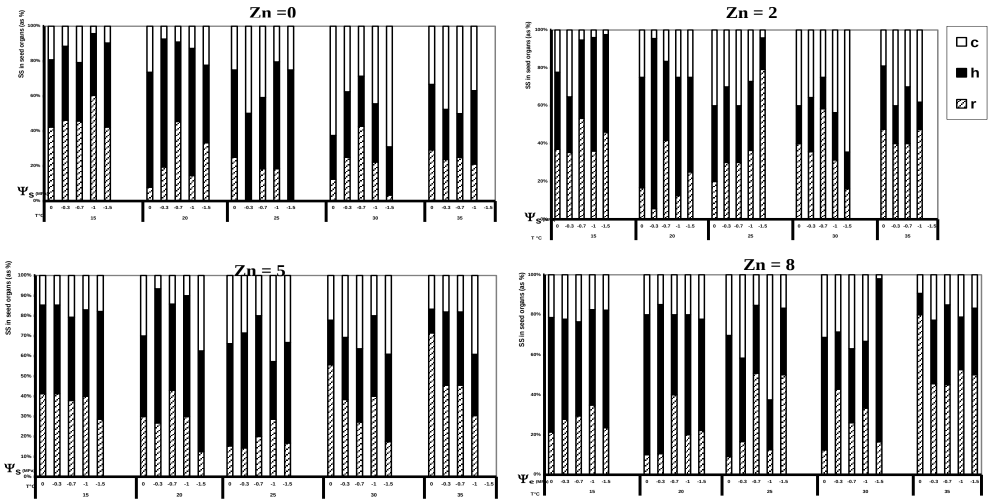


Figure (5): Total content of soluble sugars (SS) in germinating *Senna italica* seeds at different osmotic water potentials (Ψ_s), temperatures (T) and zinc (Zn) concentrations.

Allocation of soluble sugars content in seeds organs (Figure 6) was more in the embryonic axis (especially in hypocotyls) than in the storage tissue with different osmotic water potentials and zinc levels. Soluble sugars tended to a maximum percent (63%) in storage tissue at temperature 30^{o}C, with low zinc concentration (0-2 ppm), whereas the hypocotyl gained the highest proportion at 8ppm under low osmotic water potential (-1.5 MPa).

Under high temperature (35^{o}C) and Zn 8 ppm there was a remarkable increase in soluble sugars in the embryonic axis, particularly in radicle.



r = radicle h = hypocotyl c = storage tissue

Figure (6): Relative distribution (as %) of soluble sugars (SS) in germinating *Senna italica* seed organs at different osmotic water potentials (Ψ_S), temperatures (T) and zinc (Zn) concentrations.

In *S. italica*, a remarkable increase in hydrolysable carbohydrates (32.0 mg.g^{-1} dry weight) was noticed (Figure 7) in the absence of zinc at low temperature (15^{o}C) with low osmotic water potential (-1.5 MPa). Low zinc concentration (2 ppm) showed two peaks at 25^{o}C: one at -0.7 and the other at -1.5 MPa. At high Zn concentration (8 ppm), 20^{o}C and 35^{o}C induced the increase in hydrolysable carbohydrates content both at high and low osmotic water potential levels (0 and-1.5 MPa). Additionally, an increase in hydrolysable carbohydrates was observed at low temperature with zinc concentrations 5 and 8ppm both in absence of stress (0 MPa).

In the absence of zinc, increased osmotic water potentials lead to increase in the hydrolysable carbohydrates content in the embryonic axis, where the hypocotyl contained larger proportion at temperatures (15 - 30^{o}C), while radicle gained the larger proportion at high temperature 35^{o}C. At optimum temperatures 25 and 30^{o}C the storage tissue gained the larger share than the embryonic axis in the absence of zinc with osmotic water potentials -0.7 and -1.5 MPa, respectively. In general, addition of zinc increased hydrolysable carbohydrates towards the embryonic axis rather than the storage tissue at all temperatures and osmotic water potentials.

