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Effect of Foliar Nano Fertilizers and Irrigation Intervals on Soybean Productivity and Quality

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ABSTRACT

During summer seasons of 2015 and 2017, a field experiment was conducted at the Research and Experimental Station (30°19′ N, 31°16′ E), Faculty of Agriculture, Ain Shams University at Shalakan, Kalubia Governorate, Egypt, to investigate the effects of combinations between hydroxyl apatite nanoparticles (0, 3, and 6 kg/fad) and calcium carbonate nanoparticles (0, 500g/fad) as nano-fertilizers under irrigation intervals, (irrigation every 2 or 3 weeks whereas irrigation every 2 weeks as a recommended practice) on yield components and quality of soybean plants. Plants irrigated every two weeks produced higher seed and biological yield in the two resulted seasons; and its combined. Interaction between 6 kg/fad hydroxyl apatite nanoparticles (A_3) and 500 g/fad calcium carbonate nanoparticles (C_2) under irrigation every 2 week (IR_1) recorded the maximum values of 100-seed weight, pod yield, seed and biological yield . On the other hand the lowest means values were recorded at combination between zero kg/fed hydroxyl apatite nanoparticles (A_1) and zero g/fed calcium carbonate nanoparticles (C_1) under irrigation every 3 week (IR_2). Regarding to chemical composition interactions of irrigation intervals x apatite concentrations x nano calcium carbonate scored the highest and significant oil% and protein %. Interaction between 6 kg/fed hydroxyl apatite nanoparticles (A_3) and 500 g/fed calcium carbonate nanoparticles (C_2) under irrigation every 2 week (IR_1) recorded the maximum values of yield and quality studied traits of soybean plants.

Keywords: Soybean, Nano fertilizers, Calcium Carbonate Nanoparticles, Hydroxyl Apatite Nanoparticles, Irrigation Intervals.

INTRODUCTION

Soybean (*Glycine max*, L. Merr.) is a fundamental wellspring of vegetable protein for human food and animal feed around the world. It is anticipated to turn into a noteworthy crop in Africa (Sinclair *et al.*,, 2014). Soybean assumes a vital job in providing oil and protein required by people (Agarwal, 2007; Shi *et al.*,, 2010).

Water has become a limited resource in Egypt. Hence, the search for technologies/ measures to save/ conserve water in irrigated agriculture has intensified. Therefore, decreasing plant water consumption by stretching irrigation intervals will keep water through reducing number of irrigation but still attain similar economic yield (Mahmoud, *et al.*,, 2013). Ibrahim and Kandil (2007) in clay loam soil in Egypt reported that irrigation intervals significantly affected growth and yield attributes. Highest values of growth traits and productivity were achieved by irrigation every two week as compared with irrigation one week and three weeks days.

Nanotechnology it considers the great solution we can depend on now to develop agriculture practices. Consequently, our information's about that technology must be growing up. Nanotechnology focused on the application of modern strategies for water management and pesticides (Prasad *et al.*,, 2014). Promising nanotechnology applications address low use effectiveness of agricultural production inputs and worry of drought and high soil temperature. Nano-scale agrichemical formulations can proficiency expands use and decline ecological losses. Nano-porous materials which able to storing water and gradually discharging it amid times of water shortage could likewise expand yields and save water (Bouwmeester *et al.*,, 2009).

Usage of phosphorus from the applied traditional phosphate fertilizers by plants is low because of its intricate reactions in soils. It's considered that the competence of utilized phosphates manures is as low as about 20% relying upon soil properties. This has prompted a look for increasingly proficient methodologies for improving yield generation in low phosphates soils (Shenoy and Kalgudi 2005). Phosphorus proficiency use can be improved by advancing soil use, preventing disintegration soils, keeping up soil quality, improving manure recommendations and fertilizer position techniques, yield genotypes, advancing mycorrhizas (Schreoder *et al.*,, 2011) and utilizing fertilizers and bio charcoal (Gunes *et al.*,, 2014). In addition to these, utilizing manufactured Nano-hydroxyapatite [$Ca_{10}(PO_4)_6(OH)_2$; NHA] can be promising strategy to upgrade phosphates fertilizer use effectiveness. The present literature on Nano-hydroxyapatite is chiefly centered on its biomedical applications while potential farming applications have been not enough tended to (Kottegoda *et al.*,, 2011). In addition, he used modified urea hydroxyapatite as slow release fertilizer. Liu and Lal (2014) considered Nano-hydroxyapatite as alternative P fertilizer and they suggested that Nano-hydroxyapatite can potentially upgrade soybean grown in peat-perlite mixture.

Calcium carbonate is a primary component of garden lime, and known as agricultural lime, which use to

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enhance the soil quality by adjusting pH and water holding capacity of acidic soils. Calcium carbonate sources as limestone and chalk, along with other chemical compounds are used in the preparation of agricultural lime, when added to soil acts as a calcium source for plants (Sabriye and Ozdemir 2012). Plants need calcium for growth, enhance activate number of enzymes, metabolism systems, nitrate take-up a useable type of nitrogen, biomass proportion (Savithramma, 2002) and photosynthetic rate (Savithramma, 2004 and Savithramma *et al*.,, 2007).

