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Impact of Magnetized Water Irrigation, Soil Mineral Fertilization and Foliar Spraying with Nanomaterial on Potato Plants.

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ABSTRACT

The present work was conducted at the Experimental Station Farm, Faculty of Agriculture, Mansoura University, Egypt, during the two successive winter (critucal) cultivation of 2015/2016 and 2016/2017 to investigate the impact of irrigation water (normal water - magnetized water), levels of soil mineral fertilizers and foliar spraying with nano-material (without - Lithovit) as well as their interactions on growth, yield, chemical composition and quality of potato cv. Spunta. Obtained data cleared that irrigation with magnetized water produced the highest significant values of plant growth, chlorophylls, yield, chemical composition and quality parameters except nitrate (NO_3) and nitrite (NO_2) contents compared to normal water treatments. Meanwhile, fertilized potato plants with 100% NPK from recommended dose gave the maximum values of all studied parameters, except nitrate (NO_3) and nitrite (NO_2) concentrations which increased compared to other treatments. Moreover, foliar spraying with Lithovit as a nono material increased significantly all studied characters, except nitrate and nitrite, which gave the lowest values in both seasons. It could be recommended that irrigation potato plants with magnetized water, 50% NPK from the recommended dose and foliar spraying with Lithovit (1g/L) in order to maximize productivity, quality parameters and limiting the environmental pollution comparing to plant irrigated with normal water + 100% NPK.

Keywords: potato, magnetized water, nano-materials, NPK.

INTRODUCTION

Potato (*Solanum tuberosum* L.) occupied an important position in the world after rice, wheat and maize in terms of the human consumption. In Egypt, it grows under different environmental conditions. It is known as one of the most important vegetable crops for local market and exportation. It is a source of energy; thus it contains a high concentration of carbohydrates and considerable amounts of vitamins B, C, free amino acids, fiber and minerals (Muthoni and Nyamango, 2009). The cultivated areas of potato in Egypt were 409372 feddan producing 4.61 million tons with an average of 11.26 ton/fed (FAO, 2017).

Magnetic water treatment may change the water structure, minimizing surface tension, raising dissolvability of minerals and providing adequate nutrients for plants (Babu, 2010). Plants which irrigated with magnetized water had many benefits as well as; raising rate of germination, growth of roots and shoots system, development of inflorescence and fruiting, fruits number, yield and quality as well as decrease the amounts of irrigation water, conductivity, the solubility of salts and pH (Grewal and Maheshwari, 2011). Magnetized water treatment might potentially diminish the application of fungicides, insecticides, herbicides, which are expensive costs and often harmful human health and environment (Aliverdi *et al*., 2015).

Hozayn and Abul Qados (2011) reported that the magnetized water treatment increased growth parameters, biochemical constituents, photosynthetic pigments, yield and its components traits of all tested crops. As well as, Hozayn *et al.* (2013) on sugar beet showed that magnetized water could be used as the most important modern technologies, which helps in saving irrigation water and improving yield and quality under the sandy soil. The usage of magnetized water in the agricultural will enable intense to get more yield and quality production. Also, Sadeghipour and Aghaei (2013) reported that water use efficiency was increased by irrigation with magnetized water as compared to the normal water. Meanwhile, Elsayed (2014) obtained that irrigation broad bean plants with magnetized water caused significant increments in chlorophylls, carotenoids and photosynthetic activity over the irrigation by normal water. Yusuf and Ogunlela (2015) reported that irrigation with magnetized water affected the vegetative growth of tomato by inducing the rate of growth, decrease the time to maturity and enhanced yield. By the same token, Abd El-latif *et al.* (2015) on strawberry showed that irrigation with magnetized water + 50% NPK of recommended dose gave the maximum values of chlorophylls, carbohydrates, yield and TSS. Also, Abdel Nabi *et al*. (2017) indicated that the highest means of yield/fed., dry matter %, TSS, total sugars, crude protein and carbohydrates (%), chlorophylls and the lowest values of nitrate and nitrite were recorded when head lettuce plants were irrigated with magnetized water.