Exceptionally, at high Zn concentration (8 ppm) storage tissue conserved a larger proportion with 30^{o}C under high osmotic water potential (Figure 8)

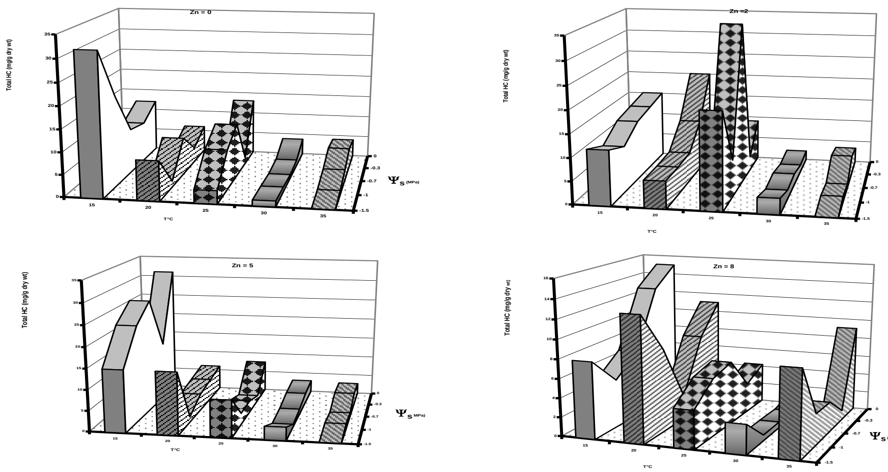
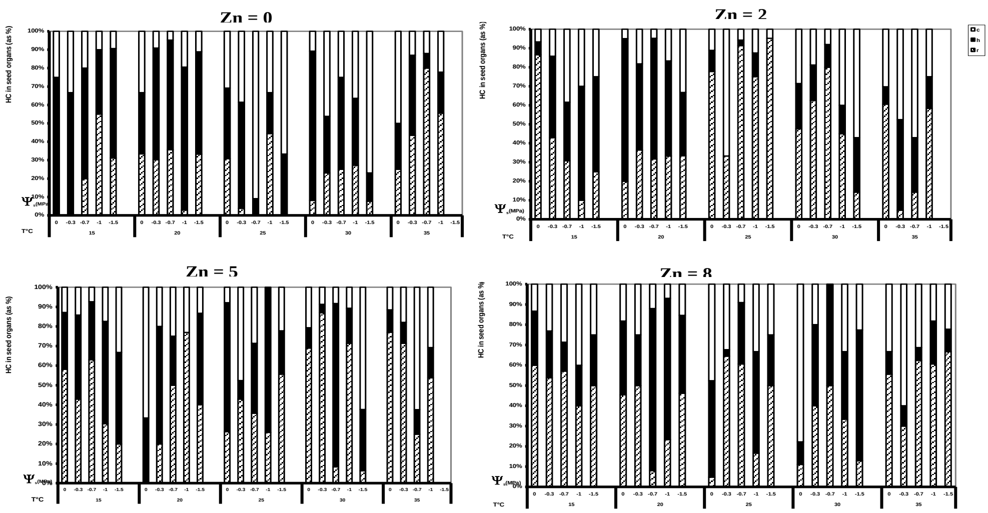


Figure (7): Total content of hydrolysable carbohydrates (HC) in germinating *Senna italica* seeds at different osmotic water potentials (Ψ_s), temperatures (T) and zinc (Zn) concentrations.



r = radicle h = hypocotyl c = storage tissue

Figure (8): Relative distribution (as %) of hydrolysable carbohydrates (HC) in germinating *Senna italica* seed organs at different osmotic water potentials (Ψ_s), temperatures (T) and zinc (Zn) concentrations.

All single factors showed significant effects in the three organs with few exceptions (Tables 1&2). According to η^2 values, temperature played the dominant role on soluble sugars and hydrolysable carbohydrates in different seed organs, except the interaction (Ψ_s x T x Zn) was the dominant in affecting hydrolysable carbohydrates content of radicle and played the sub-dominant role in both the hypocotyl and storage tissue.

3- *Senna occidentalis*

In *S. occidentalis*, it was observed that low Zn concentration (2 ppm) induced an increase in soluble sugars content (51.0 mg.g^{-1} d. wt.) at temperatures 15^{o}C - 25^{o}C under moderate osmotic water potentials. At temperature 25^{o}C, soluble sugars reached a peak (36.0 mg.g^{-1} dry weight) with high Zn concentration (8 ppm) at -0.7 MPa. In the absence of both water stress and zinc there was a remarkable increase in SS (40.0 mg.g^{-1} dry weight) of whole seedlings at 20^{o}C (Figure 9).