Kara and Sabir (2010) tested a natural product made of Ca, Mg, Fe and Si elements and they found beneficial in production of robust plants by accelerating vegetative growth in nursery stage. Sprayed onto leaves it activate micronized particles penetrate through stomata into the leaves. In leaves the particles are split into CO_2 and CaO and MgO which are immediately available for plant. This process is triggered by chlorophyll absorbing light resulting in CO_2 plus H_2O which converted to carbohydrates and O_2. Nano-particles can directly enter through stoma into leaf. Calcite particles are then split into CaO and CO_2 which, as demonstrated by Chen *et al*.,, (2004), is the driving force of the photosynthesis. The aim of work is to evaluate response of soybean plants growth, yield and yield quality to hydroxyl apatite nanoparticles and calcium carbonate nanoparticles under two irrigation intervals.

MATERIALS AND METHODS

Experimental site

During summer seasons of 2015 and 2017, a field experiment was conducted at the Research and Experimental Station (30°19′ N, 31°16′ E), Faculty of Agriculture, Ain Shams University at Shalakan, Kalubia Governorate, Egypt, to study the effects of combinations between hydroxyl apatite nanoparticles and calcium carbonate nanoparticles as nano-fertilizers under two irrigation intervals, on yield, yield attribute and seed chemical composition of soybean plants (*Glycine max*, Merrill c.v. Giza 111). The soil was clay loam and its properties are shown in Table 1. The preceding crop was wheat in both seasons.

Table 1. Soil properties of the Research and Experimental Station at Shalakan

Soil depth (cm)	Mechanical analysis %			Chemical properties				
	Clay	Silt	Sand	Organic matter %	pH	EC dSm^{-1}	$CaCo_3$ (%)	
0–30	40	43	17	1.65	7.72	1.5	2.1	
	Available macronutrients (mg kg^{-1} soil)							
	N			P			K	
	1189			2.2			327	
	Soluble cations and anions (mg 100g $soil^{-1}$)							
	CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}	Ca^{++}	Mg^{++}	Na^+	K^+
	0.0	11.5	26.2	19.4	7.8	2.7	15.3	0.9

Experimental treatments

The experiment included 12 treatments which were the combinations of:-

1- **Hydroxyl apatite nanoparticles (HA):** foliar application of three concentrations, i.e. 0 kg fad^{-1} (control), 3 kg fad^{-1}, 6 kg fad^{-1} (faddan = 4200 m^2). A Hydroxyl apatite nanoparticle was sprayed three times after 25, 45, and 65 days from sowing. A Hydroxyl apatite nanoparticle was purchased from Bio-Nano fertilizer company and was characterized by x – ray diffraction, average crystal size 16.9 Nano-meters (fig 1).

2- **Calcium carbonate nanoparticles (CC):** foliar application of two concentrations, i.e. zero g fad^{-1} (control), 500 g fad^{-1} calcium carbonate nanoparticle was sprayed three times after 25, 45, and 65 days from sowing. Calcium carbonate nanoparticles was purchased from Bio-Nano fertilizer company and was characterized by x – ray diffraction, average crystal size 93.3 Nano-meters (fig 2).

3- **Irrigation intervals:** irrigation treatments, (irrigation at 2 and 3 weeks whereas irrigation every 2 weeks as a recommended practice). Irrigation treatments were followed after the first irrigation (25 days after planting).

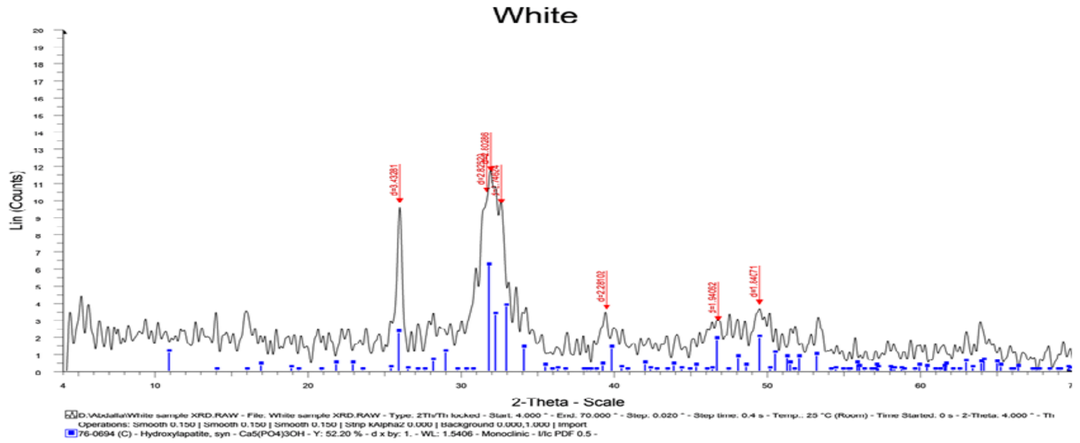

Figure 1: X-ray diffraction patterns of hydroxyapatite nanoparticles)

