NANOPARTICLES FOR SUSTAINABLE PRODUCTION OF *Kochia indica* IRRIGATED WITH LOW QUALITY WATER

Medhat Mekhail Tawfik[1]*, Howida Hassn Khedr[1], Mervat Shamoon Sadak[2], and Mohamed Omar Kabesh[1]

[1]Field Crops Research Department, Agricultural and Biological Division
National Research Centre, 33 El-Behooth St., Dokki, Giza, Egypt
[2]Botany Department, Agricultural and Biological Division, National Research Centre
33 El-Behooth St., Dokki, Giza, Egypt

*Corresponding author: medhatnrc@hotmail.com

Abstract — Green revolution had led to the increased consumption of chemical fertilizers which resulted in the higher productivity and caused environmental hazards. Nutrient use efficiency of conventional fertilizers is very low. To overcome all these drawbacks in a better way, nanotechnology can be a ray of hope. Nano fertilizer is an important tool in agriculture to improve crop growth, yield and quality parameters with increased nutrient use efficiency. Careful and judicious use of nanotechnology can ensure help in maximizing plant productivity especially in new reclaimed salt affected sandy soil which usually suffer from abiotic stress (drought and salinity). Nanoparticles have potential to improve growth and yield of plant under this circumstances. This paper studied the effect of ZnO nanoparticles on *Kochia indica* grown under saline conditions. To realize the previous tasks, a field trial was conducted at the Model Farm of the National Research Centre, El Tour, South Sinai to test the impact of foliar application with ZnO (20, 40 and 60 ppm) in addition to control treatment on some growth characters, photosynthetic pigments content, crude protein content, crude fiber, ash and some physiological aspects as well as nutrients content of *K. indica*. The results show that foliar application of ZnO nanoparticle improved growth, pigment content, crude protein, and crude fiber. The best results were obtained under foliar application with 40 ppm ZnO nanoparticle treatment. Thus, this concludes that zinc nanoparticles can improve productivity of *K. indica* in salt affected soils.

***Keywords — Kochia indica*, Zn nanoparticles, growth, physiological aspects, saline habitats**

INTRODUCTION

Soil salinity is one of the worst environmental problem around the world which affects arid and semi-arid regions. In general, it could be increased in irrigated lands because of poor drainage, bad irrigation system, low rainfall and high transpiration rate. It was stated that approximately 20% of irrigated land is affected by salts, which nearly about 1000 million hectare of land (Munns and Tester, 2008). Salinity tolerance is defined as the capability of plants to grow under salt stress evironment (Munns et al., 2002). Another essential factor of salt tolerance mechanisms is the ability of plant cells to regulate osmotically and to accumulate organic solutes (i.e. proteins, sugar, amino acids, etc.).

Kochia as a halophytic plant receiving attention by many researchers as it could be a very good opportunity as fodder or forage crop, it's a good plant for soil bioremediation in dry regions. many scientists reported that *kochia* is a promising forage crop for salt-affected environment (Youssef et al., 2009).

Recent agricultural managements associated with the green revolution have greatly increased the global food supply. They have also had an inadvertent, detrimental impact on the environment and on ecosystem services, highlighting the need for more sustainable agricultural methods (Tillman et al., 2002). It is well documented that excessive and inappropriate use of fertilizers has improved nutrients and toxins in both ground and surface waters, incurring health and water purification costs, and decreasing fishery. Agricultural practices that degrade soil quality contribute to eutrophication of aquatic habitats and may necessitate the expense of increased fertilization, irrigation, and energy to maintain productivity on degraded soils, they also kill beneficial insects and other wildlife (Presley et al., 2004) and Mukhopadhyay (2005). Intensive tillage, irrigation, and fertilizer dressing have also caused more extensive damage to the carbon profile in soils than early agrarian practices did (Knorr et al., 2005).

Recently, there has been a rapid growth of interest in the field of nanoscience and nanotechnology because of the realization that nano-sized materials are more effective in a multitude of agricultural technology (Nair et al., 2010).