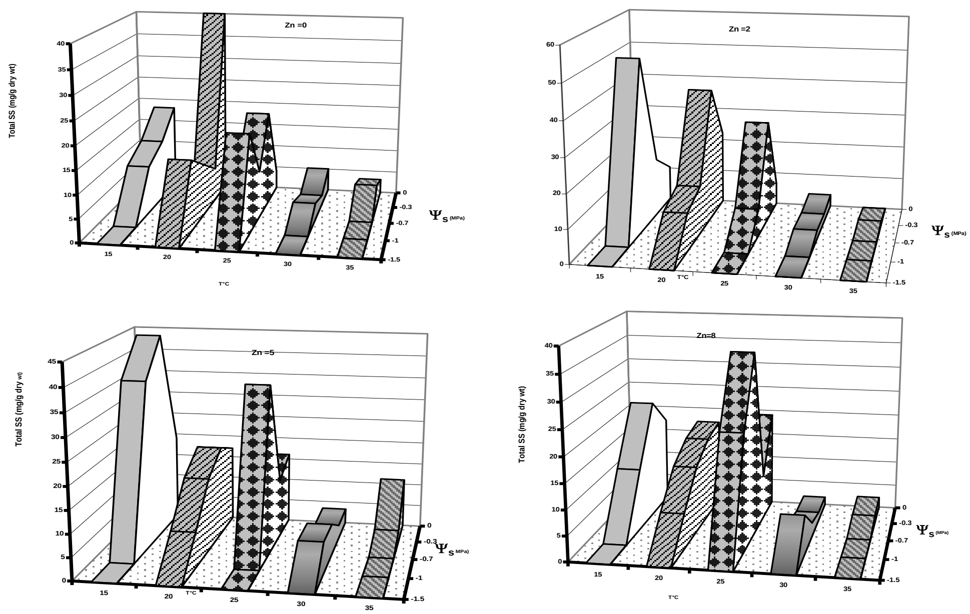
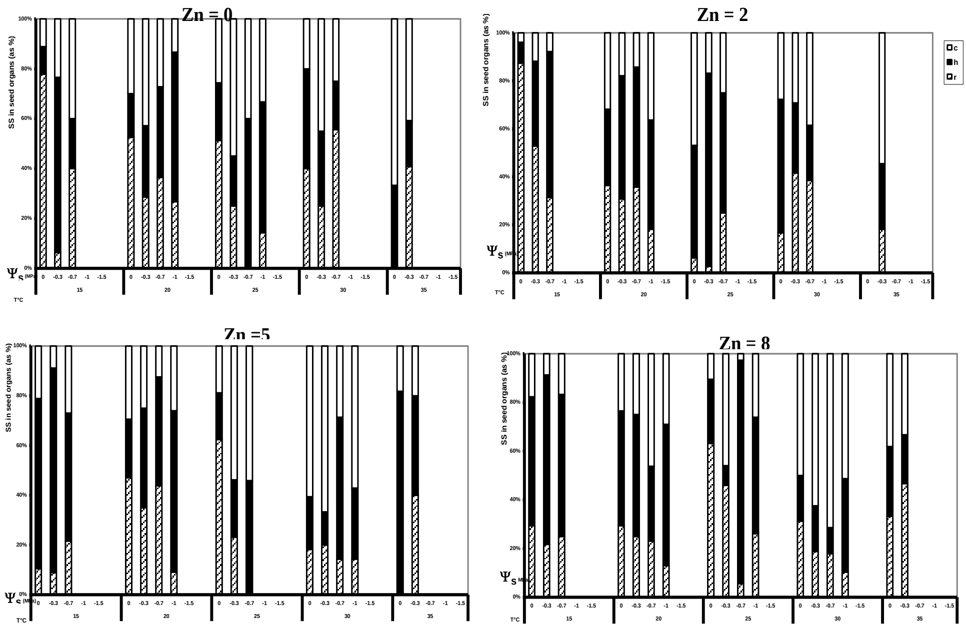


Figure (9): Total content of soluble sugars (SS) in germinating *Senna occidentalis* seeds at different osmotic water potentials (Ψ_s), temperatures (T) and zinc (Zn) concentrations.