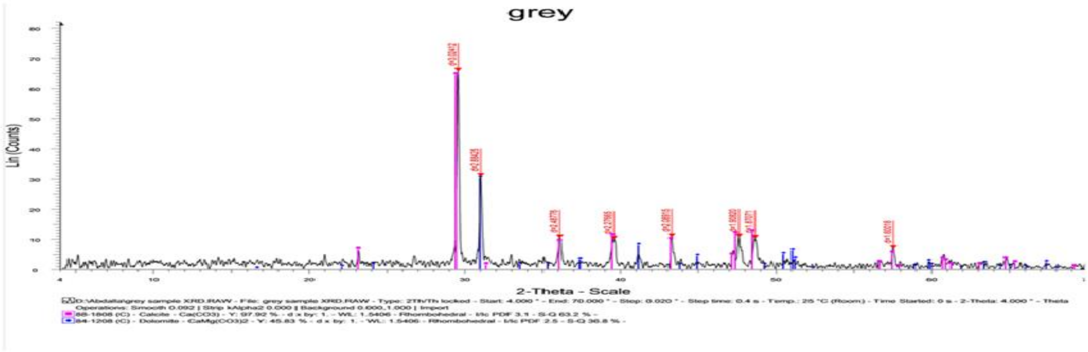

Figure 2: X-ray diffraction patterns of calcium carbonate nanoparticles)

Experimental practices and design:

Treatments were arranged in the strip split plot design in 4 replicates. Plot area was 10.8 m^2 (6 ridges 3 m as long 0.60 m apart). Soybean seeds were sown in hills (20 cm between hills) on 25th May and 28th May in 2015 and 2017, respectively. Two plants were left in every hill while plant cultivation in the two sides of hill. Seeds were inoculated with (*Bradyrhizopium Jabonicum)* before sowing directly and nitrogen fertilizer (urea 46% N) was applied at the rate of 15 kg nitrogen as an active dose after 25 days from sowing.

Soybean (C.V. Giza111) seeds (gained from, Field Crops Research Institute, ARC) were broadcasted at a rate of 30 kg fad^{-1}, after irrigation. All other recommended agricultural practices were adopted throughout the two seasons.

Data recorded

Yield and yield attributes: Soybean plants were harvested in October 15th and October 25th during 2015 and 2017, respectively from two inner ridges in every plot to estimate the following yield characters:-

a. 100 - seed weight (g) b. Hulling %

Moreover, plants from the two inner ridges were collected to estimate:-

a. Biological yield fad^{-1} (ton) b. seed yield, fad^{-1} (ton) c. Pods yield fad^{-1} (ton),

Seed chemical composition

a. Crude protein percentage:-Total nitrogen was determined in seeds using the modified micro Kjeldahl method as described in A.O.A.C. (1995). Crude protein content was calculated by multiplying the total nitrogen by 5.7. Then, protein yield in kg per feddan was computed.

b. Seed oil percentage:-

For oil percentage determination, the technique for extraction and the methods used for determination were mainly by using petroleum ether in a Soxhelt apparatus according to A.O.A.C (1995)

Statistical analysis

All data were subjected to the analysis of variance (ANOVA) as single seasons and combined data using least significant difference (LSD) at 0.05 and 0.01 probability levels according to Gomez and Gomez, (1983).

RESULTS AND DISCUSSION

1- Seed yield and its components

A- Effect of irrigation intervals:-

Data presented in Table 2 stated that 100-seed weight was significantly affected by irrigation intervals in the two successive seasons; 2015 and 2017 as well as its combined data. On the contrary Hulling% did not affect by irrigation intervals in the two studied seasons; 2015 and 2017 or combined data. Similar trends were obtained by Kobraei *et al.* (2011), Golezani and Lotfi (2012) and Mahmoud, Gamalat *et al.* (2013).

Table 2. Effect of irrigation intervals on soybean pod yield ton per faddan, hulling percentage and 100-seed weight in the two studied seasons; 2015, 2017 and their combined data

Irrigation intervals(weeks)	Pod yield (ton/fed)	Hulling %	100-seed weight (g)
	Season 2015		
2	2.506	68.24	16.296
3	1.952	63.44	17.488
LSD at 5%	0.231	n.s	0.790
	Season 2017		
2	3.213	69.09	16.188
3	2.790	65.60	17.463
LSD at 5%	0.272	n.s	0.245
	combined data		
2	2.859	68.66	16.242
3	2.371	64.52	17.475
LSD at 5%	0.170	n.s	0.472

