

Green-Synthesized Nanocellulose Enhanced Germination, Morphology Roots, Nutrients Influx of Wheat Seedlings under Salinity Stress

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ABSTRACT

Nanoparticles have been widely used in agriculture in the past few years. The purpose of this work was to illustrate the potential of nanocellulose (NC) at different concentrations (0, 0.3%, and 0.6%) for priming wheat to enhance seed germination under different saline concentration (0.7, 5, 10, 15, and 20 dSm⁻¹) and to investigate the impacts of NC seed priming treatments on growth, root morphology, water relation, Superoxidase enzyme (SOD) and nutrient influx under salt stress. Results indicated that salt stress decreased germination percent, root length, root surface area, and water content. Moreover, increased root radius, Na influx and SOD enzyme. Seed priming with NC at 0.3% was the best treatment in improving germination percent, root length, root surface area and Na influx. While seed priming with 0.6% was the most effective treatment in decreasing SOD enzyme. Overall, the results of this study showed that applying NC as a priming seed treatment can improve wheat germination and seedling growth while shielding the plants from the damaging effects of salinity stress.

Keywords: Nanocellulose; Wheat; Germination; Salinity.

INTRODUCTION

In dry and semiarid locations, salinity is the main environmental stressor that limits agricultural output and sustainability by slowing down germination and delaying the start of germination and the subsequent establishment of seedlings. Salt has a deleterious impact on crop productivity all over the world. Since most plants that are grown are glycophytes that are sensitive to salt. Osmotic stress, ion toxicity, and oxidative stress are the three ways that salt stress impacts seed germination and seedling establishment. By raising ABA levels, lowering the levels of seed germination stimulants such GAs, and changing the seed's membrane permeability and water behavior, salinity can have a negative effect on seed germination. Under salt conditions, rapid seed germination and the establishment of subsequent seedlings are critical variables influencing crop productivity (Uçarlı, 2020).

Under typical conditions, the germination of seeds typically occurs in three stages Phase I of seed germination is defined by the dry seed's quick

absorption of water, or imbibition. This phase is followed by an inactive phase, or phase II. In phase II, the metabolisms of the cells are revived and the intake of water is restricted. Phase III, or the post-germination phase, comes next and is distinguished by ongoing water uptake until germination is finished. Based on these three stages, it is often possible to attribute phase I osmotic stress and phase II ionic stress as the causes of the inhibition of seed germination or delay in germination time under salt stress. Phase III seed germination is inhibited or delayed by the combined effects of osmotic and ionic stress (El-Hendawy *et al.*, 2019).

One helpful physiological strategy for helping glycophyte species adapt to salinity during germination and the subsequent establishment of seedlings is seed priming. By encouraging seed germination and seedling establishment in agricultural regions, it is a straight forward, inexpensive, and effective biotechnological method used to address the salt problem (Maili and Pramanik, 2013). The seeds are continuously exposed to an evoking solution, which permits partial hydration, but re-drying of the seed does not cause radicle emergence. According to Hussain *et al.* (2015), the purpose of seed priming is to prolong the reactivation of metabolisms, which permits pre-germinative physiological and biochemical activities but inhibits the seed's progression towards full germination. Reduced imbibition time and enzyme activation result in improved and uniform germination of primed seeds., the start of the biochemical processes that repair cells; an increase in RNA content and DNA replication; a reduction in ROS and lipid peroxidation with an increase in the activity of antioxidant enzymes such as glutathione reductase, catalase, and superoxide dismutase; and an increase in starch metabolism and osmotic adjustment (Lemmens *et al.*, 2019 and Martínez-Ballesta *et al.*, 2020).

Wheat (*Triticum aestivum* L.) is considered as one of the most important food crops grown in arid and semiarid regions of the world. Due to the enhanced salinity effect caused by low rainfall, high evapotranspiration, high temperatures, poor water

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quality, and inadequate soil management techniques, these locations have a serious problem with salinity in their soil (Azevedo-Neto *et al.*, 2006). Since soil salinity is frequently too high for ideal crop production, the majority of marginal lands are found in arid and semiarid locations (Cai *et al.*, 2011). Thus, it is vitally crucial to design crop management strategies for raising the salinity of wheat soil.

In recent years, nanotechnology has provided new opportunities in the field of biotechnology and agriculture (Siddiqui *et al.*, 2015). Through nanotechnology, nanotechnology has opened up new avenues for biotechnology and agriculture in recent years (Siddiqui *et al.*, 2015). By manipulating matter at the atomic and molecular levels to take advantage of unique features, functional materials can be produced using nanotechnology (Maynard *et al.*, 2006), which could open up new avenues for the agricultural industry. Materials with at least one dimension that is roughly between 1 and 100 nm are classified as nanoparticles (NPs) by the USEPA (Ditta *et al.*, 2015). These NPs have special physicochemical properties like high specific surface area and strong reactivity (Siddiqui *et al.*, 2015). Depending on their chemical makeup, reactivity, application method, and size, nanoparticles (NPs) can alter a variety of morphological and physiological processes in plants and positively impact plant growth and development (Tripathi *et al.*, 2017). based on the type of plant, its size, concentration, method of application, reactivity, and chemical makeup (Ma *et al.*, 2010). However, there is little research on the advantageous functions of NPs, specifically how they help crop plants recover from the damaging impacts of abiotic stress (Siddiqui *et al.*, 2015). According to recent research, treating seeds with nanomaterials can enhance their physiology, development, and germination (Du *et al.*, 2017). Iron oxide nanoparticles (NPs) applied topically or in the soil have been shown to increase growth and yield in studies on wheat (*Triticum aestivum* L.), rice (*Oryza sativa* L.), soy beans (*Glycine max* L.), and peanuts (*Arachis hypogaea* L.) (Alidoust & Isoda, 2013, 2014; Li *et al.*, 2013; Rui *et al.*, 2016 and Sherif *et al.*, 2022). In another study, iron oxide nanoparticles (NPs) were applied to watermelon (*Citrullus lanatus* L.) and resulted in an increase in chlorophyll content, antioxidant enzyme activity (catalase, peroxidase, and superoxide dismutase), and a decrease in malondialdehyde (Li *et al.*, 2013). A greater deal of attention has been paid to the generated agricultural biomass wastes in an effort to replace petrochemicals with safe, readily available, renewable, and environmentally acceptable alternatives. The most prevalent biopolymer component produced from all plant fiber waste is and has always been cellulose. In the