The relative distribution of soluble sugars in *S. occidentalis* seedling organs is shown in (Figure 10). It is noticed that, soluble sugars increased in the embryonic axis at different osmotic water potentials with different zinc concentrations, especially at the temperature range 15- 25^{o}C. While at high temperatures it was found that, soluble sugars were relatively higher in the storage tissue.



r = radicle h = hypocotyl c = storage tissue

Figure (10): Relative distribution (as %) of soluble sugars (SS) in germinating *Senna occidentalis* seed organs at different osmotic water potentials (Ψ_s), temperatures (T) and zinc (Zn) concentrations.

In case of hydrolysable carbohydrates (Figure 11), the absence of zinc stimulated a peak at temperatures 20 and 25^{o}C with osmotic water potentials (0 and -1 MPa, respectively). At the same temperatures hydrolysable carbohydrates were enhanced with low zinc concentration (2 ppm) and relatively high osmotic water potential (-0.3 MPa). At low temperature (15^{o}C), moderate zinc concentration (5 ppm) induced an increase in hydrolysable carbohydrate contents (59.0 mg.g^{-1} d. wt.) at -0.3 MPa. The same pattern was observed at optimum temperature (25^{o}C) but with osmotic water potential -0.7 MPa. High Zn concentration (8 ppm) yield a remarkable increase in hydrolysable carbohydrates content under high water potentials.

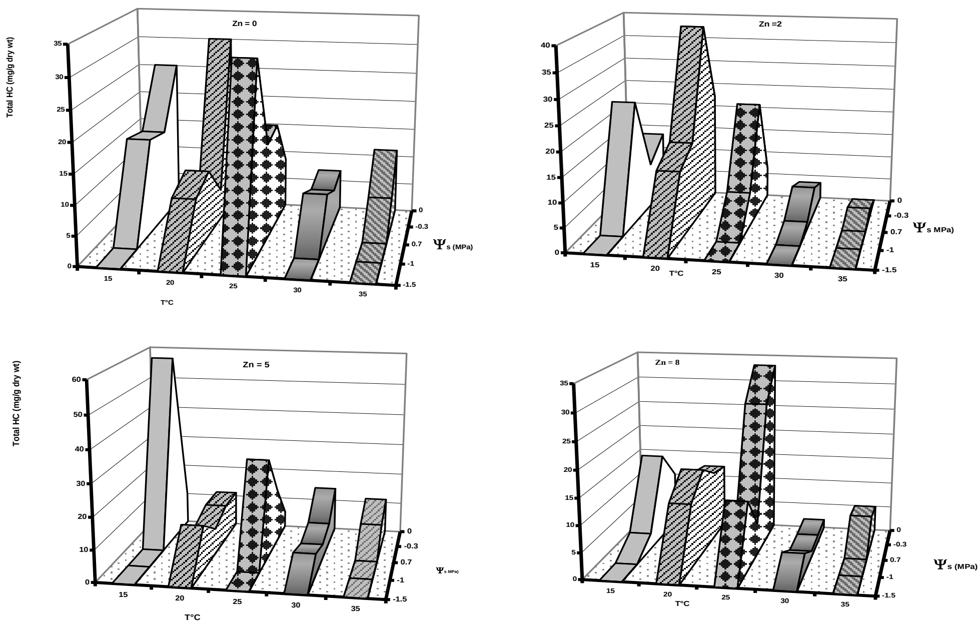
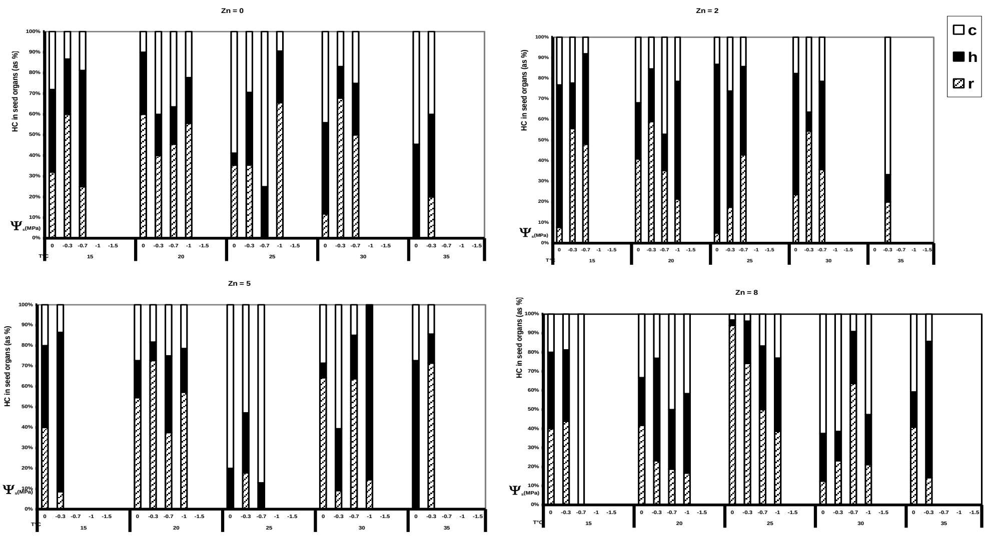


