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Response of Mineral Status to Nano-Fertilizer and Moisture Stress during Different Growth Stages of Cotton Plants.

Hussien M.M.[1]; Soad M. El-Ashry[2]; Wafaa M. Haggag[3] and Dalia M. Mubarak[2]*

[1]Water Relations &Field Irrigation Dept.; [2]Soil & Water Use Dept. and [3]Pathology Dept., Agric. Div., NRC, Cairo, Egypt

Abstract: Pot experiment was conducted in the greenhouse of the National Research Centre during the 2014 summer season to investigate the effect of nano-fertilizer on mineral status of cotton plants grown under water stress. The treatments were as follows: a)-Water stress treatments: Missing of irrigation at budding (D1) and flowering stages (D2) more than regular irrigation (RI) as control. b)- Fertilizer treatments: 0.5 and 1.0 g l^{-1} nano-phosphorus (nano-P) and distilled water as a control.

Generally, nano-fertilizer affects the macronutrients and micronutrients status under different irrigation treatments. Application of nano-P led to improve the nutrients uptake under stress conditions as well as regular irrigation. The interaction effect of nano-fertilizer and drought through some growth stages of cotton plants indicated that application of nano-P at rate 0.5 g l^{-1} promote the nutrients uptake under D1, while 1.0 g l^{-1} depicted the best nano-P fertilizer rate enhanced the nutrients uptake under D2 condition.

keywords: Cotton (*Gossipyum barbadense L.*)-irrigation - nano-phosphorus - macronutrients – micronutrients – uptake.

Introduction

From a long time, Soil is considered as a basic anchor to support plant growth, and recently it is one of our most valuable natural resources (1). In activities for increasing its productivity attempts, when properly fertilized, a handful of soil gives a meaningful crop yield. Many soils are fragile, especially in tropical and semi-tropic areas, and overuse generally leads to a continuing problem of millions of hectares of land every year in different parts of the world becoming unproductive and affecting the growth and yield of plants (2). Phosphorus from organic or inorganic sources, the amount of a nutrient that a plant may need for growth and reproduction varies among plant species and/or varieties. A common perception is that plant response to nonsufficient nutrient supply involves physiological changes in metabolic processes that are unique to nutrient stress. Nutrient uptake by crop plants grown in soil is greatly influenced by root morphology, soil properties, climate, cultural and management practices, and plant species (3 and 4). In addition, soil water potential at the soil-root interface appears to be the main soil characteristic controlling the availability of soil water for plant growth and nutrient concentrations at the root surface directly control nutrients uptake. It has also been reported that the uptake of water and ions by a plant root creates a concentration gradient in response to which water and ions flow from the surrounding soil to the root (5).

For enhancement the efficiency of amendments that should increase contact of fertilizer with plant leading to increase in nutrient uptake, minimize of particle size, resulting in increased number of particles per unit of weight and specific surface area of a fertilizer that should increase contact of fertilizer with plant leading to increase in nutrient uptake (6). The particles below 100 nm as nano-particles could make plants use fertilizer more efficiently, more environmentally friendly through hamper of pollution and, dissolve in water more effectively thus increase their absorption and distribution. (7). Therefore, nanotechnology such as using nano-scale fertilizer may offer new techniques to be used for crop management.

Phosphorus plays an important role in Agricultural production. Agriculture is the major user of phosphorus resources (P), accounting for 80–90% of the world demand for P (8). Increasing population, growing favorites towards diets meals and rising demands for bio-energy crops will increase the future demand for P fertilizers. However, application of P fertilizers aggravates eutrophication problem in surface waters (9). Thus, numerous regulations, best managements practices (10), and remediation technology (11) have been proposed to reduce P fertilizer application to prevent the applied P from entering water bodies. However, few work on attempting to solve the eutrophication problem via the modifications of the chemical properties of fertilizers (e.g., reducing the fertilizer mobility in the soil or decreasing bioavailability of nutrients to the algae. The nano-scaling of a fertilizer is considered a mitigation method to get an effective fertilizer as well as reduces the risk of eutrophication.