meantime, scientists have focused their attention on creating nanocellulose (NC) due to the recent advancements in nanoscience. The great range of sizes and forms of nanocellulose allowed for a multitude of uses and applications; they included food, packaging, and biological applications. Since each glucose molecule, the building block of the cellulosic chain, contains three active hydroxyl groups, NC has several benefits, including non-toxicity, biocompatibility, good mechanical properties, a high surface area-to-volume ratio, and potential versatility in terms of chemical modification or functionalization (Hanwell *et al.*, 2012). Because it is readily available and reasonably priced, plant cellulose is regarded as the primary source of cellulose. According to the source (Li *et al.*, 2018), cellulose is primarily found in the secondary cell wall of the plant as primary fibrils or nanofibrils with a diameter ranging between 10 and 100 nm and a micrometric length.

As far as we are aware, there is no evidence available about the effects of nanocellulose seed priming on the physiology of seedlings in salinized circumstances and the germination of wheat seeds. We speculate that under salt stress, seed priming using nanocellulose may improve wheat seed germination and seedling physiology. Therefore, the following goals guided the design of the study: (i) to investigate how seed priming with nanocellulose affects wheat seed germination; (ii) to measure the impact of salinity stress on the physiology of wheat seedlings; and (iii) to measure the impact of seed priming with nanocellulose in mitigating the inhibiting effects of salinity stress on wheat plants.

MATERIALS AND METHODS

The experiment was conducted during December 2023 at 403 soil fertility and plant nutrition Lab, faculty of agricultural, Alexandria University, Egypt.

Bulk Cellulose (BC): Rice straw was obtained from The farm of the Faculty of Agriculture, Alexandria University. Cellulose was extracted from rice straw according to Hasan *et al.* (2014).

Nano cellulose crystals (NCC): The obtained BC was used to prepare NCC according to Hossain *et al.* (2018).

Wheat seeds (*Triticum aestivum* L.) of an Egyptian local genotype (Gimiza 11) were used for the germination experiment. Seeds were initially washed with distilled water and then primed in a combination of NC (0, 0.3, and 0.6) and saline solutions (0, 5, 10, 15, 20 dSm⁻¹) in Erlenmeyer flasks for 3 hrs. All treatments had six replicates. After priming, ten seeds were germinated on a filter paper

moistened with distilled water in Petri dishes at room temperature (28 ± 2 °C). Seedlings were harvested after 7 days from germination (3 replicates) and the others 3 replicates after 16 days from germination. On the 7th day, germinated seeds were counted, and the length of root (L, cm) was measured by a ruler (± 0.1 cm). A seed was considered germinated when radicle was larger than 2 mm long. Germination percentage (GP, %) was calculated.

Germination percentage (GP) was calculated using the following formula given by Manmathan and Lapitan (2013).

GP, % = (No. of actual germinated seeds)/(total number of sown seeds) \times 100.

Volume of root (V, cm³) was measured by the volume displacement method using a 25-mL graduated cylinder.

Root radius (R_r, cm) was then calculated using the following equation Hallmark and Barber (1984). $R_r = \sqrt{V/\pi L}$

Root surface area (RSA) was calculated using the following equation according to Hallmark and Barber (1984). $RSA = 2\pi R_r L$

Then, root fresh weight (RFW) was measured.

Nutrient concentration

Shoots were separated from roots, washed and wet ached with concentrated H₂SO₄ and 30% H₂O₂. Na⁺ and K⁺ were determined in shoot and root using flame photometry (Corning 410C-England CO9 -2DX-U.S.A)

Na/K ratio in root, and Na translocation from root to shoot were calculated.

Na translocation = $(Na_r - Na_s) / Na_r$

Where Na_r and Na_s are Na concentration in root and shoot.

Net nutrient influx

Net nutrient influx between 7 and 16 days in plant root was determined using the equation

$In = [(U - U_o)(\ln RSA - \ln RSA_o)] / [(t - t_o)(RSA - RSA_o)]$

Where In is net nutrient influx nmolm⁻²s

U is nutrient content

T is time at 7 and 16 days.