Soybean seed yield /faddan and biological yield /faddan significantly influenced by irrigation intervals in the two studied seasons; 2015 and 2017 as well as combine result as shown in Table 3. Plants irrigated every two weeks produced higher seed yield /faddan and its biological yield /faddan in the two resulted seasons; 2015 and 2017 and its combine. The increments in seed yield /faddan and biological yield were (0.358 and 0.232 ton seeds /faddan) and (1.123 and 0.963 ton /faddan), respectively in the two growing seasons. The increases in seed yield /faddan or biological yield /faddan of irrigated plants every two weeks may be owing to its increases in number of branches and number of seeds /plant (Hussein, *et al.* 2019) or pod yield /faddan or/and 100-seed weight Table 2. Same workers came to similar conclusions as Kobraei *et al.* (2011), Golezani and Lotfi (2012) and Mahmoud, Gamalat *et al.* (2013).

B- Effect of calcium carbonate nanoparticles rates:-

Data in Table 4 revealed that pod yield /faddan and 100-seed weight were significantly affected by calcium carbonate nanoparticles in the two successive seasons; 2015 and 2017 as well as its combined result. Soybean plants treated by 500 g/faddan calcium carbonate nanoparticles produced higher pod yield /faddan, hulling% and 100-seed weight. These results mean that soybean plants were affected by calcium carbonate nanoparticles which encourage soybean plants to produce more pods as well as heavier seeds. Seed yield /faddan as well as biological yield /faddan (as shown in table 5) significantly influenced by adding 500 g/feddan calcium carbonate nanoparticles in the two studied seasons; as well as combine result except the first season of study. The increases in seed yield /faddan or biological yield /faddan by adding 500 g/faddan calcium carbonate nanoparticles may be due to the increases in number of branches /plant and number of seeds /plant.

Same workers came to similar trends as Yugandhar and Savithramma (2013), Sabir *et al.*,, (2014), Georgieva *et al.*,, (2017) and Abd El-Aal and Eid (2018).

Table 3. Effect of irrigation intervals on seed yield (ton/fad) and biological yield (ton/fad) of soybean plants in the two studied seasons; 2015, 2017 and their combined data

Irrigation intervals (weeks)	Seed yield (ton/fed)	Biological yield (ton/fed)
	Season 2015	
2	1.553	4.154
3	1.195	3.031
LSD at 5%	0.072	0.131
	Season 2017	
2	1.576	6.592
3	1.344	5.629
LSD at 5%	0.111	0.915
	combined data	
2	1.565	5.373
3	1.269	4.330
LSD at 5%	0.084	0.457

Table 4. Effect of calcium carbonate nanoparticles on pod yield ton/fad, hulling percentage and 100-seed weight of soybean plants in the two studied seasons; 2015, 2017 and their combine data.

Calcium Carbonate (g/fed)	Pod yield (ton/fad)	Hulling %	100-seed weight (g)
	Season 2015		
Zero	2.069	68.30	17.00
500	2.389	63.38	16.78
LSD at 5%	0.190	3.61	n.s
	Season 2017		
Zero	2.804	69.82	16.98
500	3.198	64.87	16.67
LSD at 5%	0.062	4.12	n.s
	combined data		
Zero	2.436	69.06	16.99
500	2.793	64.12	16.73
LSD at 5%	0.087	3.28	n.s

Table 5. Effect of calcium carbonate nanoparticles on seed yield ton per faddan and biological yield ton per faddan of soybean plants in the two studied seasons; 2015, 2017 and their combined data.

Calcium carbonate (g/fed)	Seed yield (ton/fad)	Biological yield (ton/fad)
	Season 2015	
Zero	1.319	3.391
500	1.430	3.794
LSD at 5%	n.s	0.270
	Season 2017	
Zero	1.387	5.770
500	1.533	6.450
LSD at 5%	0.039	0.253
	combined data	
Zero	1.353	4.580
500	1.481	5.122
LSD at 5%	0.073	0.195

C- Effect of hydroxyl apatite nanoparticles:-

Data presented in Table 6 indicated that Pod yield /faddan and 100-seed weight were increased significantly with increasing hydroxyl apatite nanoparticles from 3 kg/faddan up to 6 kg/faddan. These results were fairly true in the two growing seasons; 2015 and 2017 as well as combine result. The increase in pod yield /faddan and 100-seed weight were (19.6% and 26.8%) and (7.0% and 7.0%) in the two growing seasons; 2015 and 2017, respectively.

In Table 7, Seed yield /faddan as well as biological yield /faddan were significantly affected by applying 6 kg/fed hydroxyl apatite nanoparticles in the two studied season; 2015 and 2017 as well as combine result. Soybean plants treated with 6 kg /faddan hydroxyl apatite nanoparticles produced the highest seed yield /faddan or/and biological yield /faddan in the two growing seasons. These results may be due to the more great permeability and high speed of hydroxyl apatite nanoparticles which mean more easily to penetrate into soybean leaves and release P and Ca which play an important role in pushing plant growth of soybean plants and there reflects on yield attributes. Some investigators come to similar trends as Subbaiya *et al.*,, (2012), Liu and lal (2014), Liu and lal (2015), Upadhyaya *et al.*,, (2017) and Taşkın *et al.*,, (2018).