It is showed in a study on soybean that application of nano-iron oxide particles increased the yield (12). In another investigation, the authors reported that nano-iron promoted the growth, photosynthesis and yield of peanut plants (13). At the same manner using of nano-scale zinc oxide particles increased stem and root growth and pod yield of peanut as compared with $ZnSO_4$ application(14). Other study showed the significant effect of nano oxide iron compared with iron chelate, and iron sulphate application on yield and quality of Wheat plants (15).

Cotton considered the main fiber crop in the global, because of its widespread uses in today's world, is of great economic and a commercial importance. Therefore, the area under cultivation of this crop is ever increasing. Generally, cotton fiber as the main product and seeds of cotton as the by-product play an important role in industry and commerce (16). However, in Egypt its cultivated area cultivated in a continuous decreasing in the last decade. Area of cotton decreased from 2.2 million feddan to about three hundred thousand feddan during the last two decade in Nile valley and Delta of Egypt. One of the national targets is to increase the aria and productivity of cotton to face the increasing demands of the high population. For achieved the target it is necessary to the extension in the new reclaimed soil in which the lack of water is main problem. Water stress (drought) is also an important limitation to crop production. Reduction in photosynthetic activity and increases in leaf senescence are symptomatic of water stress and adversely affect crop growth. Other effects of water stress include, a reduction in nutrient uptake, reduced cell growth and enlargement, leaf expansion, assimilate translocation and transpiration. Water stress also reduces the net CO_2 assimilation (1). Water deficit affected most of physiological process of cotton plants which intern reflected on its yield quality and quantity as mentioned by (17) who found that the lowest tops or roots yield were shown when plants subjected to holding the 2^{nd} irrigation followed by that when fodder beet plants did not received the 4^{th} irrigation. In addition, water stress reduced chlorophyll and carotenoids concentrations this intern reflected on photosynthetic activity of fenugreek (18).

Amelioration of drought using different fertilizers was reported by many authors (17, 18, 19, 20, 21) and by nano-fertilizers (22).

Thus, this work was designed to investigate the response of mineral status of cotton plants to nano-fertilizer and drought.

Materials and Methods

A pot experiment was conducted in the greenhouse of the National Research Centre during the 2014 summer season to investigate the effect of nano-fertilizer on mineral status of cotton plants grown under water-stress. The treatments were as follows: a)-Irrigation treatments: Missing of irrigation at budding (D1) and flowering (D2) stages more than regular (RI) irrigation. b)- Fertilizer treatments: 0.5 and 1.0 g l^{-1} nano-phosphorus (nano-P) and distilled water (DW) as a control.

The experiment included 9 treatments which was the combination between 3 treatment of water-stress and three treatments of nano-fertilizer. The experimental design was conducted as a split plot in a randomized complete block design with six replicates. Seeds of cotton (*Gossipyum barbadense L.*) were sown in pots 40 cm in diameter and 45 cm in height, filled with 30 kg clay loam soil (Table 1). After germination, plants were thinned twice to be two plants per pot. Calcium super phosphate (15.5 % P_2O_5) and potassium sulphate

(48.5 % K_2O) in the rate of 1 g and 2 g, respectively, broadcasted before sowing. Ammonium sulphate was added in two equal portions, the 1^{st} was three weeks after sowing and the 2^{nd} was two weeks later. Nano-fertilizers were sprayed after 21 days of sowing and the second application were 15 days after sowing. The control plants were sprayed with the same quantity of distilled water.

Two plants from every replicate were picked, cleaned and dried in electric oven at 70 ºC until the weight stable. Samples ground in a stainless still mill. Determination of nutrients was done using the reference methods (23). Collected Data were subjected to the proper statistical analysis using MSTATIC Software.

Results and Discussions

Water stress

In general means, all estimated nutrients in branches of cotton plants increased at budding period whilst the uptake decreased at fruiting period by water deficit to be less than that in the control plants Table (2). Nutrients uptake in leaves followed the same response of that in branches except for Fe uptake that gave higher values with the deficit irrigation in comparison with that by the regular irrigation treatment.

Figs. (2 & 3) showed no significant changes in the values of Ca:Na, Mg:Na and Ca:(Na+K) ratios in leaves by the drought, meanwhile K:Na ratio was slightly affected compared to the values by the regular irrigation treatments. In branches, the deficit treatments did not exhibit significant effects on the values of Na ratios.