Peroxidase enzymes activity

Seedlings were collected from each treatment for determination of Superoxide dismutase activity (SOD) was measured spectrophotometrically at 560 nm according to Beyer Jr and Fridovich (1987) in the root (second harvest). One gm fresh plant was weighted and homogenized in 10 ml of 0.1 M phosphate buffer (pH=7) The suspension was centrifuged for 15 min at 15000 rpm. The supernatant was used for enzyme activity assay (Esfandiari *et al.*, 2007).

Peroxidase activity was assayed according to Shannon *et al.* (1966), two ml of 100 mM phosphate buffer (pH=7) was transferred to test tube followed by 1 ml of 250 mM H₂O₂ and 0.1 ml of the obtained supernatant were added. Distilled water (0.9ml) and 1 ml of 250 mM pyrogallol were then added to the tube immediately before the decrease in the absorbance has been measured at 420 nm for 5 min.

Statistical analysis

The treatments were set up according to the completely randomized design with six replicates. Statistical analysis of experimental data was carried out using CoStat Software package (CoHort, 2004). Differences between means of treatments were tested using the least square difference technique of Student Newman-Keuls at 5% significance level (LDS.05).

RESULTS AND DISCUSION

1- Effect of seed primming in nanocellulose on germination percentage:

The plant growth and development start from germination process, and hence, it is important to understand the impacts of nanocellulose on this process. Data in Table (1) and Fig. (1) showed that salinity significantly affects seed germination percentage (GP%). Increasing salinity from 0.7 dSm⁻¹ to 20 dSm⁻¹ decreased seed germination. The treatment 15 dSm⁻¹ decreased by 30% while the 20 dSm⁻¹ did not germinate. Results indicated that seed primming with 0.3 nanocellulose was the best seed treatment in improving germination percent. Results also indicated that priming seed in nanocellulose increased GP% from 20 to 50% and 20 to 30% by priming seed in 0.3 and 0.6 nanocellulose, respectively relative to saline treatment. The increased germination percentage due to nanoparticles is related to their penetration into seeds (Feizi *et al.*, 2013). Furthermore, Alidoust and Isoda (2014) illustrated that small particle size of n-Fe₂O₃ may lead to a higher bioavailability of iron to seeds and can increase the motion and uptake of water, nutrients and oxygen via pores in seed coat. The results agree with those observed by Achakzai *et al.* (2010) who reported the negative impact of salinity on growth and physiological parameters.

2-Effect of seed primming in nanocellulose on water relation:

Under salinity stress, the osmotic potential of plant cells becomes more negative due to the presence of a high salt concentration in the soil, which creates an osmotic gradient that drives water out of the plant cells and decreases turgor pressure. Data presented in Table (1) showed that salinity reduced water content in seedlings significantly. This trend was found with

the two different stages at 7 and 16 days. Priming seeds in 0.3% NC increased water content by 14.28 and 225% at 7 and 16 days, respectively relative to control. The highest water content was observed with the treatment 0.3% NC and 15 dSm⁻¹ at 7days. However, the treatment of 0.6% NC did not record significant increase at 7days, it recorded higher water content after 16 days of germination time, it increased by 89 and 118% with 5 and 10 dSm⁻¹, respectively.

3- Effect of seed priming in nanocellulose on root morphology:

Salinity reduced root length significantly as shown in Table (2) and Fig.(1). Priming seeds in NC ameliorate root growth as illustrated in Table (2) and Figs. (2, 3). The same trend was observed after 7 and 16 days of germination time.

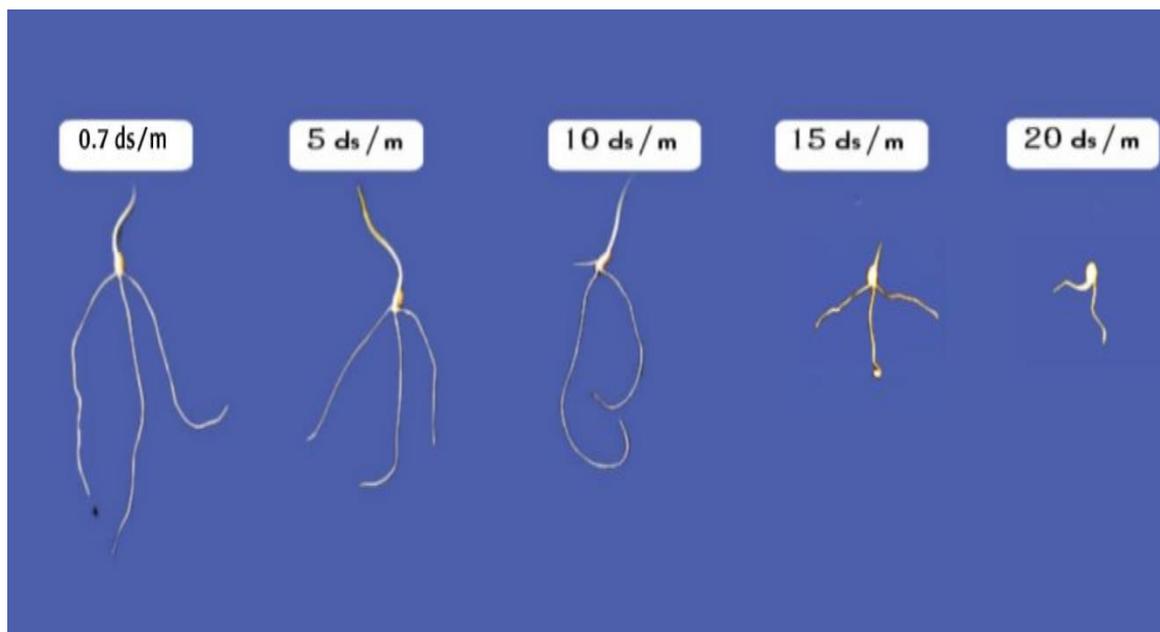


Fig.1. Effect of different salinity concentration on wheat seedling growth after 7 days of germination time.