Mineral nitrogen, phosphorus and potassium fertilizers are rapidly half lost by either leaching in drainage water or by evaporation. The problem does not only decrease losing high amounts of chemical fertilizers but also it extends to other hazardous environmental pollution and protect human health. N is an indispensable elementary part of numerous organic compounds *i.e.* amino acids, nucleic acids, protein and formation of protoplasm and new cells. P and K are essential elements herded for physiological mechanisms of growth in the plant. Verma *et al.* (2010) found that *Azotobacter* plus 75% NPK from recommended dose produced the highest tubers number, total yield and highest percent of potato plant nutrient uptake. Singh *et al.* (2010) and Eleiwa (2012) showed that increasing levels of fertilizers increased the potato yield. Also, Devi and Zaman (2012) reported that stems and leaves number, plant height, total dry matter accumulation, crop growth rate of potato plants were significantly increased when supplied with the recommended NPK rate. Meanwhile, Abdel Nabi *et al*. (2017) on potato found that fertilization with 75% from recommended NPK dose led to the maximum values of vegetative growth parameters, total yield and quality in both seasons of the experiments.

The positive effect of Lithovit as (nanomaterials) may be due to its magnesium content, which is the central component in chlorophyll molecule and silica plays an important role in overcome drought stress and induces plant resistance to pathogens and pests (Cai *et al*., 2009). Nanomaterials fertilizers caused germination increment and root and shoot length as well as seedlings vegetative biomass in some plants including; tomato, rape, lettuce, radish, spinach, pumpkin, onion and cucumber (Rico *et al*., 2011). It is obvious that nano-materials have an important role in avoid degradation environment agrochemicals, minimize the fertilizers quantities, reduce costs and control excess chemicals (Ditta, 2012 and Grover *et al*., 2012). Recently nano-technology becomes very important in biosensors fabrication. It could be used as an alternative method in a wide scientific area. Nanotechnology could be clarified as the creation of functional materials, systems and devices through control of matter at a scale of 100 nanometers (nm) or less (Otles and Yalcin, 2013). Lithovit compound (a natural intensified CO_2 foliar fertilizer) containing 75% calcium carbonate, 5% silica, 4% magnesium carbonate and particles extremely small, that enhance their ability to penetrate plant stomata, when spraying Lithovit. Also, Byan (2014) on snap bean plants indicated that foliar spraying with Lithovit improved vegetative growth parameters and plant chemical constituents*, i.e.,* chlorophyll, nitrogen, potassium and phosphorus % as compared to normal water. As well as, Abdel Nabi *et al*. (2017) found that applying nanomaterials as a foliar application (Lithovit) on head lettuce plants gave the maximum values of all studied characters, except NO3 and NO2 contents as compared to control.

Therefore, the objective of this investigation is to determine the effect of magnetized irrigation water, different levels of NPK fertilizers and foliar spraying with nano-material (Lithovit) as well as their interactions on plant growth, yield, chemical composition and quality of potato cv. Spunta under environmental conditions of Mansoura district, Dakahlia Governorate, Egypt.

MATERIALS AND METHODS

Factorial experiment was conducted in strip split-plot design with three replicates for each treatment. The experiment consists of 12 treatments two irrigation water (normal and magnetized water), three mineral fertilizers (100%, 75% and 50%) from the recommended dose and two foliar spraying with nano-material (without and Lithovit 1g/L) with three replicates each. Thus, the total numbers of experiment were 36 experimental units.

Tubers pieces were planted on 7 November in both seasons at 25 cm apart on one side of ridges (9m long and 0.7 m wide). The plot consisted of 2 ridges thus the plot area was 11.6m. All another agricultural practical for potato crop was used as recommended by Ministry of Agriculture.

Physical and chemical properties of experimental soil before the beginning of the experiment are recorded in the following Table (1) during the two seasons of study.