Table 6. Effect of Hydroxyl apatite nanoparticles on pod yield ton/fad, hulling percentage and 100-seed weight of soybean plants in the two studied seasons; 2015, 2017 and their combined data.

Hydroxyl apatite (kg/fad)	Pod yield (ton/fad)	Hulling %	100-seed weight (g)
	Season 2015		
Zero	2.055	69.77	16.29
3	2.174	64.54	16.94
6	2.458	63.21	17.44
LSD at 5%	0.178	3.32	0.58
	Season 2017		
Zero	2.620	69.06	16.38
3	3.062	67.08	16.57
6	3.321	65.88	17.53
LSD at 5%	0.170	n.s	0.48
	combined data		
Zero	2.338	69.42	16.33
3	2.618	65.81	16.76
6	2.889	64.54	17.48
LSD at 5%	0.136	3.85	0.41

Table 7. Effect of Hydroxyl apatite nanoparticles on seed yield ton per faddan and biological yield ton per faddan of soybean plants in the two studied seasons; 2015, 2017 and their combined data.

Hydroxyl apatite (kg/fad)	Seed yield (ton/fad)	Biological yield (ton/fad)
	Season 2015	
Zero	1.233	3.101
3	1.350	3.608
6	1.539	4.068
LSD at 5%	0.097	0.299
	Season 2017	
Zero	1.379	5.179
3	1.403	6.595
6	1.598	6.556
LSD at 5%	0.076	0.541
	combined data	
Zero	1.306	4.140
3	1.377	5.102
6	1.568	5.312
LSD at 5%	0.066	0.346

D- Effect of interaction between irrigation intervals and calcium carbonate nanoparticles:

Data presented in Tables 8 revealed that pod yield /faddan, hulling%, 100-seed weight, seed yield ton/faddan and biological yield ton/feddan were significantly affected by interaction between irrigation intervals and calcium carbonate nanoparticles in the two growing seasons 2015 and 2017 except number of seeds /pod in the first season of study. Soybean plants irrigated every two weeks and treated by 500 g/fed calcium carbonate nanoparticles scored the highest value of pod yield /faddan, hulling %, 100-seed weight, seed yield ton/faddan and biological yield ton/faddan in the two studied seasons 2015 and 2017, respectively while soybean plants irrigated every 2 or 3 weeks and treated by 500 g/fed calcium carbonate nanoparticles had more seed/pod and hulling% either during 2015 or 2017 seasons as shown in Tables 8. These results may be regarded to the effect of calcium carbonate nanoparticles in pushing growth of plants to accumulate more dry matter which intern in yield attributes some worker came to similar trends as Kobraei *et al*.,, (2011), Golezani and Lotfi (2012), Sabir *et al*.,, (2014) and Abd El-Aal and Eid (2018).

Table 8. Effect of interaction between irrigation intervals and calcium carbonate nanoparticles on soybean yield attributes during the two growing seasons 2015 and 2017.

	Calcium carbonate nanoparticles (g/fad)			
	2015		2017	
Irrigation intervals (weeks)	Zero	500	Zero	500
	Pod yield (ton/fed)			
2	2.328	2.684	2.895	3.530
3	1.811	2.093	2.713	2.866
LSD at 5%	0.261		0.163	
	Hulling %			
2	70.76	65.72	70.40	67.78
3	65.84	61.04	69.23	61.96
LSD at 5%	3.74		6.97	
	100-seed weight (g)			
2	16.17	16.43	15.98	16.39
3	17.84	17.13	17.98	16.95
LSD at 5%	0.85		0.68	
	Seed yield (ton/fad)			
2	1.473	1.634	1.483	1.669
3	1.165	1.225	1.291	1.397
LSD at 5%	0.172		0.090	
	Biological yield (ton/fad)			
2	3.778	4.531	5.866	7.318
3	3.004	3.058	5.674	5.583
LSD at 5%	0.315		0.620	

E- Effect of interaction between irrigation intervals and hydroxyl apatite nanoparticles:

Data tabulated in Tables 9 observed that all studied yield attributes pod yield /faddan, hulling%, 100-seed weight, seed yield ton/faddan and biological yield ton/faddan were statistically influenced by interaction between irrigation intervals and hydroxyl apatite nanoparticles in the two growing seasons 2015 and 2017 except number of seeds /pod in the first season of study.

These results were so great and enough to reach the 5% level of significance. Irrigated soybean plants every two weeks and received 6 kg/faddan hydroxyl apatite nanoparticles had the highest value of pod yield ton/faddan, seed yield ton/faddan and biological yield ton/faddan in the two studied seasons 2015 and 2017, as shown in tables (9). More effects in the same trend done by Kobraei *et al*.,, (2011), Golezani and Lotfi (2012), Mahmoud, Gamalat *et al*.,, (2013), Liu and lal (2015) and Upadhyaya *et al*.,, (2017).