Table 1. Effect of different levels of salinity and nanocellulose on germination percentage and seedling growth at two different stages.

Treat	%GP	7days			16 days		
		F.W	D.W	Water cont.	F.W	D.W	Water cont.
0.7 dSm ⁻¹	100	0.477 ^a	0.054 ^a	0.42	0.898 ^a	0.306 ^a	0.59
5 dSm ⁻¹	100	0.503 ^a	0.064 ^a	0.44	0.755 ^b	0.061 ^b	0.69
10 dSm ⁻¹	70	0.184 ^c	0.048 ^a	0.14	0.335 ^c	0.049 ^c	0.29
15 dSm ⁻¹	30	0.232 ^b	0.052 ^a	0.18	0.223 ^c	0.024 ^d	0.20
20 dSm ⁻¹	--	--	--	--	--	--	--
% 0.3NC	100	0.529 ^c	0.05 ^c	0.48	2.00 ^a	0.084 ^b	1.92
% 0.3NC+5 dSm ⁻¹	100	0.732 ^a	0.335 ^a	0.40	1.08 ^b	0.099 ^a	0.98
% 0.3NC+10 dSm ⁻¹	100	0.671 ^b	0.069 ^b	0.60	0.467 ^c	0.039 ^c	0.43
% 0.3NC+15 dSm ⁻¹	60	0.065 ^d	0.008 ^d	0.06	0.177 ^d	0.018 ^d	0.16
% 0.3NC+20 dSm ⁻¹	20	0.041 ^d	0.012 ^d	0.03	0.092 ^e	0.004 ^c	0.09
% 0.6NC	100	0.237 ^b	0.057 ^b	0.18	1.305 ^a	0.058 ^b	1.25
% 0.6NC+5 dSm ⁻¹	100	0.395 ^a	0.039 ^c	0.36	1.204 ^b	0.083 ^a	1.12
% 0.6NC+10 dSm ⁻¹	66.6	0.215 ^{bc}	0.126 ^a	0.09	1.347 ^a	0.054 ^c	1.29
% 0.6NC+15 dSm ⁻¹	50	0.078 ^d	0.013 ^d	0.07	0.266 ^c	0.009 ^d	0.26
% 0.6NC+20 dSm ⁻¹	30	0.19 ^c	0.019 ^d	0.17	0.185 ^c	0.009 ^d	0.18

Table 2. Effect of different levels of salinity and nanocellulose on root morphology at two different stages.

	7days			16 days		
	R.L	R.r	RSA	R.L	R.r	RSA
0.7 dSm ⁻¹	28.05 ^a	0.07 ^d	11.9 ^a	34.84 ^a	0.057 ^b	13.1091 ^a
5 dSm ⁻¹	22.7 ^b	0.076 ^c	10.9 ^b	27.81 ^b	0.087 ^a	10.6795 ^b
10 dSm ⁻¹	12.17 ^c	0.11 ^b	6.9 ^c	16.49 ^c	0.092 ^a	8.8194 ^c
15 dSm ⁻¹	3.35 ^d	0.14 ^a	3.67 ^d	4.19 ^d	0.092 ^a	3.05564 ^d
20 dSm ⁻¹	0 ^e	0 ^e	0.00 ^e	0 ^e	0 ^b	0 ^e
% 0.3NC	32.54 ^a	0.06 ^d	13.06 ^a	37.03 ^a	0.061 ^c	13.8515 ^a
% 0.3NC+5 dSm ⁻¹	30.13 ^b	0.06 ^c	12.20 ^b	26 ^b	0.075 ^b	11.2085 ^b
% 0.3NC+10 dSm ⁻¹	22.92 ^c	0.077 ^b	10.93 ^c	18.25 ^c	0.074 ^b	8.72922 ^c
% 0.3NC+15 dSm ⁻¹	7.29 ^d	0.065 ^c	4.82 ^d	3.47 ^d	0.095 ^a	3.04111 ^d
% 0.3NC+20 dSm ⁻¹	2.68 ^e	0.086 ^a	2.31 ^e	1.89 ^e	0.043 ^d	1.62168 ^e
% 0.6NC	27.72 ^a	0.07 ^e	11.89 ^a	31.97 ^a	0.067 ^e	12.8225 ^a
% 0.6NC+5 dSm ⁻¹	16.88 ^b	0.094 ^b	9.30 ^b	18.58 ^b	0.097 ^c	9.54534 ^b
% 0.6NC+10 dSm ⁻¹	12.36 ^c	0.113 ^a	7.57 ^c	18.47 ^b	0.081 ^d	9.00513 ^d
% 0.6NC+15 dSm ⁻¹	4.83 ^e	0.08 ^d	3.30 ^e	3.75 ^c	0.139 ^b	3.56038 ^e
% 0.6NC+20 dSm ⁻¹	7.83 ^d	0.09 ^c	4.94 ^d	3 ^d	0.125 ^a	2.92804 ^f