Table 1. Physical and chemical analysis of experimental soil during 2015 and 2016 seasons:

Seasons	Mechanical analysis (%)				Texture class	SP	$CaCO_3$%	EC $dS.m^{-1}$ 1:5	pH (1:2.5)	Available (ppm)		
	Clay Sand	Fine Sand	silt	clay						N	P	K
1st	3.51	26.95	39.09	30.45	S.Cl.L	51.8	4.13	1.16	7.84	53.9	4.92	187.5
2nd	2.85	28.66	37.91	30.58	S.Cl.L	54.5	3.79	0.98	7.96	57.2	5.13	193.5

S.Cl.L: Sandy clay loamy SP: Saturation percentage EC: Electrical conductivity

N, P and K fertilizers were applied at the rate of 50, 75 and 100% from recommended doses by the Ministry of Agriculture and Soil Reclamation for potatoes in forms of ammonium nitrate (33.5 % N) at the level of 120 kg N/fed, superphosphate (15 % P_2O_5) at the level of 75kg P_2O_5/fed. and potassium sulfate (48 % K_2O) at the level of 96 K_2O/fed. A full dose of phosphorus was applied before cultivation to the soil while; nitrogen and potassium were added in two equal doses, before the first and second irrigation in both seasons of study.

Lithovit was sprayed three times at 1 g /liter water, the first after one month from bud sprouting and the others every 15 days later.

Data recorded:

Vegetative growth measurements:

After 70 days from planting; samples of 10 plants were randomly chosen from each plot for measuring plant growth parameters:

- Plant length (cm)
- Fresh and dry weights of plant foliage (g /plant).
- Dry matter percentage of tuber determined at harvest after 120 days from planting by allowing 100g of fresh tubers to dry at 70 ^{C} till constant weight.

Yield:

After 120 days from planting all tubers of plants in each plot were harvested and data were recorded to calculate yield ton/ fed.

Chemical analyses of leaves and tubers:

- After 70 days from planting chlorophyll a, b and total (mg g^{-1} F W) content was estimated in potato leaves according to the methods described by Sadasivam and Manickam (1996).

- N, P and K contents in leaves and tubers of potato: N content was estimated according to Jones *et al.* (1991) while, P and K were determined due to the methods described by Peters *et al.* (2003).
- Ca and Mg in potato leaves were estimated as described by Peters *et al.* (2003).

Quality parameters of potato tubers:

- Total soluble sugar was estimated due to the method reported by Sadasivam and Manickam (1996).
- Reducing sugar was determined by Nelson-Somogy method and non-reducing sugar in the samples was calculated as reported by Somogy (1952).
- TSS % was determined by using hand refractometer model.
- Starch was determined by the method described by Somogy (1952).
- Nitrate and nitrite content were estimated as described by Singh (1988).
- Vitamin C (mg/100g); It was measured due to the method described in AOAC (2000).

Statistical analysis:

Data collected in this experiment were statistically analyzed using the analysis of variance (ANOVA) technique for the strip split-plot design. Treatment Means were compared using the method of LSD at the probability of 5 % due to the procedure reported by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Effect of irrigation water:

Results in Tables 2, 4, 6, 8 and 9 show significant increments in all measured characters, *i.e.* plant height, fresh and dry weight/plant, fresh, dry matter percentage of the tuber, total tubers yield, chlorophyll a, b and total, chemical constituents *i.e.* N, P and K in leaves and tubers, Ca and Mg in leaves, quality parameters *i.e.* reducing, non-reducing, total sugar, TSS, starch and vitamin C. Meanwhile, nitrate and nitrite were decreased significantly by using magnetized water irrigation comparing to normal water in both seasons. These results could be attributed to the change of water structure due to reducing surface tension, increasing minerals dissolvability and providing adequate nutrients for plant growth, development of roots and shoots. It increases electroconductivity, the solubility of salts and decrease pH moreover it plays an important role in insecticides, fungicides and herbicides, as well as, magnetized water caused increments in microorganism's number which reflected on the positive effect of the aforementioned parameters. These results agree with those recorded by Abd El-latif *et al.* (2015), Yusuf and Ogunlela (2015) and Abdel Nabi *et al.* (2017).

Effect of soil mineral fertilizers:

As for the impact of soil mineral NPK fertilizers, data in the same Tables show that fertilization with 100% NPK from recommended dose gave the highest values of vegetative growth parameters, yield, chlorophyll content, chemical constituents and quality parameters of potato except for nitrate and nitrite thus the lowest values were recorded when plants fertilized with 50% NPK and the differences were significant both seasons of the study. These results may be due to the important role of nitrogen in plants. N is a major component of proteins, co-enzymes and nucleic acids, phosphorus also has a role in N_2 fixation and increase photosynthesis, While, potassium activates some enzymes and play an important role in regulating the opening and closing of stomata. These results are agree with those recorded by Devi and Zaman (2012) and Abdel Nabi *et al*. (2017).