Figure (11): Total content of hydrolysable carbohydrates (HC) in germinating *Senna occdentalis* seeds at different osmotic water potentials (Ψ_s), temperatures (T) and zinc (Zn) concentrations.

For relative distribution of hydrolysable carbohydrates in the three organs, absence of zinc lead to an increase in hydrolysable carbohydrates content in the embryonic axis, particularly the radicle at all temperatures and water stress levels (Figure 12). At optimum temperature (25^{o}C) and moderate zinc concentration (5 ppm), the storage tissue maintained the largest proportion of hydrolysable carbohydrates particularly at high and moderate osmotic water potential levels. Comparatively, it is observed that in *S. italica* and *S. occidentalis*, total hydrolysable carbohydrates increased more at low and moderate temperatures (15 - 25^{o}C).

All single factors and their interactions showed significant effects on soluble sugars and hydrolysable carbohydrates content in the three seedling organs (Tables 1 & 2). The interaction (Ψ_s x T x Zn) played the predominant role in the three organs. The temperature and/or the interaction (Ψ_s x T) showed a sub-dominant effect. In the three organs, it is observed that the interaction (Ψ_s x T x Zn) exhibited the dominant role in allocation of soluble sugars and hydrolysable carbohydrates in the germinating *S. alexandrina* and *S. occidentalis* seeds; whereas, temperature was the dominant factor in hypocotyl of *S. italica*.



r = radicle h = hypocotyl c = storage tissue

Figure (12): Relative distribution (as %) of hydrolysable carbohydrates (HC) in germinating *Senna occidentalis* seed organs at different osmotic water potentials (Ψ_s), temperatures (T) and zinc (Zn) concentrations.

Table (1): F& η^2 values for the effect of temperature (T), zinc (Zn), osmotic water potential (Ψ_s) and their interactions on soluble sugars of seedling organs in investigated *Senna* species.

Species		*S. alexandrina*						*S. italica*						*S. occidentalis*					
		Radicle		Hypocotyl		cotyledon		Radicle		Hypocotyl		cotyledon		Radicle		Hypocotyl		cotyledon	
Source of variance	DF	F	η^2	F	η^2	F	η^2	F	η^2	F	η^2	F	η^2	F	η^2	F	η^2	F	η^2
T	4	30.05**	0.10	3.35*	0.05	39.84**	0.16	69.88**	0.58	206.48**	0.78	74.93**	0.59	27.05**	0.21	15.78**	0.16	31.24**	0.18
Zn	3	12.01**	0.03	1.24	0.01	18.28**	0.06	4.00**	0.02	3.99**	0.01	1.63	0.01	1.10	0.006	2.92*	0.02	7.02**	0.03
Ψ_s×T	16	19.45**	0.26	4.01**	0.24	13.46**	0.22	1.80*	0.06	4.64**	0.07	2.29**	0.07	5.78**	0.18	4.82**	0.2	7.99**	0.18
Ψ_s×Zn	12	9.56**	0.09	2.57**	0.12	8.76**	0.11	1.86*	0.05	0.80	0.009	2.54**	0.06	3.06**	0.07	1.98*	0.06	5.09**	0.09
T×Zn	12	13.34**	0.13	2.22*	0.10	6.30**	0.08	6.49**	0.16	3.41**	0.04	3.11**	0.07	3.87**	0.09	2.41**	0.07	3.22**	0.06
Ψ_s×T×Zn	48	9.07**	0.36	2.34**	0.43	6.42**	0.32	1.19	0.12	1.38	0.06	1.76**	0.17	2.69**	0.25	2.77**	0.34	4.18**	0.29

* Significant at P< 0.05 ** Significant at P< 0.01

Table (2): F& η^2 values for the effect of temperature (T), zinc (Zn), osmotic water potential ($\square_s$) and their interactions on hydrolysable carbohydrates of seedling organs in investigated *Senna* species.

