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THE EFFECT OF HYDROXYAPATITE AND IRONE OXIDE NANOPARTICLES ON MAIZE AND WINTER WHEAT PLANTS

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Abstract

In the last few decades, the intensive use of agricultural lands affected crop productivity and thus raised serious concerns due to competing demands for food to feed the ever-growing world population (projected to be 9.7 billion by 2050). In this context, the development of nanotechnology-based fertilizers for crop nutrition has been suggested as an alternative tool to overcome the drawbacks arising from the current agricultural practices. Unfortunathelly, there is little studies about the effects of nanomaterials on plants.
In this study we presented the effect of hydroxyapatite (nHA) and iron oxides (nIO) nanoparticles obtained in Romania on growth and photosintesis of corn and winter wheat plants.
The results show that hydroxyapatite nHA) and iron oxides (nIO) treatments applied by watering the soil had a positive effect on the photosynthesis of maize and winter wheat plants.
In the case of treatments with solutions of iron oxides a negative effect on the length of main root was observation, but a compensating effect was found by increasing root density. This and also the higher chlorophyll content, led to a positive effect on height of maize and winter wheat plants.

Key words*: hydroxyapatite and iron oxides nanoparticles, maize, winter wheat, chlorophyll content, growth.*

INTRODUCTION

In modern agricultural production, the application of nitrogen and phosphorus fertilizers is a necessary measure to ensure high and stable yields for cereals and beyond. Unfortunately, the plants do not take all the amount of nutrients from the applied fertilizers but less than 50%, depending on the crop species and soil conditions.
Conventional fertilizers have low nutrient uptake efficiencies and are often associated with high losses in the environment. Therefore, is necessary the avoid these nutrient losses and the increase its uptake by crops. In this sense in last time nanofertilizers were been studied.
However, the extremely appealing prospects of use nanofertilizers in large part have still to be experimentally demonstrated in field conditions.
Hydroxyapatite [$Ca_{10}(PO_4)_6(OH)_2$] nanoparticles (nHA) have an interesting potential to be used as nanofertilizers (Marchiol et al., 2019). With regard to plant macronutrients, studies on hydroxyapatite [$Ca_{10}(PO_4)_6(OH)_2$] nanoparticles (nHA) explored their potential use as carrier of nitrogen (N) or as phosphorus (P) fertilizer. The main advantage of using nHA with respect to other nanomaterials is that they are widely renowned for their intrinsic biocompatibility and biodegradability, being the main component of human bones and teeth (Tampieri et al., 2016).

Other nanoparticles used are those based on iron oxides which have been used for environmental remediation's (Chen et al., 2008).
Most of the current published studies regarding nanoparticles and plants are centred around the effects of this on seed germination and vegetative plant growth.
Several studies were showed positive effect of hydroxyapatite nanoparticles (applied alone or in combination with urea) on the germination rate, biomass yield for several plants or the effects of iron oxide nanoparticles on vegetative growth in maize plants under optimal and hydric stress conditions (Gunaratne et al., 2016; Kottegoda et al., 2017; Petcu et al., 2019).
Also, it has been reported that daily additions of Fe3O4-NPs in the presence of static magnetic fields, increased the growth of *Zea mays* and the levels of chlorophyll (Răcuciu and Creangă, 2007). No trace of toxicity but translocation into soybean stems was reported (Mahmoudi, 2013). Furthermore, it has been found that aqueous suspensions of Fe3O4-NPs can be translocated throughout pumpkin plant tissues and accumulated into the roots and leaves (Zhu et al., 2008).
In Romania few studies concerning the effects of nHA or other nanoparticles on plants have been carried out. In this study, the effects of different treatment with hydroxyapatite and iron oxide nanoparticles were evaluated on growth, chlorophyll content and biomass accumulation of maize and winter wheat plants.

MATERIALS AND METHODS

In this study we used the solutions of hydroxyapatite and iron oxide nanoparticles provided by National Institute of Materials Physics.
Seeds of maize and winter wheat were shown in pots filled with a soil-sand mixture (3:1).
The experimental variants were: pots which were watering with tap water (control), pots watering with solution of hydroxyapatite (T1), pots watering with iron oxides solution (T2).
The treatments were applied at soil once one week.
The height of plant (mm), leaf area (cm^2), length of main root (mm), root volume (in cm^3, measured by water displacement), chlorophyll content and dry matter (g/plant) were determined. The chlorophyll content was carried out by using chlorophyll matter Minolta and results are expressed in SPAD units.
The statistical significance of the treatments was evaluated by Analysis of Variance (ANOVA). Means were compared by Least Significant Difference (LSD), according to Fisher's statistical test.

RESULTS AND DISCUSSIONS

The results of the analysis of variance showed that the treatments applied have not a significant influence on the growth of corn plants and rather, the source of the variant was the analysed organ and the interaction between these factors, which were statistically significant (Table 1).