`Effect of nano-material (Lithovit):

The same Tables show the impact of foliar application with Lithovit (nanomaterial) at the rate of 1g/liter water as compared to untreated plants. Treated potato plants with Lithovit had the highest values of all parameters mentioned previously and the differences were significant, while, nitrate and nitrite gave the lowest values in both seasons in this study. The efficiency of spraying with Lithovit may be due to the favorable impacts of it in avoiding degradation of the environmental agrochemicals, decrease the fertilizers doses. As well as the impact of Lithovit components, *i.e.* Ca (3%), Mg (2%), magnesium carbonate (41%) and calcium carbonate (24%), which penetrated rapidly into the plant tissues throughout the stomata and plays important roles in some physiological and biological processes of potato plants, which reflected on increasing vegetative growth parameters, yield, chlorophyll content, chemical constituents and quality parameters . These results are parallel with those recorded by Byan (2014) and Abdel Nabi *et al*. (2017).

Effect of interactions:

As for the impact of interactions treatments i.e. water treatments, soil mineral NPK-levels and foliar application with nano material (Lithovit) data presented in Tables 3, 5, 7 and 10 show that the highest values of fresh and dry weights of plants/ g, dry matter percentage of the tubers, total tuber yield (ton), chlorophyll a, b, total (mg/g FW.), K%, ca% and Mg% in leaves, TSS%, starch% and Vitamin C (mg/100g) in potato tubers were recorded when plants irrigated with magnetized water and fertilized with 100% NPK from a recommended dose as well as foliar sprayed with Lithovit (1g/L) followed by plant treated with magnetized water plus 75% NPK plus Lithovit in both seasons. Meanwhile, plants treated with magnetized water plus 50% NPK and spraying with Lithovit came in the third place, but it gave superiority compared with plants irrigated with normal water and fertilized with 100% NPK from recommended dose without Lithovit. Such results could be due to the roles played by every factor under study in the impact on vegetative growth, yield and chemical constituents as mentioned previously. These findings, however, are in harmony with those obtained by Abdel Nabi *et al.* (2017) on head lettuce.

Table 2. Plant height, fresh and dry weights of plant, tuber dry weight percentage and total tubers yield/fed. as affected by irrigation water treatments, soil mineral NPK-levels and foliar application with nanomaterial as well as their interactions during 2015/2016 and 2016/2017 seasons.

Characters / Treatments	Plant height (cm)		Fresh weight of plant (g)		Dry weight of plant (g)		Dry weight of tuber (%)		Total tubers yield (t/fed.)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
A- Irrigation water treatments:										
Normal	42.66	56.33	355.9	233.5	45.77	41.44	13.54	13.78	7.928	9.139
Magnetized	46.38	60.27	367.4	264.8	47.18	45.51	14.36	14.28	9.928	10.839
F. test	*	*	*	*	*	*	*	*	*	*
B- Mineral NPK-levels:										
100 %	45.25	58.66	406.2	258.1	46.71	45.65	14.16	14.19	9.283	10.217
75 %	45.00	58.75	376.0	251.3	46.55	44.17	14.01	14.61	8.842	9.867
50 %	43.33	57.50	302.7	238.1	46.16	40.60	13.68	13.27	8.658	9.883
LSD at 5%	0.74	0.84	1.5	1.7	0.45	0.55	0.26	0.31	0.140	0.154
C- Foliar with nano-material :										
Without	43.16	56.50	337.6	244.3	46.34	42.21	13.84	13.80	8.694	9.461
Lithovit	45.88	60.11	385.7	254.0	46.61	44.73	14.07	14.26	9.161	10.517
F. test	*	*	*	*	*	*	*	*	*	*
D- Interactions:										
A × B	NS	NS	NS	*	NS	NS	NS	*	*	*
A × C	NS	*	NS	*	NS	*	NS	NS	NS	NS
B × C	NS	NS	NS	*	*	NS	NS	NS	*	*
A × B × C	NS	NS	*	*	NS	*	*	*	*	*

Table 3. Fresh and dry weights of the plant, dry weight of tuber and total tubers yield/fed as affected by the interaction among irrigation water treatments, soil mineral NPK-levels and foliar application with nanomaterial during 2015/2016 and 2016/2017 seasons.