Nanotechnology deals with the production and utilization of substances with nanoscale dimension. Nanoscale dimension provides nanoparticles a large surface area to volume ratio and thus very specific properties (Agarwal et al., 2017). Attempts to apply nanotechnology in agriculture began with the growing realization that conventional farming technologies would neither be able to increase productivity any further nor recover damaged ecosystems. Nanotechnology is an emerging technology, which can lead to a new revolution in every branch of science (Abbasifar et al., 2020). Research in this field has gained momentum especially in the recent years by providing innovative solutions in different scientific fields (Rico et al., 2011). Nanotechnology deals with nanoparticles that are atomic or molecular aggregates characterized by size less than 100 nm. These are actually modified form of basic elements derived by altering their atomic as well as molecular properties of elements (Kato, 2011). Zinc oxide is an inorganic compound with the molecular formula ZnO. It appears as a white powder and is nearly insoluble in water (Kokina et al., 2020). In this regard, Raliya and Tarafdar (2013) stated that, ZnO NPs in lower concentration increased seed germination in wheat. They recorded improved plant biomass, root and shoot length, chlorophyll and protein synthesis and other growth parameters *Cyamopsis tetragonoloba* when exposed to ZnO NPs. Moreover, Burman et al., (2013) reported that foliar application of ZnO NP at 1.5 mg/L concentration increased biomass in chickpea as compared to normal ZnSO4.

The objective of this experiment was to test the effect of some nano-concentration of ZnO treatments on growth, photosynthetic pigments content, crude content as well as some physiological aspects of *K. indica*.

MATERIALS AND METHODS

A field experiment was carried out at the Model Farm of National Research Centre, El Tour, South Sinai to study the impact of foliar application of ZnO nanoparticles (control, 20, 40 and 60 ppm) on some growth characters, photosynthetic pigments content, crude protein content and some physiological aspects as well as nutrients content of *K. indica*. Zinc oxide (ZnO) NPs about 18 nm sizes were synthesized by mixing 10 ml of sodium hydroxide (NaOH) solution (4mM) to 0.1 ml of 0.5 M solution of 1- thioglycerol and to 10 ml of 10-3 M solution of zinc acetate (Dhobale et al., 2008). The synthesized ZnO NPs were dried in oven, suspended in water and then used for treatment.

K. indica seedlings were transplanted at the 15th May 2020 and grown under drip irrigation system with salt affected water (EC: 8.7 dSm-1), water analysis of Abo Kalam Well are presented in Table 1. Each experiment included four (4) treatments. RCBD was used in this experiment with 1.5 x 1 m distance between plants having a total of 2800 plants/field. Mechanical and chemical analyses of the soil were carried out by using the standard method described by Klute (1986) shown in Table 2. Each plant was fertilized with 50 g calcium superphosphate (15.5% P2O5) and 30 g potassium sulphate (48.0 % K2O) and 60 g urea (46.5% N) mixed with 500 g green manures (compost). Foliar application with ZnO nanoparticles was applied 30 days from transplantation and 30 days later. Three replicates from vegetative samples for each treatment were taken at 2nd Sep 2015 to determine some growth characters such as plant height, number of branches, number of leaves, dry weight of leaves, dry weight of whole plant and leaf area as well photosynthetic pigments content as Von Wettstein (1957).Then samples were washed, dried thoroughly, then dried at 70° C to constant weight in an aerated oven to determine, proline (µg/g) according to Bates et al. (1979), osmotic potential were obtained from the corresponding values of cell sap concentration tables given by Gusev (1960) as well as values of succulence (ratio of fresh weight/dry weight) according to Tiku (1979). Soluble carbohydrates content determined by the method described by Dubois et al., (1956). The contents of sodium and potassium were determined in the digested material using Jenway flame photometer as described by Eppendrof and Hing (1970). K/Na ratio was also calculated for each treatment. crude fiber and ash were determined by standard analytical methods after A.O.A.C. (2010). Nitrogen was determined with micro Kjeldhal's apparatus according to the method described by A.O.A.C. (2010). Crude protein was calculated by multiplying nitrogen contents by 5.75.The obtained data were subjected to statistical analysis of variance described by Snedecor and Cochran (1982).

Table 1. Water analysis of Abo Kalam well, El Tour, South Sinai.