Table 9. Effect of interaction between irrigation intervals and hydroxyl apatite nanoparticles on soybean yield attributes during the two growing seasons 2015 and 2017.

	Hydroxyl apatite nanoparticles (kg/fad)					
Irrigation	2015			2017		
intervals (weeks)	Zero	3	6	Zero	3	6
	Pod yield (ton/fad)					
2	2.330	2.280	2.908	2.725	3.366	3.546
3	1.780	2.068	2.009	2.515	2.758	3.095
LSD at 5%	0.321			0.224		
	Hulling %					
2	70.78	66.90	67.04	67.80	71.64	67.82
3	68.76	62.19	59.38	70.33	62.53	63.94
LSD at 5%	6.93			7.12		
	100-seed weight (g)					
2	15.62	16.33	17.30	15.16	15.94	17.46
3	17.33	17.56	17.58	17.59	17.20	17.60
LSD at 5%	0.62			0.59		
	Seed yield (ton/fad)					
2	1.461	1.409	1.790	1.471	1.511	1.745
3	1.006	1.291	1.288	1.286	1.295	1.450
LSD at 5%	0.155			0.123		
	Biological yield (ton/fad)					
2	3.870	4.069	4.524	5.581	6.818	7.376
3	2.333	3.148	3.613	4.778	6.373	5.736
LSD at 5%	0.503			0.892		

F- Effect of interaction between calcium carbonate nanoparticles and hydroxyl apatite nanoparticles:

Data in Tables 10 reported that all studied measurements of soybean seed yield and its attributes were significantly influenced by the interaction between calcium carbonate nanoparticles and hydroxyl apatite nanoparticles in the two studied seasons 2015 and 2017, except 100-seed weight in the first season.

Table 10. Effect of interaction between hydroxyl apatite and calcium carbonate nanoparticles on soybean yield attributes during the two growing seasons 2015 and 2017.

	Hydroxyl apatite nanoparticles (kg/fad)					
	2015			2017		
Calcium carbonate (g/fed)	Zero	3	6	Zero	3	6
	Pod yield (ton/fad)					
0	1.783	2.149	2.276	2.344	2.904	3.164
500	2.328	2.199	2.640	2.896	3.220	3.478
LSD at 5%	0.169			0.299		
	Hulling %					
0	76.60	65.20	63.10	75.39	67.34	66.73
500	62.94	63.89	63.31	62.74	66.83	65.04
LSD at 5%	6.45			6.02		
	Seed yield (ton/fad)					
0	1.092	1.310	1.524	1.259	1.346	1.555
500	1.375	1.390	1.553	1.499	1.460	1.640
LSD at 5%	0.189			0.113		
	Biological yield (ton/fad)					
0	2.725	3.371	4.060	5.026	6.400	5.883
500	3.478	3.845	4.076	5.332	6.790	7.229
LSD at 5%	0.243			0.856		

Soybean pod yield /faddan, seed yield ton/faddan and biological yield ton/faddan of plants treated with 500 g/faddan calcium carbonate nanoparticles and 6 kg/faddan hydroxyl apatite nanoparticles were so great and enough to reach the 5% level of significance in the two studied seasons 2015 and 2017. These results may be due to the role of calcium carbonate nanoparticles and/or hydroxyl apatite nanoparticles in seed filling and plant metabolism. Similar trends were obtained by Liu and lal (2014), Sabir *et al.*,, (2014), Liu and lal (2015), Abd El-Aal and Eid (2018) and Taşkın *et al.*,, (2018).

G- Irrigation intervals X calcium carbonate nanoparticles X hydroxyl apatite nanoparticles interaction:

Figures from 3 to 7 show the effect of the triple interaction among calcium carbonate, hydroxyl apatite levels and irrigation intervals treatments on soybean yield attributes. Results revealed clearly that the interaction effect was significant. These significant effects reflect that tested calcium carbonates nanoparticles along with hydroxyl apatite nanoparticles levels do not take the same behavior under the different treatments of irrigation intervals. Interaction between 6 kg/fed hydroxyl apatite nanoparticles (A_3) and 500 g/fed calcium carbonate nanoparticles (C_2) under irrigation every 2 week (IR_1) recorded the maximum values of 100-seed weight (17.613 g), pod yield (3.454 ton/fed.), seed yield (1.866 ton/fed.) and biological yield (6.606 ton/fed.). On the other hand the lowest means values were recorded at combination between zero kg/fed hydroxyl apatite nanoparticles (A_1) and zero g/fed calcium carbonate nanoparticles (C_1) under irrigation every 3 week (IR_2) on all yield attributes on contrary, this combination scored the highest hulling% may be due to decreased in number of sinks (seeds) which made all dry mater accumulations distribute on small number of seeds which reflect increases in hulling%. As shown from figures (11 to 18) there weren't significant results between plants treated with nano-mineral fertilizers under irrigation every 3 week and plants untreated but irrigated every 2 week (normal case) in all yield attributes, which reflect appositive result of these chemical substances in mitigation harmful effect of water shortage consequently, achieve great productivity. Erkan *et al.*,, (2004), Liu and Zhao (2013), Mahmoud Gamalat *et al.*,, (2013), Liu and Lal (2014), Liu and Lal (2015) and Mehmet *et al.*,, (2018) came to the same trends.