Treatments		Characters	Fresh weight of plant (g)		Dry weight of plant (g)		Dry weight of tuber (%)		Total tubers yield (t/fed)	
			1st	2nd	1st	2nd	1st	2nd	1st	2nd
Irrigation	NPK	Nano-material								
Normal water	100 %	Without	372.8	235.5	45.83	41.86	13.63	13.41	8.300	8.933
		Lithovit	427.3	251.2	46.16	45.80	13.84	13.98	8.500	9.867
	75 %	Without	341.6	229.6	45.67	40.33	13.48	14.58	7.800	8.767
		Lithovit	398.4	240.9	46.04	43.80	13.75	15.06	8.233	10.033
	50 %	Without	282.5	219.2	45.41	37.66	13.20	12.68	7.000	8.467
		Lithovit	312.5	224.7	45.53	39.20	13.37	12.97	7.733	8.767
Magnetized water	100 %	Without	383.6	267.5	47.26	46.43	14.43	14.41	9.867	10.067
		Lithovit	441.1	278.1	47.62	48.53	14.74	14.99	10.467	12.000
	75 %	Without	351.6	262.4	47.11	45.30	14.27	14.13	9.433	9.800
		Lithovit	412.3	272.3	47.40	47.26	14.55	14.69	9.900	10.867
	50 %	Without	293.4	251.9	46.76	41.70	14.01	13.58	9.767	10.733
		Lithovit	322.6	256.8	46.94	43.83	14.16	13.87	10.133	11.567
LSD at 5%			3.0	3.6	NS	0.75	0.58	0.61	0.236	0.246

Table 4. Chlorophyll a, chlorophyll b and chlorophylls a+b as affected by irrigation water treatments, soil mineral NPK-levels and foliar application with nanomaterial as well as their interactions during 2015/2016 and 2016/2017 seasons.

Characters / Treatments	Chlorophyll a (mg/g FW)		Chlorophyll b (mg/g FW)		Chlorophylls a+b (mg/g FW)	
	1st	2nd	1st	2nd	1st	2nd
A- Irrigation water treatments:						
Normal	0.526	0.555	0.369	0.388	0.895	0.943
Magnetized	0.545	0.620	0.384	0.422	0.929	1.042
F. test	*	*	*	*	*	*
B- Mineral NPK-levels:						
100 %	0.549	0.598	0.388	0.420	0.937	1.018
75 %	0.540	0.587	0.381	0.409	0.920	0.996
50 %	0.517	0.577	0.362	0.387	0.879	0.964
LSD at 5%	0.002	0.005	0.004	0.003	0.005	0.007
C- Foliar with nano-material:						
Without	0.527	0.584	0.370	0.397	0.897	0.981
Lithovit	0.544	0.591	0.384	0.414	0.928	1.005
F. test	*	*	*	*	*	*
D- Interactions:						
A × B	NS	NS	NS	NS	NS	NS
A × C	NS	NS	NS	NS	NS	NS
B × C	*	NS	NS	*	*	NS
A × B × C	NS	*	*	NS	*	*

Table 5. Chlorophyll a, chlorophyll b and chlorophylls a+b as affected by the interaction among irrigation water treatments, soil mineral NPK-levels and foliar application with nanomaterial during 2015/2016 and 2016/2017 seasons.