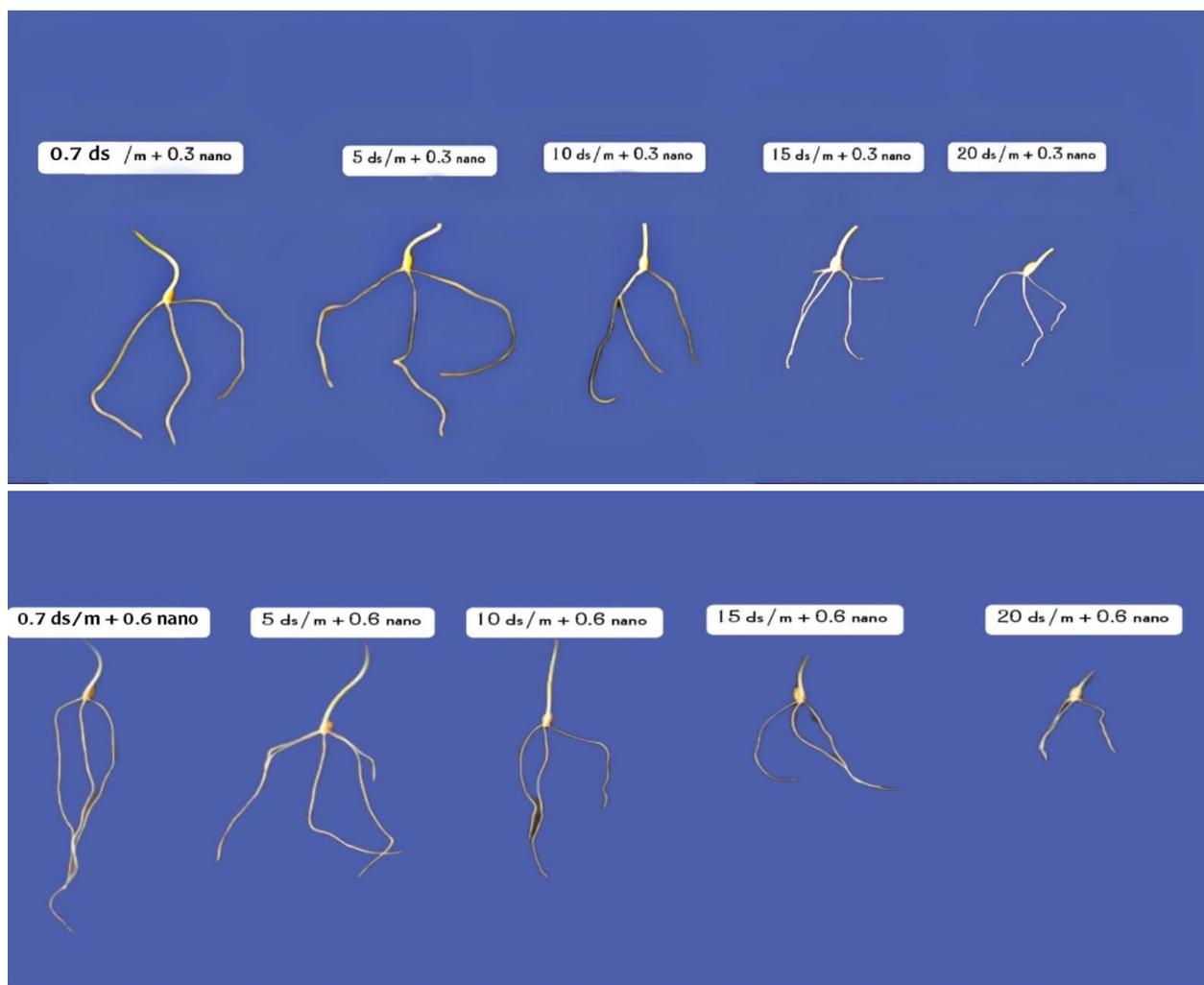


Fig. 2. Effect of priming seed in different concentration of NC and salinity.

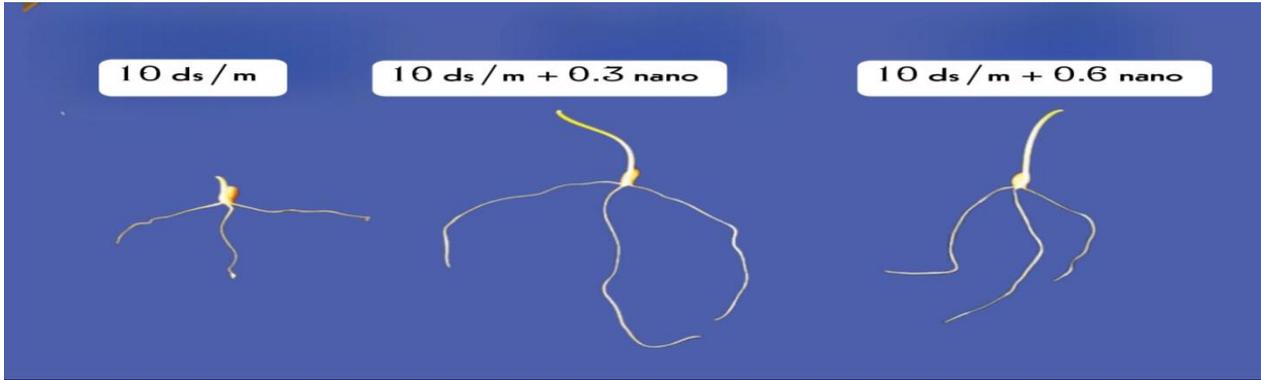


Fig.3. Effect of priming seed in 0.3 and 0.6% NC after 7days of germination time.