Parameters		
pH		7.49
EC dS^{-1}		8.71
Soluble cations	K^+	0.52
Meq/L	Na^+	69.23
	Mg^{++}	11.92
	Ca^{++}	21.64
Soluble anions	SO4--	26.61
Meq/L	Cl-	74.20
	HCO3-	2.44
	CO--	-

Table 2. Mechanical and chemical analyses of the soil.

Parameters			
Depth		00 - 30 cm	30 - 60 cm
Soil texture		Sandy soil	Sandy soil
pH		8.1	8.43
EC dS^{-1}		15.1	4.52
Soluble cations	K^+	0.4	0.24
Meq/L	Na^+	112.0	27.02
	Mg^{++}	28.8	5.53
	Ca^{++}	60.5	12.51
Soluble anions	SO4--	61.0	10.64
Meq/L	Cl-	139.0	31.04
	HCO3-	2.7	3.63
	CO--	-	-

RESULTS AND DISCUSSION

Effect of Foliar Application with Nanoparticles ZnO on some Growth Characters of *K. indica*

Data in Table 3 show that all foliar treatments significantly affected the studied growth characters. The highest values for plant height, number of branches, leaf area, dry weight of shoot, dry weight of root as well as shoot / root ratio were recorded in plants sprayed with 40 ppm ZnO. Similar results were obtained by (Franklin et al., 2007). Nanofertilizers have important role in physiological and biochemical processes of crops by increasing the availability of nutrients, which help in enhancing metabolic processes and promoting meristematic activities causing higher apical growth and photosynthetic area. It was documented by some research studies, where foliar spraying of nanoformulations of NPK and micronutrients mixture increased the plant height and number of branches in black gram as indicated by Marimuthu and Surendran (2015). and also Abdel-Aziz et al., (2018) found that nano NPK increased the growth of leaves in wheat, which was obtained by enhanced availability of nutrients by easy penetration of nano formulation of NPK through stomata of leaves via gas uptake. In this concern, Prasad et al. (2012) stated that zinc oxide have potential to boost the yield and growth of crops. Likewise, Naderi and Abedi (2012) stated that the increase in vegetative growth in plant could be due to basic role of Zn in protecting and maintaining structural stability of cell membranes. Cakmak (2000) added that Zn can be used in protein synthesis, membrane function, cell elongation as well as tolerance to environmental stresses. Prasad et al. (2012) suggested that ZnO nanoparticles are absorbed by plants to a larger extent as compared to ZnSO4. They also observed beneficial effects of nanoparticles in promoting plant growth, development and yield in peanut at lower doses, but at higher concentrations ZnO nanoparticles were detrimental just as the bulk nutrients. Mahajan et al. (2011) stated that, ZnONPs promoted the root and shoot length, and root and shoot biomass.

Table 3. Effect of foliar application withnanoparticles ZnO on some growth characters of *K. indica*.

Treatments	Plant height (cm)	Number of branches / plant	Leaf area (cm^2)	Shoot dry weight (g)	Root dry weight (g)	Shoot / root ratio
Control	95.68	31.57	95.36	157.60	44.98	3.50
ZnO 20 ppm	101.54	35.25	100.87	179.57	47.65	3.77
ZnO 40 ppm	115.36	42.30	121.30	201.35	50.58	3.98
ZnO 60 ppm	108.39	39.65	112.60	185.94	48.65	3.82
LSD 5%	6.36	2.03	7.15	8.98	2.44	0.15

Effect of Foliar Application with Nanoparticles ZnO on Photosynthetic Pigments of *K. indica*