Characters / Treatments			Chlorophyll a (mg/g FW)		Chlorophyll b (mg/g FW)		Chlorophylls a+b (mg/g FW)	
			1st	2nd	1st	2nd	1st	2nd
Irrigation	NPK	Nano-material						
Normal water	100 %	Without	0.530	0.560	0.372	0.392	0.902	0.952
		Lithovit	0.550	0.580	0.390	0.412	0.940	0.992
	75 %	Without	0.519	0.550	0.364	0.383	0.883	0.933
		Lithovit	0.540	0.572	0.381	0.401	0.921	0.783
	50 %	Without	0.502	0.526	0.350	0.367	0.852	0.893
		Lithovit	0.514	0.539	0.360	0.375	0.874	0.914
Magnetized water	100 %	Without	0.548	0.616	0.388	0.425	0.936	1.041
		Lithovit	0.568	0.636	0.404	0.449	0.972	1.085
	75 %	Without	0.539	0.602	0.381	0.416	0.921	1.018
		Lithovit	0.560	0.624	0.397	0.437	0.957	1.061
	50 %	Without	0.522	0.651	0.364	0.398	0.885	1.049
		Lithovit	0.532	0.592	0.373	0.409	0.905	1.001
LSD at 5%			NS	0.009	0.012	NS	0.016	0.014

Table 6. Nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) percentages in potato leaves as affected by irrigation water treatments, soil mineral NPK-levels and foliar application with nanomaterial as well as their interactions during 2015/2016 and 2016/2017 seasons.

Characters / Treatments	N %		P %		K %		Ca %		Mg %	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
A- Irrigation water treatments:										
Normal	2.155	1.772	0.254	0.266	2.717	2.764	2.010	1.209	1.017	0.631
Magnetized	2.387	2.113	0.276	0.303	2.909	3.088	2.241	1.449	1.151	0.758
F. test	*	*	*	*	*	*	*	*	*	*
B- Mineral NPK-levels:										
100 %	2.403	2.105	0.278	0.300	2.944	3.092	2.266	1.516	1.157	0.793
75 %	2.322	2.003	0.270	0.290	2.849	2.955	2.135	1.353	1.097	0.701
50 %	2.087	1.720	0.247	0.265	2.646	2.732	1.975	1.118	0.997	0.589
LSD at 5%	0.036	0.042	0.004	0.002	0.047	0.060	0.020	0.028	0.019	0.020
C- Foliar with nano-material:										
Without	2.198	1.856	0.258	0.277	2.752	2.849	2.010	1.128	1.002	0.533
Lithovit	2.343	2.030	0.271	0.293	2.874	3.003	2.241	1.529	1.167	0.856
F. test	*	*	*	*	*	*	*	*	*	*
D- Interactions:										
A × B	NS	NS	NS	NS	NS	NS	*	*	*	NS
A × C	NS	NS	NS	NS	*	NS	NS	*	NS	NS
B × C	*	*	*	*	NS	*	*	*	*	*
A × B × C	NS	NS	NS	NS	NS	*	NS	*	*	NS

Table 7. Potassium (K), calcium (Ca) and magnesium (Mg) percentages in potato leaves as affected by the interaction among irrigation water treatments, soil mineral NPK-levels and foliar application with nanomaterial during 2015/2016 and 2016/2017 seasons.

Characters / Treatments			K %		Ca %		Mg %	
			1st	2nd	1st	2nd	1st	2nd
Irrigation	NPK	Nano-material						
Normal water	100 %	Without	2.757	2.793	2.070	1.180	1.073	0.570
		Lithovit	2.943	3.017	2.223	1.683	1.117	0.873
	75 %	Without	2.660	2.710	1.893	1.023	0.860	0.490
		Lithovit	2.867	2.897	2.110	1.493	1.150	0.793
	50 %	Without	2.493	2.537	1.727	0.883	0.857	0.360
		Lithovit	2.583	2.630	2.037	0.990	1.047	0.700
Magnetized water	100 %	Without	2.997	3.163	2.303	1.373	1.183	0.707
		Lithovit	3.080	3.393	2.467	1.827	1.257	1.023
	75 %	Without	2.890	3.063	2.143	1.223	1.113	0.603
		Lithovit	2.980	3.150	2.393	1.670	1.267	0.917
	50 %	Without	2.713	2.830	1.923	1.087	0.923	0.470
		Lithovit	2.793	2.930	2.213	1.513	1.163	0.827
LSD at 5%			NS	0.104	NS	0.041	0.032	NS

Table 8. Nitrogen (N), phosphorus (P), potassium (K), reducing, non-reducing and total sugars percentages in potato tubers as affected by irrigation water treatments, soil mineral NPK-levels and foliar application with nanomaterial as well as their interactions during 2015/2016 and 2016/2017 seasons.