Priming seeds by 0.3% NC recorded the highest increase in root length. Meanwhile, priming seeds with 0.6 NC had the ability to improve root length especially at the highest salinity concentration (20 dSm⁻¹). We observed that the increase in root length in response to nanocellulose treatments is consistent with the findings of Alidoust and Isoda (2013, 2014).

In contrary to root length, root radius was increased by increasing salinity. This increasing of root radius considered as one of the different strategies that plant acts towards stress. ANOVA (Tables 3, 4) indicated that root radius was affected significantly by salinity, priming in NC and the interaction between them.

Root surface area is important in supplying the essentials elements required for plants. The data presented in Table (2). showed that root surface area was decreased significantly as salinity increased. While priming seeds with NC increased RSA. The highest RSA. was recorded with 0.3% NC that increased RSA by 9, 11, 58, and 31% at different concentration of salinity 0.7, 5, 10, 15 dSm⁻¹ respectively, relative to control. Also, it enhances the germination of seeds at 20 dSm⁻¹ that did not germinate in the absence of NC. The analysis of variance shown in Tables (3, 4) illustrate that RSA also affected significantly by salinity, NC and the interaction between them.

Table 3. Analysis of variance of seed germination of wheat seedling under different salinity levels and priming in NC after 7 days of germination time.

Source of variance	F value							
	FW	DW	RL	Rr	RSA	K/Na Ratio	NaR/NaS	NaR - NaS/NaR
LSD0.05(Salinity)	0.044	0.02	0.48	0.005	0.583	0.092	0.328	0.09
LSD0.05(Nano)	0.034	0.015	0.37	0.004	0.451	0.071	0.254	0.069
LSD0.05(Salinity*nano)	0.98	0.86	0.99	0.988	0.993	0.999	0.922	0.999
Salinity	***	***	***	***	***	***	***	***
Nano	***	Ns	***	***	***	***	**	***
Salinity*Nano	***	**	***	***	***	***	**	***

Table 4. Analysis of variance of seed germination of wheat seedling under different salinity levels and priming in NC after 16 days of germination time.

Source of variance	F value								
	FW	DW	RL	Rr	RSA	K/Na Ratio	NaR/NaS	NaR - NaS/NaR	IN
LSD0.05(Salinity)	0.121	0.004	0.462	0.01	0.48	0.172	0.328	0.031	0.185
LSD0.05(Nano)	0.094	0.003	0.358	0.008	0.372	0.133	0.254	0.024	0.143
LSD0.05(Salinity*nano)	0.984	0.998	0.995	0.953	0.996	0.964	0.922	0.997	0.984
Salinity	***	***	***	***	***	***	***	***	***
Nano	***	***	***	***	*	**	**	***	***
Salinity*Nano	***	***	***	***	***	***	**	***	***

4- Effect of seed priming in nanocellulose on nutrient uptake:

Net nutrients influx into roots plays an important role in determining the nutrient status of plants. The physiological response to salinity is a complex phenomenon that normally includes rapid Na⁺ influx in root cells. High levels of Na⁺ and Cl⁻ do not have specific cellular targets. Therefore, NaCl toxicity is related to a long-term and non-specific disturbance of cellular osmotic (Isayenkov and Maathuis, 2019). The key mechanisms of toxic Na⁺ influx into the root cells is its entry through the plasma membrane-associated non-selective cation channels (Demidchik and Maathuis, 2007). However, the existence of other pathways, such K⁺-selective channels, has also been hypothesized (Assaha *et al.*, 2017). Na⁺ influx-induced depolarization triggers the generation of reactive oxygen species (ROS) catalyzed by nicotinamide adenine dinucleotide phosphate (NADPH) oxidases and other redox systems which additionally stimulate Ca²⁺ influx and loss of K⁺ (as well as the loss of other electrolytes), leading to a long-term ionic and redox disequilibrium, which is considered to be the prime reason for NaCl toxicity among most plants (Demidchik *et al.*, 2014 and Demidchik & Shabala, 2018).

The results presented in Table (5) showed that increasing salinity increased Na⁺ influx significantly. Priming wheat seeds in 0.3% NC decreased Na influx significantly by 15, 88, and 30% at 5, 10, and 15dSm⁻¹, respectively. This may be due to high content of Ca²⁺ ions in NC. Hryvusevich *et al.* (2021) reported that Ca²⁺ ions are blockers of plant Na⁺-permeable NSCCs. However, the decrease of external Ca²⁺ resulted in the increase in the inward Na⁺ current. Interestingly, the response of Na⁺ influx to Ca²⁺ induced protection of root growth in wheat seedlings treated with NC. The results agree with Hryvusevich *et al.* (2021).

Under saline conditions, there is intense competition between K⁺ and Na⁺. The cellular balance between Na⁺ and K⁺ is essential for plant survival in saline soil. However, they both have a molecular similarity, which causes potassium replacement by sodium even though it cannot take over the function of potassium in cellular processes. An increased Na⁺ concentration decreases K⁺ and Ca²⁺ concentrations, as Na⁺ and K⁺ compete at root uptake sites.