Data in Figure 1 revealed that foliar application with nanoparticles ZnO, positively affected photosynthetic pigments content, with superiority to 40 ppm concentration over all the other treatments. Results are in a harmony with those of Prasad et al. (2012) who reported a higher content of chlorophyll (1.97 mg g−1 rt.wt) in peanut leaves by foliar application of ZnO NPs at 1000 mg L−1 (25 nm) compared to ZnSO4. Similar results were obtained by Franklin et al. (2007). Such increase in photosynthetic pigments content in the leaves of plants may be attributed to the enhancing effect of ZnO nanoparticles on chlorophyll accumulation through the useful importance of Zn on plant growth. In this regard, Raliya and Tarafdar (2013) reported that ZnONPs induced a significant improvement in chlorophyll synthesis. In this regard, Siddiqui et al. (2014) stated that SiO2NPs can improve photosynthetic rate by improving activity of carbonic anhydrase and synthesis of photosynthetic pigments. Moreover, the exogenous application of TiO2NPs improves net photosynthetic rate, conductance to water, and transpiration rate in plants (Qi et al., 2013). According to Govorov and Carmeli (2007), metal nanoparticles can induce the efficiency of chemical energy production in photosynthetic systems.

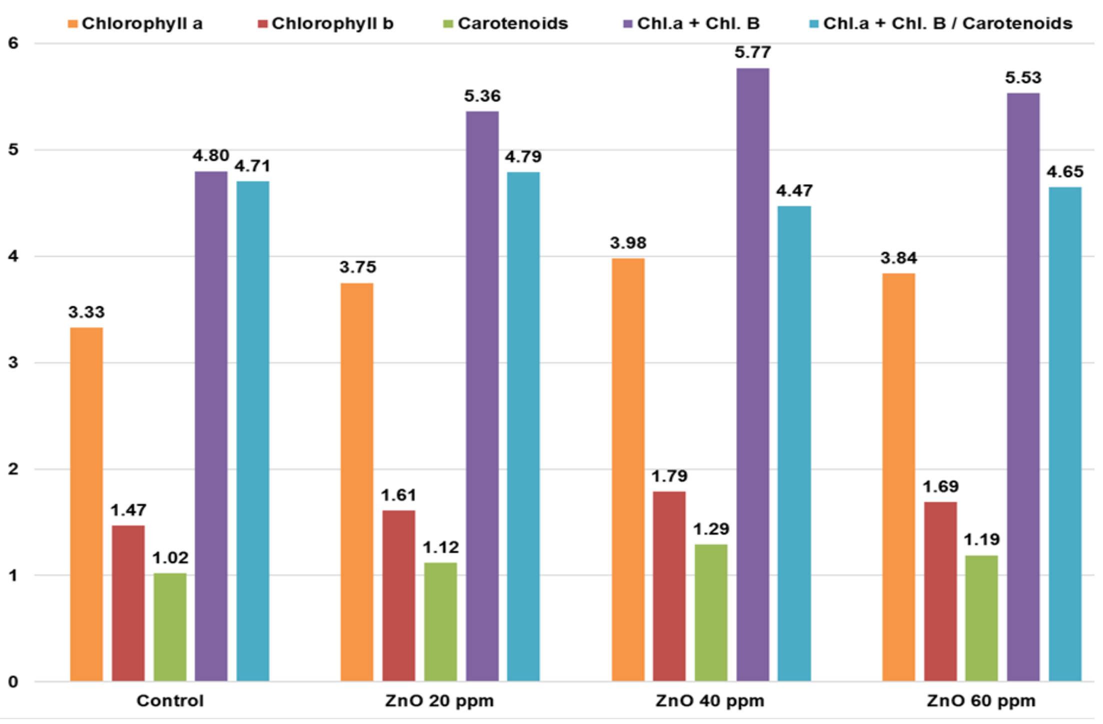

Fig. 1. Effect of foliar application with nanoparticles ZnO on photosynthetic pigments content of *K. indica* (LSD 5% = 0.19).

Effect of Foliar Application with Nanoparticles ZnO on some Physiological Aspects of *K. indica*