S. alexandrina						*S. italica*						*S. occidentalis*					
Radicle		Hypocotyl		cotyledon		Radicle		Hypocotyl		cotyledon		Radicle		Hypocotyl		cotyledon	
F	η^2	F	η^2	F	η^2	F	η^2	F	η^2	F	η^2	F	η^2	F	η^2	F	η^2
7.14**	0.02	3.25*	0.04	11.68**	0.09	5.73**	1.03	4.28**	0.03	2.43*	0.02	24.46**	0.14	17.97**	0.13	45.69**	0.17
13.00**	0.04	6.49**	0.08	11.86**	0.09	37.47**	0.19	72.64**	0.43	34.10**	0.3	22.70**	0.13	12.47**	0.09	32.20**	0.12
13.82**	0.03	3.34*	0.03	6.27**	0.03	11.17**	0.04	10.04**	0.05	3.56*	0.02	2.10	0.01	1.77	0.01	9.90**	0.03
14.62**	0.19	3.27**	0.16	11.29**	0.33	4.51**	0.09	2.06*	0.05	3.71**	0.13	4.00**	0.09	5.16**	0.15	11.75**	0.18
11.97**	0.12	4.51**	0.17	2.54**	0.06	3.33**	0.05	1.08	0.02	2.20*	0.06	3.92**	0.07	3.33**	0.07	6.71**	0.08
11.84**	0.12	2.86**	0.10	3.09**	0.07	14.82**	0.23	8.11**	0.15	8.13**	0.21	9.78**	0.17	3.21**	0.07	12.24**	0.14
12.25**	0.48	2.84**	0.42	3.85**	0.33	5.71**	0.36	3.75**	0.27	2.50**	0.26	5.54**	0.39	5.11**	0.46	6.54**	0.29

* Significant at P< 0.05   ** Significant at P< 0.01

DISCUSSION

Total soluble sugar levels must be closely regulated in germinating seeds to ensure an adequate supply of energy and building materials for developing seedling. Levels of starch and soluble sugar mobilization are dependent on plant species considered, being more expressive during the early or late stages of seed germination [15,16]. It was observed that in *S. alexandrina* and *S. occidentalis*, soluble sugars content decreased with osmotic water potential reduction (except at 25^{o}C in *S. alexandrina*). Salt stress has been reported to limit the mobilization of starchy endosperm reserves in several species, as a result of inhibition of different enzymatic activities [17,18]. In *S. italica*, it was clearly noticed that, there was an increase in soluble sugar content with low osmotic water potential at high zinc concentration. The maximum content of soluble sugars was found to be at 15^{o}C in seedlings of *S. italica* and *S. occidentalis* with low zinc concentrations. This suggests that, zinc addition seems to induce adjustment to sub-optimal temperatures through increasing the total amounts of metabolites in organs and improvement of seedling growth. On the other hand, the maximum increase in soluble sugars of *S. alexandrina* was found at high temperature with moderate osmotic water potential and zinc concentration.

The carbohydrate content and its allocation to the organs of the germinating seeds play an important role in water relations as well as in respiration. Its role in water relations is related to osmoregulation [19]. The germinated seeds under experimentation adapted to decreasing osmotic water potential through allowing more translocation of soluble sugars from the storage tissue to the embryonic axis over an experimental temperature range both in the absence and presence of zinc, especially at low temperatures (in *S. italica).* However, the role of zinc concentrations (5 & 8 ppm) in enhancement of the amount of soluble sugars to the embryonic axis was restricted to few instances like in *S. alexandrina* and *S. occidentalis* at 30^{o}C and moderate osmotic water potential levels.