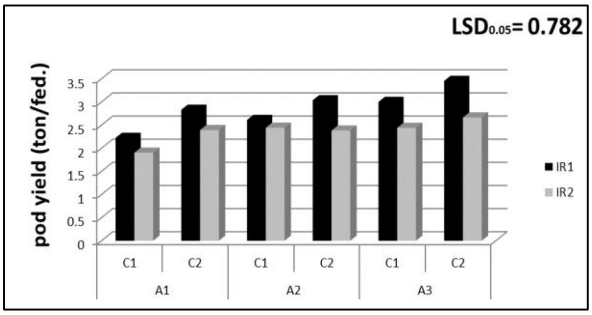

Figure 3. The significant interaction among irrigation intervals (IR1 every 2 weeks and IR2 every 3 weeks), calcium carbonate nanoparticles (C1 zero g/fed and C2 500 g/fed) and hydroxyl apatite nanoparticles (A1 zero kg/fed, A2 3 kg/fed and A3 6kg/fed) of soybean pod yield (ton/fed.).

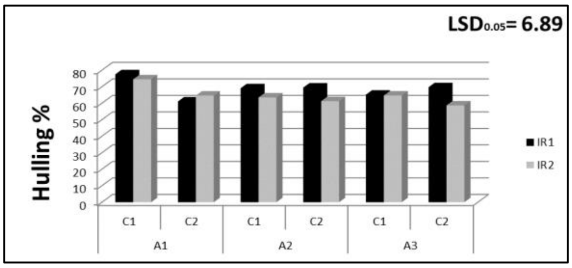

Figure 4. The significant interaction among irrigation intervals (IR1 every 2 weeks and IR2 every 3 weeks), calcium carbonate nanoparticles (C1 zero g/fed and C2 500 g/fed) and hydroxyl apatite nanoparticles (A1 zero kg/fed, A2 3 kg/fed and A3 6kg/fed) of soybean Hulling%

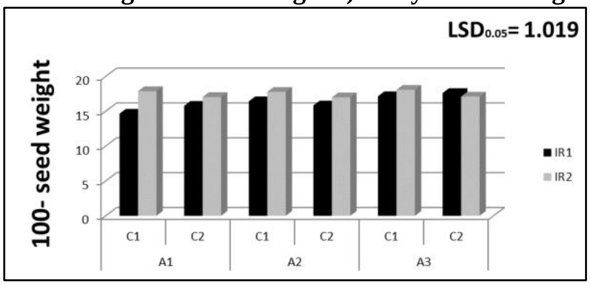

Figure 5. The significant interaction among irrigation intervals (IR1 every 2 weeks and IR2 every 3 weeks), calcium carbonate nanoparticles (C1 zero g/fed and C2 500 g/fed) and hydroxyl apatite nanoparticles (A1 zero kg/fed, A2 3 kg/fed and A3 6kg/fed) of soybean 100-seed weight (g).

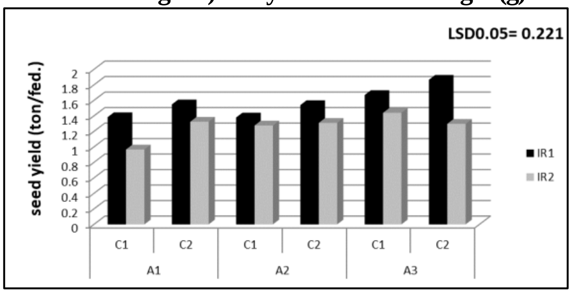

Figure 6. The significant interaction among irrigation intervals (IR1 every 2 weeks and IR2 every 3 weeks), calcium carbonate nanoparticles (C1 zero g/fed and C2 500 g/fad) and hydroxyl apatite nanoparticles (A1 zero kg/fed, A2 3 kg/fed and A3 6kg/fed) of soybean seed yield (ton/fad.).

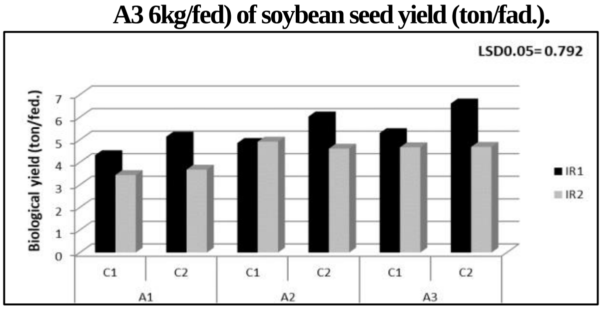

Figure 7. The significant interaction among irrigation intervals (IR1 every 2 weeks and IR2 every 3 weeks), calcium carbonate nanoparticles (C1 zero g/fed and C2 500 g/fed) and hydroxyl apatite nanoparticles (A1 zero kg/fed, A2 3 kg/fed and A3 6kg/fed) of soybean biological yield (ton/fad.).