Those results were in agreement with that recorded with different crops. Under water-stress conditions, the uptake of N decreased in soybean plants. This decline in shoot N uptake can be attributed to the decreased transpiration rate to transport N from roots to shoots. It is reported that the uptake of N, Na, K, Ca, S, Mg were significantly reduced by water stress (24). Further the stress increased the content of organic acids and sugars which improved fruit quality.

Decreasing in the nutrients uptake of crop plants under water stress mainly due to the decrease in transpiration rates, damage of the membrane permeability and active transport (25), resulting in reduce absorbance activity of the plant roots. In addition, the nutrients uptake from the soil is strongly related to the plant root system and soil water status. Low content of soil moisture reduces the diffusion rate of the nutrients to the absorbing surface of the root system. A study reported that the changes in the soil moisture regime could alter the root morphology and anatomy, the pore size distribution, and the angle of roots penetration, which affect root proliferation (1). Further, the development of the root system linked with the water status of the plants. Under water stress condition, highest water uptake occurs at the young roots stage. With growing of the root and reduction of water availability, a decline of root activity mainly root permeability will take place, causing disturbance in the root metabolism (26). Moreover, this condition declines the internal water content of the shoots and influence stomata opening, ultimately, affecting the transpiration and nutrients uptake processes.

Nano-fertilizer

Under the regular irrigation treatment, the two levels of nano-fertilizer spraying enhanced the uptake of all studied nutrients in cotton plants in comparable with distilled water treatment (Table 2). Application of nano-P at the rate of 1.0 g l^{-1} achieved the highest values of nutrients uptake in leaves of cotton plants. Similar trend were recorded for the uptake of N, K, P, Ca, Mg and Na nutrients in branches. However, the uptake of the micronutrients were higher with nano-P treatment at the rate of 0.5 g l^{-1} related to that at the rate of 1.0 g l^{-1}. The values of K:Na, Ca:Na, Mg:Na and Ca:(Na+K) ratios in leaves gave their higher or similar values with the first rate of Nano-P (1.0 g l^{-1}) treatment compared with the second rate (0.5 g l^{-1}). The reverse of that trend were showed by ratios values in the branches of cotton plants (Figs. 2 & 3).

Using nano-fertilizer for control of nutrient release could be considered as an effective way to achieving sustainable agriculture and Environment (27). Some soluble phosphate salts, heavily used in agriculture as highly effective phosphorus (P) fertilizers, causing surface water eutrophication, while solid phosphates are less effective in supplying the nutrient P. In contrast, synthetic apatite nano-particles could hypothetically supply sufficient P nutrients to crops but with less mobility in the environment and with less bioavailable P to algae in comparison to the soluble counterparts (28). In a study on effect of nano-fertilizer application on the growth of soybean (28), enhancement of the growth rate and seed yield were reported with the application of nano-apatite fertilizer as P source compared with conventional fertilizer treatment. The authors stated that the nano-fertilizers augmented the biomass production at the same time hinder the risks of water eutrophication. It is also reported in a study on the use of chelated iron nano spray on nutrient contents in spinach plants that the application of nano-chelate levels of fertilizer encourage accumulation of iron, potassium and declined accumulation of sodium, nitrate in spinach leaves (29).