The data obtained in this study indicated that in *S. occidentalis* and *S. alexandrina*, there was a decrease in total hydrolysable carbohydrates (HC) content by lowering the osmotic water potential over all experimental temperatures and zinc concentrations (except at 25^{o}C in *S. alexandrina*, there was an increase in hydrolysable carbohydrates content under Ψ_s =-1.5 MPa at low zinc concentrations). On the contrary, hydrolysable carbohydrates content increased in *S. italica* with the decrease in osmotic water potential except at high temperature with low and moderate zinc concentrations. This concludes that, carbohydrates are considered major category of compatible solutes which accumulate during water stress [20,21]. In *S. alexandrina* and *S. italica*, the maximum content of hydrolysable carbohydrates content was shown at the optimum temperature with low zinc concentration (at -1.5 & -0.7 MPa, respectively), while in *S. occidentalis* seedlings, the maximum content of hydrolysable carbohydrates was obtained at low temperature with moderate zinc and osmotic water potential levels.

In seeds, there are two distinct metabolic centers:1- the storage organs where reserve metabolites are hydrolyzed and,2- the elongating embryo axis where incoming nutrients are utilized for the synthetic activities associated with cell expansion [22]. Similar to total soluble sugars, allocation of hydrolysable carbohydrates in the embryonic axis (radicle had a large share) was greatly noticed in the seedlings of the three species investigated (except at 35 ^{o}C with moderate concentrations of zinc and osmotic water potential in the seedling of *S. alexandrina*). Apparently, addition of zinc increased the translocation of soluble sugars to the radicle leading to condensation (allocation) of more complex reserve materials (hydrolysable carbohydrates) in the embryonic axis. This may increase the radicle capacity for water uptake and retention as well as building up of reserve metabolites in the growing embryonic axis under arid and semi-arid conditions [23,24] On the contrary, allocation of hydrolysable carbohydrates in the embryonic axis in *S. occidentalis* was inhibited at 25 & 35^{o}C in the presence of zinc with moderate osmotic water potentials.

It is noticed from statistical data of the three organs that, the interaction (Ψ_s x T x Zn) showed the dominant role in changes of soluble sugars and hydrolysable carbohydrates in germinating *S. alexandrina* and *S. occidentalis*; whereas, temperature played the major effect in hypocotyls and cotyledons of *S. italica.* This may suggest that, the reversibility of the hypothetical carbohydrate conversion:

$$\text{hydrolysable} \rightleftarrows \text{soluble sugars form}$$

was sensitive to (Ψs x T x Zn) interaction. The relative role of the single factors can be considered secondary in such cases [19,25,26].

CONCLUSION

Apparently, addition of zinc improved the adjustment of radicles to water deficiency conditions through increasing the allocation of water soluble metabolites into the radicles and hence increasing the osmotic potentials of radicles. Also, zinc induced additional adaptation of the plants to extreme temperatures through increasing total osmotically active metabolic fractions in the radicle.

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التغيرات فى المواد الكربويدراتية الذائبة لبذورثلاثة انواع من نبات السنا المستنبتة تحت ثلاثة انواع من الضغوط

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استهدف موضوع هذا البحث دراسة تأثير نقص الجهد المائي و درجة الحرارة و اضافة عنصر الزنك(الى وسط نمو البذور وكذلك التأثير التفاعلي بين هذه العوامل على عملية الانبات لثلاثة أنواع برية من نبات السنامكى(السنا - سنا صعيدى – سلميكة). وقد تم انبات بذور نوعان ينتميا الى البيئة الصحراوية الجافة ونوع اخر برى ينتمى الى البيئة الوسيطة تحت الظروف المعملية. وقد تم دراسة التحولات الايضية للمواد المختزنة الكربوهيدراتية (السكريات الذائبة والقابلة للتحلل المائى) ذات التأثير الاسموزي وكذلك التوزيع النسبي لهذه المواد الايضية في الجذير والريشة والفلقات. وقد أظهرت الدراسة ان اضافة الزنك ادى الى زيادة الانضباط الاسموزي الايضي في البادرات المعرضة لنقص الجهد المائي من خلال زيادة التحلل المائي داخل انسجة البادرة (الجنين) النامي وزيادة معدل انتقالها الى الجذير مما أدى الى زيادة الضغط الأسموزي في جذير النبات.ايضا اضافة عنصر الزنك الى محاليل الانبات تزيد من مدى تكيف النباتات لدرجات الحرارة المتطرفة وذلك من خلال الزيادة الكلية للمواد الايضية المختلفة في البادرات حيث أكد التحليل الاحصائي ان تأثيرات التفاعل التبادلى بين العوامل الثلاثة كان لها دور هام في التأثير على العمليات الايضية المختلفة في الانواع الثلاثة .