Characters Treatments	N %		P %		K %		Reducing sugars (%)		Non-reducing sugars (%)		Total Sugars (%)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
A- Irrigation water treatments:												
Normal	1.488	1.628	0.228	0.249	2.526	2.671	2.357	2.175	3.689	3.866	6.04	6.041
Magnetized	1.611	1.762	0.244	0.272	2.747	2.940	2.566	2.368	4.202	4.366	6.76	6.734
F. test	*	*	*	*	*	*	*	*	*	*	*	*
B- Mineral NPK-levels:												
100 %	1.684	1.837	0.249	0.275	2.782	2.955	2.598	2.418	4.085	4.265	6.68	6.68
75 %	1.598	1.742	0.240	0.266	2.669	2.859	2.507	2.322	3.992	4.146	6.49	6.46
50 %	1.366	1.506	0.218	0.240	2.458	2.602	2.278	2.076	3.760	3.937	6.03	6.01
LSD at 5%	0.043	0.031	0.006	0.004	0.032	0.038	0.043	0.041	0.047	0.052	0.06	0.06
C- Foliar with nano-material:												
Without	1.470	1.604	0.228	0.252	2.553	2.728	2.386	2.191	3.869	4.038	6.25	6.22
Lithovit	1.629	1.786	0.243	0.269	2.719	2.883	2.537	2.352	4.022	4.194	6.55	6.54
F. test	*	*	*	*	*	*	*	*	*	*	*	*
D- Interactions:												
A × B	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS
A × C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
B × C	*	*	*	*	*	*	NS	*	*	*	*	*
A × B × C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 9. Total soluble solids (TSS) and starch percentages, nitrate (NO_3-N), nitrite (NO_2-N) and vitamin C contents in potato tubers as affected by irrigation water treatments, soil mineral NPK-levels and foliar application with nanomaterial as well as their interactions during 2015/2016 and 2016/2017 seasons.

Characters Treatments	TSS (%)		Starch (%)		NO_3-N (ppm)		NO_2-N (ppm)		Vitamin C (mg/100 g)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
A- Irrigation water treatments:										
Normal	8.35	8.16	17.34	17.57	1.099	1.334	30.74	31.25	19.60	22.23
Magnetized	9.22	8.89	18.02	18.32	0.939	1.227	28.62	29.56	21.11	23.99
F. test	*	*	*	*	*	*	*	*	*	*
B- Mineral NPK-levels:										
100 %	8.91	8.63	17.90	18.16	1.111	1.389	30.30	30.94	20.67	23.76
75 %	8.83	8.56	17.75	18.01	1.024	1.282	29.69	30.45	20.46	23.26
50 %	8.61	8.39	17.39	17.66	0.922	1.172	29.06	29.82	19.94	22.31
LSD at 5%	0.04	0.02	0.06	0.07	0.035	0.023	0.05	0.09	0.18	0.22
C- Foliar with nano-material:										
Without	8.71	8.46	17.56	17.82	1.157	1.423	30.62	31.26	20.17	22.81
Nano-fertilizer	8.86	8.60	17.80	18.08	0.882	1.139	28.74	29.55	20.54	23.41
F. test	*	*	*	*	*	*	*	*	*	*
D- Interactions:										
A × B	*	NS	NS	NS	NS	NS	NS	NS	NS	NS
A × C	NS	NS	NS	NS	NS	NS	NS	*	NS	NS
B × C	*	*	*	*	NS	NS	NS	*	*	*
A × B × C	NS	*	NS	*	NS	NS	NS	NS	*	NS

Table 10. Total soluble solids (TSS), starch and vitamin C content in potato tubers as affected by the interaction among irrigation water treatments, soil mineral NPK-levels and foliar application with nanomaterial during 2015/2016 and 2016/2017 seasons.