Concerning, the relation between Na and K uptake, data presented in Table (5) illustrated that increasing salinity concentration decreased K⁺/Na⁺ ratio significantly. This may be due to K⁺ outwardly directed conductance in wheat showed greater Na⁺ sensitivity under salinity stress. Priming seeds in NC increased K⁺/Na⁺ ratio significantly. This can be explained by the

influence of high content of Ca²⁺ on the Na⁺-induced blockade of KORs in the case of measurements which were carried out at 0.3% NC. Shabala *et al.* (2006) reported that salt-sensitive species *A. thaliana*, this blockade was 1.3–1.9 times both in root epidermis and leaf mesophyll cells showing a tendency to increase with an increase in the concentration of extracellular Ca²⁺. From the present findings, we hypothesize that enhanced sensitivity of K⁺ efflux system to Na⁺ can play an important role for adaptation because this will decrease K⁺ loss under salinity conditions. It fits well within the hypothesis that maintaining a high K⁺/Na⁺ ratio in plant cells and prevention of K⁺ efflux under salt stress are key mechanisms of salt tolerance in higher plants (Demidchik *et al.*, 2018).

The ionic imbalance caused by salinity stress affects many aspects of plant growth and development. However, plants maintain intracellular ion homeostasis by controlling ion influx and its compartmentalization to cope with salinity stress. Data shown in Table (5). Illustrated that Na⁺ translocation decreased significantly with increasing salinity. This may be due to different strategies root developed to protect the cytoplasm against the toxic effects of Na⁺ by restricting the Na⁺ influx into the cell, enhancing the Na⁺ exclusion out of the cell, and maximizing the compartmentalization of Na⁺ into the vacuole.

Na uptake in plants by nonselective cation channels, such as cyclic nucleotide-gated channels (CNGCs) and glutamate receptors (GLRs). The translocation of Na⁺ from roots to shoots occurs through the apoplastic pathway, transitioning to the symplast of the root epidermis before being loaded into the tracheids of the xylem, eventually reaching the leaf blades, where its effects are most pronounced (Maathuis, 2009). Priming wheat seeds in NC enhances root growth which reduced adaptation of plants towards salinity except at the highest concentration 20 dSm⁻¹.

5- Effect of seed priming in nanocellulose on Superoxide enzyme:

Salinity induced accumulation of ROS which causes oxidative damage to membrane lipids, proteins, and nucleic acids, causing irreversible metabolic dysfunction. Plants have antioxidant enzymes to detoxify salt-induced ROS. Superoxide dismutase (SOD) is one of the antioxidant enzymes. The results shown in Fig. (4) illustrated that (SOD) increased by elevated salinity concentration as a kind of defense to eliminates superoxide radicals by converting it to O₂ and H₂O₂. Many studies have

shown the correlation between salt tolerance and the increased activities of antioxidants. For example, a recent study on *A. tricolor* foliage plants showed an elevated amount of SOD, ascorbate, and APX in a salt-tolerant variety (VA14) to assist ROS detoxification (Sarker and Oba, 2020). Hussain *et al.* (2022) investigated the salt tolerance of contrasting wheat

genotypes and concluded that a lower MDA production in salt-tolerant varieties correlated with a lower-membrane lipid peroxidation (Hussain *et al.*, 2022). It is clear from Fig. (4) that priming wheat seeds in 0.3 and 0.6 %NC decreased (SOD) enzyme, which means that NC decreased the toxic effect of salinity.

Table 5. Effect of different levels of salinity and nanocellulose on K⁺/Na⁺ ratio, Na translocation and influx

Treat	K/Na	Na _r -Na _s /Na _r	Influx
0.7 dSm ⁻¹	3.17 ^a	1.846 ^a	0.00 ^b
5 dSm ⁻¹	0.37 ^b	0.925 ^b	0.058 ^b
10 dSm ⁻¹	0.12 ^c	0.734 ^c	0.060 ^b
15 dSm ⁻¹	0.09 ^c	0.350 ^d	0.536 ^a
20 dSm ⁻¹	---	---	---
% 0.3NC	5 ^a	2.091 ^a	0.007 ^c
% 0.3NC+5 dSm ⁻¹	0.42 ^c	1.111 ^d	0.049 ^c
% 0.3NC+10 dSm ⁻¹	0.40 ^c	1.617 ^c	0.007 ^c
% 0.3NC+15 dSm ⁻¹	0.03 ^d	1.862 ^b	0.372 ^b
% 0.3NC+20 dSm ⁻¹	2.32 ^b	0.024 ^e	0.3837 ^a
% 0.6NC	8.20 ^a	0.938 ^d	0.010 ^a
% 0.6NC+5 dSm ⁻¹	0.10 ^d	1.138 ^c	0.023 ^a
% 0.6NC+10 dSm ⁻¹	0.11 ^d	2.363 ^a	0.025 ^a
% 0.6NC+15 dSm ⁻¹	0.02 ^c	1.352 ^b	0.124 ^a
% 0.6NC+20 dSm ⁻¹	0.46 ^b	0.088 ^e	0.157 ^a