The interaction of water stress and nano-fertilizer

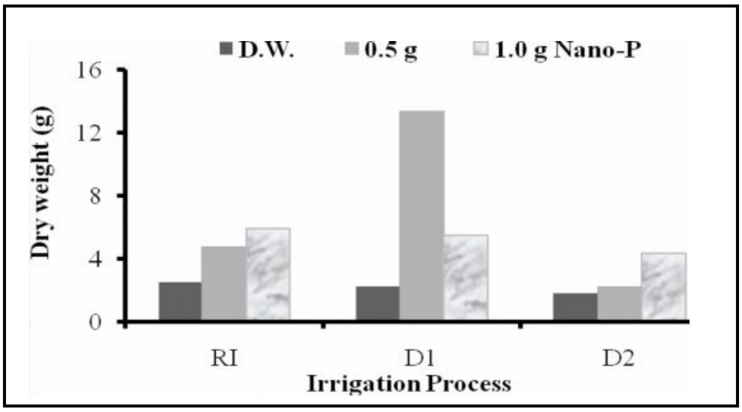
The interaction between nano-fertilizer application and water stress and its effect on macro- and micro-nutrients uptake were illustrated in Table (2) and Figs. (2 & 3). Foliar nano-fertilizer increased the uptake of nutrients in branches of cotton plants under different irrigation processes. These were true also for nutrient uptake in leaves. These might be attributed to the improvement of dry matter contents of both plant parts (Fig 1) or\and for the enhancements of nutrients absorption processes. The data depicted the role of nano-P to encourage the tolerance potential of cotton plants to drought stress, indicated by the enhancements of nutrients uptake (Table 2). Interestingly, the first rate of nano-P (0.5 g l^{-1}) showed most suitable rate to promote the nutrients uptake under water deficit treatments at the budding formation stage (D1). However, 1.0 g l^{-1} depicted the best nano-P fertilizer rate under water deficit treatments at the flowering formation stage (D2). It can be concluded from this phenomena that nano-fertilizer improved the content of nutrients and this intern reflected on the vegetative and fruiting of plants and finally the yield and its quality. The results also spot the light on control the rate of nano-fertilizers according to the growth stages of the plants under its ambient conditions, which have impact on the environment by reducing the risk of contamination of surface and ground water bodies.

Although foliar fertilization does not totally replace soil fertilization on crop with large leaf area, it may improve the uptake and the efficiency of nutrients (30). The positive role of foliar application of nano-fertilizer was stated previously by investigation on the effect of nano-iron application on cowpea grown under end season of drought stress (22). The highest rate of seed nitrogen and the greatest leaf nitrogen was achieved from nano-iron treatment of 1 per 1000 and irrigation disruption after the first harvest. The highest amount of leaf potassium was observed in iron treatment of 0.5 per 1000 and irrigation disruption after 80% pod formation. They added that application of nano-iron did not change the content of phosphorus and iron in seeds.

Table (1): The chemical analysis of soil used in this study

pH 1:2.5	EC dSm $^{-1}$ 1:5	$CaCO_3$ %	CEC cmol Kg^{-1}	OM %	Soluble cations and anions (meq/100 g soil)							
					Na^+	K^+	Ca^{2+}	Mg^{2+}	CO^{-3}	HCO^{-3}	Cl^{-1}	SO^{-2}
7.15	1.3	2.53	33.5	1.3	1.82	0.23	2.38	1.27	0.0	0.91	1.9	1.89

Available macro-nutrients (%)			Available micro-nutrients (mg kg^{-1})			
N	P	K	Zn	Fe	Mn	Cu
0.47	0.25	0.95	3.1	4.8	7.3	5.2



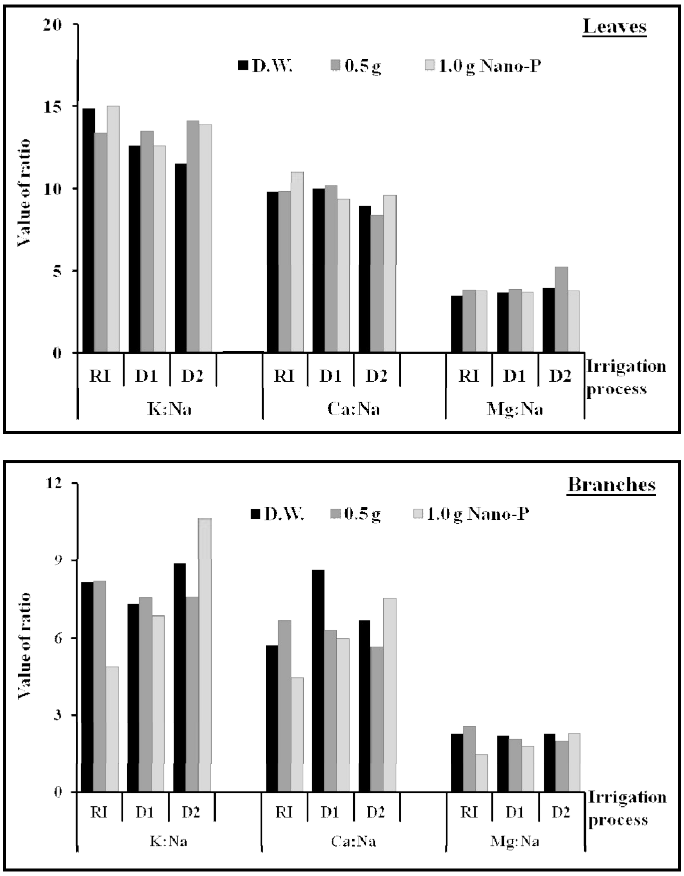
RI: Regular irrigation with tap water, D1: Deficit irrigation at bud formation stage, D2: Deficit irrigation at the flowering stage, DW: Distilled water