Characters			TSS (%)		Starch (%)		Vitamin C (mg/100 g)	
Treatments			1st	2nd	1st	2nd	1st	2nd
Irrigation	NPK	Nano-material						
Normal water	100 %	Without	8.38	8.20	17.44	17.61	22.67	22.67
		Lithovit	8.58	8.34	17.70	18.02	23.25	23.25
	75 %	Without	8.28	8.12	17.26	17.47	21.99	21.99
		Lithovit	8.50	8.28	17.58	17.80	22.74	22.74
	50 %	Without	8.14	7.99	16.98	17.20	21.19	21.19
		Lithovit	8.21	8.06	17.12	17.35	21.56	21.56
Magnetized water	100 %	Without	9.26	8.91	18.09	18.39	24.19	24.19
		Lithovit	9.42	9.10	18.39	18.64	24.93	24.93
	75 %	Without	9.19	8.85	17.95	18.27	23.75	23.75
		Lithovit	9.35	9.00	18.22	18.53	24.55	24.55
	50 %	Without	9.00	8.71	17.66	17.97	23.06	23.06
		Lithovit	9.12	8.80	17.80	18.14	23.44	23.44
LSD at 5%			NS	0.07	NS	0.12	0.25	NS

CONCLUSION

From the aforementioned study, it could be recommended that irrigation potato plants with magnetized water, 100% NPK fertilizing at the recommended dose and foliar spraying with nano material (Lithovit) at the rate of 1g/L gave the highest values of plant growth, yield, chemical constituents and quality parameters, but treated potato plants with magnetized water and fertilized with 50% of the recommended NPK and foliar spraying with Lithovit was the best treatment of beneficial effects for minimizing the environmental pollution, consumer health and production costs, moreover increasing yield quantity and quality under Dakahlia governorate condition, Egypt.

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تأثير الري بالماء الممغنط ، التسميد المعدني الأرضى و الرش بماده نانو على نباتات البطاطس

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أجريت تجربتان حقليتان بمزرعة كلية الزراعة جامعة المنصورة خلال موسمى ٢٠١٦/٢٠١٥ ، ٢٠١٧/٢٠١٦ لدراسة تأثير الري (ماء عادى- ماء ممغنط) والتسميد المعدنى (١٠٠% ، ٧٥% ، ٥٠% من الكمية الموصي بها من النتروجين والفوسفور والبوتاسيوم) والرش (بدون ، ليثوفيت ١جرام /اللتر) وكذلك التفاعل بينهم على النمو والمحصول والمكونات الكيميائية وصفات الجودة لنبات االبطاطس صنف اسبونتا.وقد اظهرت النتائج الزياده المعنوية لصفات النمو الخضرى (طول النبات- الوزن الطازج والوزن الجاف للنبات- نسبه الماده الجافة فى الدرنات) وكمية المحصول ومحتوى النبات من الكلوروفيل أ ،ب و الكلى ومحتوى الاوراق من العناصر النتروجين والفوسفور والبوتاسيوم و الكالسيوم والمغنسيوم ومحتوى الدرنات من النتروجين والفوسفور والبوتاسيوم وكذلك صفات الجوده (السكريات المختزله والغير مختزله والكلية –نسبه المواد الصلبة الكلية- النشا- فيتامين C) عند استخدام الماء الممغنط فى رى نباتات البطاطس. ادى التسميد المعدني ١٠٠% من الكمية الموصي بها إلى زياده معنوية في جميع الصفات السابقه بالاضافة لمحتوى النبات من النترات والنيتريت وكذلك ادى رش نباتات البطاطس بمادة الليثوفيت إلى زياده معنوية في جميع الصفات المدروسة ماعدا محتوى الدرنات من النترات والنيتريت. وعلى ذلك فإننا نوصي باستخدام الماء الممغنط فى ري نباتات البطاطس والتسميد بالسماد المعدني بمعدل ٥٠% من الكمية الموصي بها مع الرش بالليثوفيت بمعدل ١ جرام فى اللتر ثلاث مرات وذلك لتحسين صفات الجوده وزياده المحصول وتقليل التكاليف والحد من التلوث البيئى مقارنة بمعامله التسميد ١٠٠% من الكمية الموصى بها مع الري بالماء العادى وبدون رش بمادة الليثوفيت.