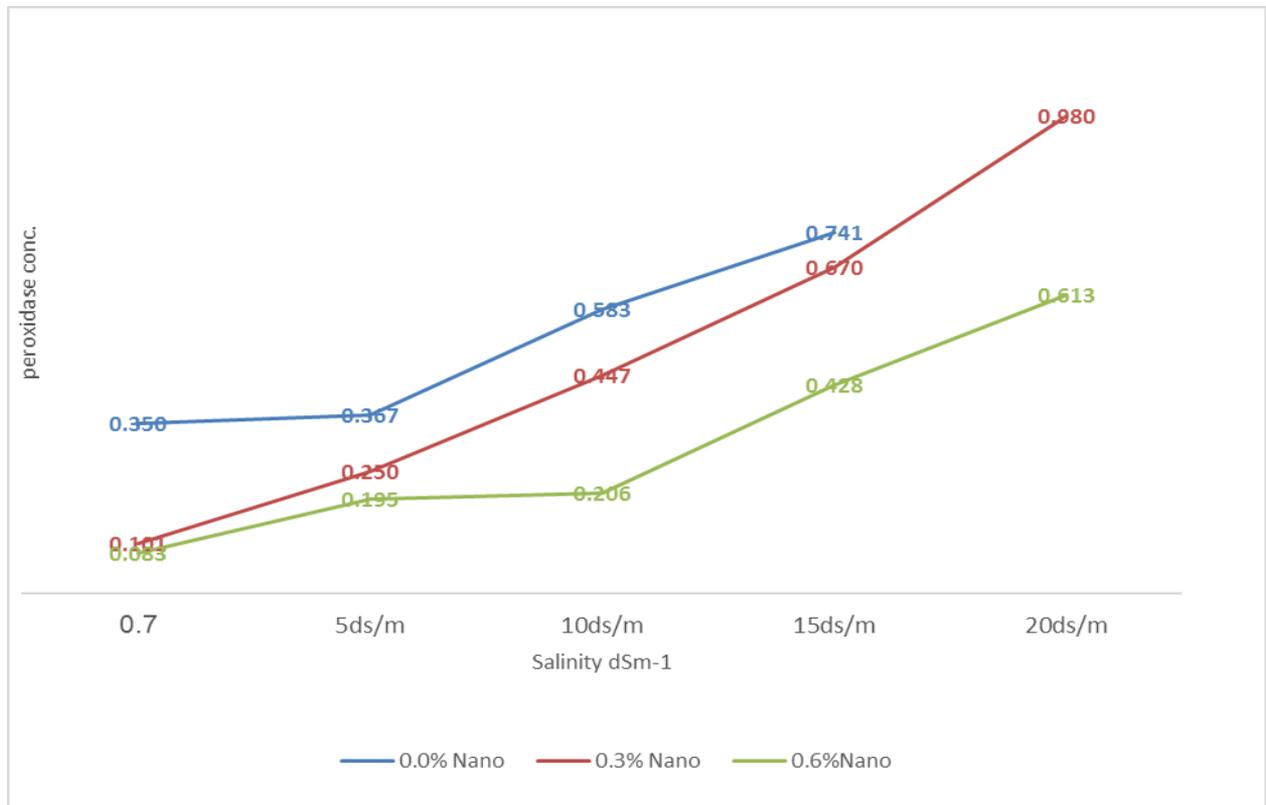


Fig.4. Effect of salinity on superoxide dismutase enzyme at different levels of nanocellulose on wheat seedlings.

CONCLUSIONS

The study found an important difference in the mean germination % across seed priming treatments due to the saline stress that the seeds experienced. This suggests that priming has more positive effects when applied under stress conditions than under normal ones. Therefore, we might speculate that NC might play a role in improving plant status in saline stress. By increasing water content and reducing sodium input to roots and translocation from roots to shoots, seed priming at 0.3% NC increased seedling root length, RSA, and germination percent when compared to control. To provide a useful advice, more research in real-world settings is required.

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الملخص العربي

النانو سليولوز المخلق لتحسين الانبات ومورفولوجى الجذور وامتصاص العناصر لشتلات القمح تحت تاثير الإجهاد الملحي

فاطمة كمال شريف، على سعيد مصطفى، هدى أحمد أرجيعة

ذلك، زيادة نصف قطر الجذر، تدفق الصوديوم ونشاط إنزيم السوبر أوكسيديز (SOD). كان استخدام NC بنسبة 0.3% هو الأفضل في تحسين نسبة الإنبات وطول الجذر ومساحة سطح الجذر وتدفق الصوديوم. بينما كان 0.6% هو الأكثر فعالية في تقليل إنزيم SOD. بشكل عام، أشارت هذه الدراسة إلى أن استخدام NC كمرحلة أولية للبذور يمكن أن يعزز إنبات القمح ونمو الشتلات ويحمي من الآثار السلبية لإجهاد الملوحة.

في العقود الأخيرة، تم استخدام الحبيبات النانوية بشكل مكثف في الزراعة. أجريت هذه الدراسة لإثبات إمكانية تطبيق النانو سليولوز (NC) بتركيزات مختلفة (0.3 و 0.6%) لتعزيز إنبات بذور القمح تحت تركيزات ملحية مختلفة ($0.7, 5, 10.15, 20 \text{ dSm}^{-1}$) وبيان ذلك على النمو، ومورفولوجيا الجذر، وعلاقة الماء، ونشاط إنزيم السوبر أوكسيديز (SOD) وتدفق المغذيات تحت ضغط الملح. أشارت النتائج إلى أن الإجهاد الملحي قلل من نسبة الإنبات وطول الجذر ومساحة سطح الجذر ومحتوى الماء. علاوة على