Table 4 shows the effect of different treatments on some physiological aspects of *Kochia indica*. It is clear that all foliar treatments significantly affected all the studied characters as compared with control treatment. It is also clear from the table that foliar application with 40 ppm ZnO nanoparticles recorded the highest values for Osmotic potential, Proline content and soluble carbohydrates % as well as succulence values, crude protein content and crude fiber in the plant leaves. On the other hand, the highest values for ash % were recorded under 60 ppm ZnO treatment. Similar results were obtained by Afshar et al. (2014) and El-Metwally et al. (2018). There was a remarkable increase in the physiological and biochemical parameters of crops with the application of nanofertilizers. In this regard, Helaly et al. (2014) stated that, ZnO NPs induced proline synthesis, and improved tolerance to abiotic stress. In another study, Nano-chelate zinc fertilizer application proved to enhance the activity of peroxidase, catalase, and polyphenol oxidase enzymes in cotton and soybean crops which increases the shoot and root growth (Rezaei and Abbasi, 2014). Moreover, Prasad et al. (2012) found that the application of fertilizer in nanoform is completely controlled and has led to an increase protein content in peanut. Furthurmore, Foliar application of nano-forms of iron and zinc fertilizers increased, and crude protein and soluble carbohydrate concentration in forage corn over chemical forms of fertilizers, (Sharifi et al., 2016). They added that, zinc fertilizers increased soluble carbohydrate concentration, probably due to involvement of zinc in photosynthesis, chlorophyll synthesis, starch formation and enzyme carbonic anhydrase, accelerating carbohydrate.

Effect of Foliar Application with Nanoparticles ZnO on Nutrients Content of *K. indica*

Data in Table 5 show that, foliar application with ZnO nanoparticles, significantly affected content of N, P, K, Na, and Zn as well as K/Na value as compared with control treatment. However, plants sprayed with 40 ppm ZnO recorded the highest values of N, P and K as well as K/Na while plants sprayed with tap water (control) recorded higher contents of Na. On the other hand, plants sprayed with 60 ppm ZnO recorded the highest values of Zn. Such results were confirmed by the findings of Bahrnanyar and Ranjbar (2008). Zinc plays a positive role in root development, it helps plants absorb important nutrients, especially nitrogen responsible for protein

Table 4. Effect of foliar application with nanoparticles ZnO on some physiological aspects of *K. indica*.

Treatments	Osmotic potential values	Proline content µg/g dry wt.	Soluble carbohydrates %	Succulence	Crude protein %	Crude fiber %	Ash %
Control	7.06	344.58	45.98	3.19	7.68	21.35	27.68
ZnO 20 ppm	7.25	365.87	47.02	3.57	8.02	20.37	28.65
ZnO 40 ppm	8.02	402.36	48.23	3.75	8.87	22.02	28.87
ZnO 60 ppm	7.68	388.25	47.85	3.67	8.47	21.36	29.03
LSD 5%	0.41	18.25	2.81	0.15	0.44	NS	NS

Table 5. Effect of foliar application with nanoparticles ZnO on nutrients content of *K. indica*.

Treatments	N %	P %	K %	Na %	K/Na	Zn ppm
Control	1.34	0.51	0.98	1.02	0.96	15.36
ZnO 20 ppm	1.39	0.55	1.03	0.96	1.07	16.58
ZnO 40 ppm	1.54	0.68	1.25	0.91	1.42	17.25
ZnO 60 ppm	1.47	0.60	1.12	0.88	1.23	17.99
LSD 5%	0.08	0.04	0.07	0.06	0.07	0.72

synthesis (El-Metwally et al., 2018). such increase could be attributed to the synergistic effect between N and Zn which might be due to increase enzymatic activity by Zn application (Keram et al., 2012).

Foliar application of nano-forms of iron and zinc fertilizers increased, phosphorus concentration in forage corn over chemical forms of fertilizers, (Sharifi et al., 2016).

CONCLUSION

Nano-fertilizers may be more effective than regular fertilizers in improving plant nutrition, enhancing nutrition use efficiency, and protecting plants from environmental stress. The results suggest safe use of ZnNPs in the agricultural fields with further suitable modifications. Results showed that *K. indica* is highly salt tolerant halophyte, foliar application with 40 ZnO nanoparticles enhanced all studied growth characters as well as photosynthetic pigments content and crude protein as well as the physiological aspects of the plant. We can conclude that zinc nanoparticles can improve plant growth in salt affected environment.

ACKNOWLEDGMENT

The authors express their appreciation to the National Research Centre who financed the project of “Sustainable production of forage crops in Egypt under water scarcity: Assessment, Mechanism and Management Strategies” (Project number 12050125).

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