Fig. (1): Influence of foliar nano-phosphorus on the dry matter of cotton leaves under deficit irrigation (DI, D2) strategies

Table (2): Influence of nano-phosphorus application on the Macro- and Micro-nutrients uptake in cotton plants under deficit irrigation (DI, D2) strategies

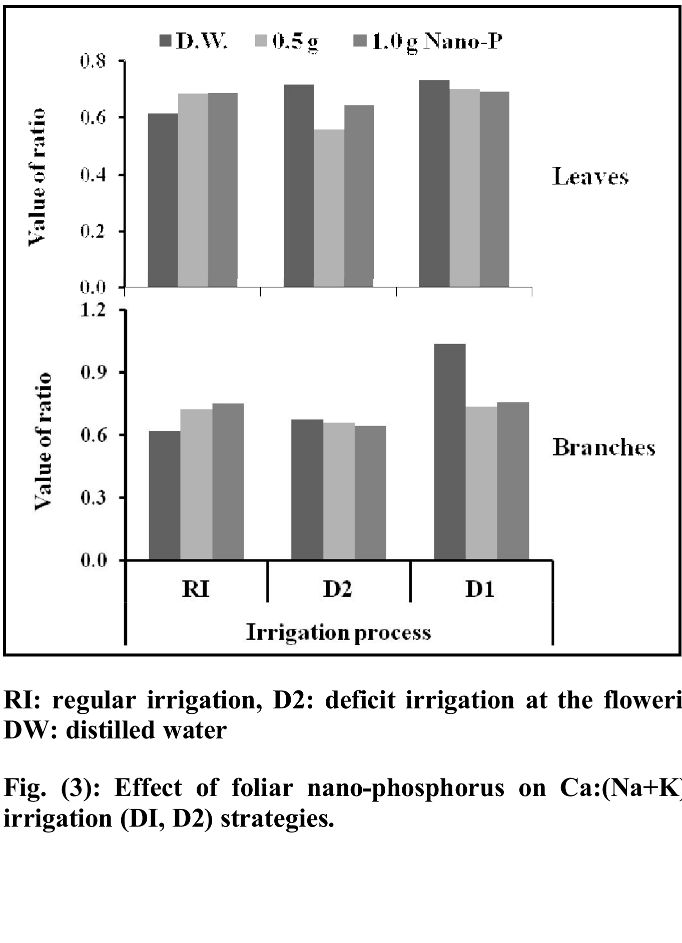
Irrigation process (I)	Nano-phosphorus rate (P)	N	K	P	Ca	Mg	Na	Fe	Mn	Cu	Zn
Leaves											
RI	**DW**	5.80	9.37	0.309	6.16	2.19	0.628	3043	147	31.8	181
	0.5 g l-1	10.5	16.6	0.495	12.2	4.75	1.24	3289	240	51.2	213
	1.0 g l-1	12.5	21.0	0.572	15.4	5.29	1.40	5279	274	64.9	252
Mean		9.60	15.7	0.459	11.2	4.08	1.09	3870	221	49.3	215
D1	**DW**	5.36	8.08	0.292	6.39	2.33	0.638	4850	231	36.4	131
	0.5 g l-1	27.7	42.2	1.60	31.8	12.1	3.12	12780	648	162	762
	1.0 g l-1	10.7	16.8	0.581	12.5	4.94	1.33	9532	397	71.7	317
Mean		14.6	22.4	0.826	16.9	6.46	1.69	9053	425	90.1	403
D2	**DW**	3.92	5.38	0.159	4.19	1.86	0.466	1431	84.7	24.5	57.3
	0.5 gl-1	4.71	6.32	0.156	3.77	2.35	0.448	2679	87.7	14.1	70.3
	1.0 g l-1	8.24	13.8	0.528	9.51	3.73	0.992	8002	233	62.2	291
Mean		5.62	8.50	0.281	5.82	2.65	0.635	4037	135	33.6	140
Mean of nano-phosphorus rates	**DW**	5.03	7.61	0.253	5.58	2.13	0.578	3108	154	30.9	123
	0.5 gl-1	14.3	21.7	0.752	15.9	6.40	1.60	6249	325	75.9	349
	1.0 g l-1	10.5	17.2	0.561	12.5	4.65	1.24	7604	302	66.3	287
LSD$_{0.05}$	**I**	1.824	3.853	0.2151	2.656	1.452	0.1897	57.6	107.4	10.47	124.9
	P	2.082	2.07	0.1488	1.095	0.6774	0.1656	93.4	66.64	8.821	59.81
	I*P	3.607	3.585	0.2578	1.897	1.173	0.2869	161.8	115.4	15.28	103.6
Branches											
RI	**DW**	2.500	4.69	0.322	3.27	1.30	0.574	859	16.0	15.0	46.3
	0.5 gl-1	6.45	7.63	0.506	6.20	2.38	0.932	1686	49.7	26.5	69.3
	1.0 g l-1	8.20	7.77	0.640	7.06	2.30	1.59	1394	23.3	33.2	45.0