H- Seed chemical composition: -

1- **Oil percentage:** Data presented in Table 11 revealed that oil % significantly affected by nano hydroxyl apatite application at 5% level of significance. Adding 6 kg/fed nano hydroxyl apatite gave the highest oil%. On the other hand, interactions of irrigation intervals x apatite concentrations x nano calcium carbonate scored the highest and significant oil% (table 11). Similar trends were observed by Golezani and Lotfi (2012) and (Mahmoud *et al.,*, 2013).

2- **Protein percentage:** Data in Table 12 clear that protein % was significantly influenced by adding apatite with the high rate to soybean plants and irrigated every two weeks. On the other hand, interactions of irrigation intervals x apatite concentrations x nano calcium carbonate scored the highest and significant protein% (Table 24). Similar trends were observed by Golezani and Lotfi (2012) and (Mahmoud *et al.,*, 2013).

Table 11. Effect of the triple interaction among irrigation intervals, hydroxyl apatite nanoparticles and calcium carbonate nanoparticles on oil percentage of soybean seeds.

Irrigation intervals	every 2 weeks		every 3 weeks		Mean apatite
Calcium carbonate	Zero g /fed	500 g /fed	Zero g /fed	500 /fed	
Zero kg apatite/fed	19.55	19.90	19.55	20.10	19.77
3 kg apatite/fed	20.75	20.95	20.05	19.75	20.37
6 kg apatite/fed	21.25	21.45	20.70	20.65	21.01
Mean irrigation	20.64		20.13		
Mean calcium	Zero= 20.31		500 g= 20.47		
LSD apatite (A)			1.18		
LSD irrigation (I)			n.s		
LSD calcium (C)			n.s		
LSD I x A x C			0.71		

Table 12. Effect of the triple interaction among irrigation intervals, hydroxyl apatite nanoparticles and calcium carbonate nanoparticles on protein percentage of soybean seeds.

Irrigation intervals	every 2 weeks		every 3 weeks		
calcium carbonate	Zero g /fed	500 g /fed	Zero g /fed	500 g /fed	Mean apatite
Zero kg apatite/fed	42.17	39.90	44.76	44.15	42.05
3 kg apatite/fed	41.25	39.81	42.66	39.19	40.37
6 kg apatite/fed	37.35	36.85	37.33	37.16	37.17
Mean irrigation	39.09		40.88		
Mean calcium	Zero= 40.92		500 g= 39.04		
LSD apatite (A)			0.94		
LSD irrigation (I)			1.05		
LSD calcium (C)			n.s		
LSD I x A x C			0.84		

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تأثير التسميد الورقي بأسمدة النانو و فترات الري علي انتاجية و جودة فول الصويا

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أثناء صيف ٢٠١٥، ٢٠١٧ أقيمت تجربة حقلية فى محطة تجارب وبحوث كلية الزراعة جامعة عين شمس بشلقان، محافظة القليوبية ، جمهورية مصر العربية، لتوضيح تأثير التفاعل بين جزيئات الهيدروكسى أباتيت النانومترية ثلاث مستويات (صفر كجم/فدان، ٣ كجم/فدان، ٦ كجم/فدان) و جزيئات كربونات الكالسيوم النانومترية مستويان (صفر جرام/فدان، ٥٠٠ جرام/فدان) تحت فترتى رى (الرى كل أسبوعين كمعاملة موصى بها، الرى كل ثلاث أسابيع) على انتاجية و جودة الفول الصويا أثر التفاعل بين فترات الرى وكربونات الكالسيوم النانومترية و جزيئات الهيدروكسى أباتيت النانومترية معنويا على صفات نمو فول الصويا. حيث أدت المعاملة بكربونات الكالسيوم النانومترية المختبرة تحت مستويات مرتفعة من جزيئات الهيدروكسى أباتيت النانومترية زيادة فى صفات محصول فول الصويا محصول القرون (طن/فدان)، نسبة التصافى%، وزن ال١٠٠ بذرة بالجرام، محصول البذور (طن/فدان) والمحصول البيولوجى (طن/فدان) و النسبة المئوية للزيت و البروتين. اظهرت النتائج ان التسميد بالهيدروكسي ابتيت بمعدل ٦ كجم / فدان في صورة النانو و ٥٠٠ جرام / فدان كربونات الكالسوم في صورة النانو و الري كل اسبوعين سجلت اعلي النتائج في صفات المحصول و الجودة لنباتات فول الصويا