Mean		5.72	6.70	0.489	5.51	2.00	1.032	1313	29.7	24.9	53.6
D1	**DW**	2.51	3.22	0.240	3.79	0.963	0.439	1027	16.3	15.8	39.3
	0.5 gl-1	16.4	18.7	1.38	15.6	5.05	2.48	6066	138	88.1	392
	1.0 g l-1	5.90	7.40	0.464	6.43	1.93	1.08	3703	55.3	31.9	139
Mean		8.27	9.77	0.694	8.62	2.66	1.33	3599	69.9	45.3	190
D2	**DW**	2.10	2.83	0.161	2.12	0.727	0.318	459	12.3	10.7	32.3
	0.5 gl-1	2.75	3.59	0.256	2.67	0.947	0.474	373	16.0	16.3	42.0
	1.0 g l-1	4.92	8.37	0.564	5.92	1.80	0.787	1592	35.7	43.0	64.3
Mean		3.26	4.93	0.326	3.57	1.16	0.526	808	21.3	23.3	46.2
Mean of nano-phosphorus rates	**DW**	2.37	3.58	0.241	3.06	0.998	0.444	782	14.9	13.8	39.3
	0.5 gl-1	8.53	9.98	0.713	8.17	2.79	1.30	2708	67.9	43.6	168
	1.0 g l-1	6.34	7.85	0.555	6.47	2.01	1.15	2230	38.1	36.0	82.7
LSD$_{0.05}$	**I**	1.585	1.793	0.2745	1.422	0.211	0.3013	746.6	17.85	11.76	159.3
	P	1.671	1.595	0.1922	1.375	1.08	0.2495	722.5	17.27	9.626	82.05
	I*P	2.894	2.762	0.3328	2.381	1.871	0.4321	1251	29.91	16.67	142.1

RI: regular irrigation with tap water, D1: deficit irrigation at bud formation stage, D2: deficit irrigation at the flowering stage, DW: distilled water



RI: regular irrigation, D1: deficit irrigation at bud formation stage, D2 deficit irrigation at the flowering stage, DW: distilled water

Fig. (2): Effect of foliar nano-phosphorus on Na ratios (uptake basis) of Cotton plants under deficit irrigation (DI, D2) strategies.



RI: regular irrigation, D2: deficit irrigation at the flowering stage, D1: deficit irrigation at bud formation stage, DW: distilled water

Fig. (3): Effect of foliar nano-phosphorus on Ca:(Na+K) ratios (uptake basis) of Cotton plants under deficit irrigation (DI, D2) strategies.

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