Table 1. Analyses of variance for stem and root length

Source of variance	DF	Sum of squares	Mean square	*F value and significance*
Factor A (treatments)	2	9209	4604	*1.27*
Error A	8	28932	3616	
Factor B (organ)	1	18233	18233	*9.59**
Interraction AxB	2	46917	23458	*12.34***
Error B	12	22800	1900	

There was an insignificant positive effect of the treatments with hydroxyapatite and iron oxide solutions on the growth of the aerial part of the plants. As compared with the positive effect of hydroxyapatite it was obviously that the treatment with iron oxide nanoparticles decrease the length of the main root compared to the control (Figure 1, Photo 1).

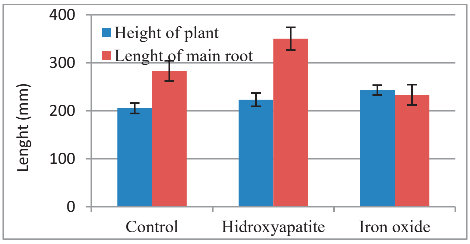

Figure 1. The effect of treatments with hydroxyapatite and iron oxide solutions on growth of maize seedling

The result obtained by Marchiol et al., (2019) showed that the germination percentage was not influenced by the increase in concentration of nHA, but the root elongation of tomato seedlings was clearly affected.
Treatment with iron oxides, although it negatively influenced the growth in root length

(Photo 1), had a beneficial effect on the volume of the root (Table 2).

Photo 1. The effect of treatments with hydroxyapatite and iron oxide solutions on growth of maize seedling (left = control; middle, 1 = hidroxyapatite; right, 2 = iron oxide)

Table 2. The effect of treatments with hydroxyapatite and iron oxides on the volume of the root system

Variants	Volume of root (cm^3)	
	cm^3	%
Control	1.6	100
T1. Hidroxyapatite	1.4	89
T2. Iron oxides	2.0	125
LDS 5%	0.22	
LDS 1%	0.37	

The biomass accumulation increase compared to the control amounted to +12%, for hydroxy-apatite and iron oxide nanoparticles (Figure 2).

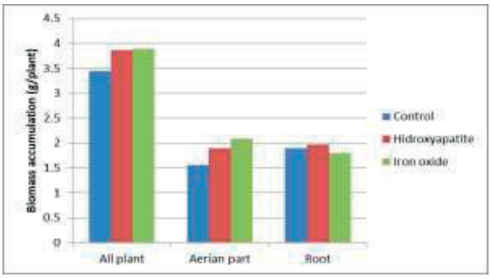

Figure 2. The effect of treatments with hydroxyapatite and iron oxide solutions on biomass accumulation

The treatment with irone oxide nanoparticle decrease the dry matter content of root by 10%, compared to the control. Although on the whole plant there was a positive effect on the dry matter content of plants grown on iron oxide solution, which had a content of 1.7 g dm/plant, while plants grown in water (control) had a content of 1, 4 g dm/plant. This also explains the positive correlation between the dry matter content and the volume of the root system, the correlation coefficient being very significant (r = 0.98***, Figure 3).

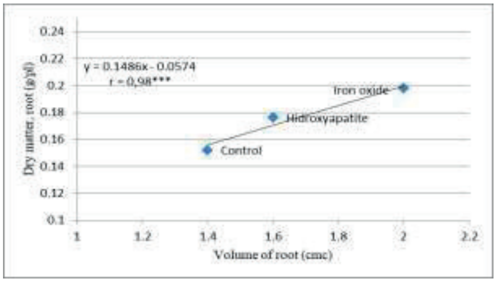

Figure 3. The correlation between the dry matter content of the roots and the volume of the root system

This means that corn plants compensate for the reduction in root length due to iron oxide treatments, with an increase in its weight. The higher amount of dry matter was due to the thickening of the main root and an increased number of absorbent hairs. This is favorable for the plant, because the absorbent hairs are the ones that achieve the absorption of water and nutrients from the soil.

The results regarding the effect of the studied substances on the photosynthesis process showed that they favorably influence this process, the leaf area and the chlorophyll content being superior to the control (Table 3).

Table 3. Effect of hydroxyapatite and iron oxide nanoparticles treatments on leaf area and chlorophyll content

Variants	Leaf area (mm^2)	Chlorophyll content (SPAD units)
Control	1676.25	29.6
T1. Hydroxyapatite (nHA)	1933.5	30.1
T2. Iron oxide (nIO)	2631	33.2

Some research has been showed that iron oxide nanoparticles caused to enhancement of growth and photosynthesis of peanut. Iron oxide nanoparticles in compared with treatments such as organic fertilizer and iron citrate facilitated the transferring of materials and increased iron transporting to leaves (Liu et al., 2005). Oil and protein production depend on the quality characteristics of seeds (oil and protein) and grain yield (Morshedi’s, 2000) showed that the usage of iron caused to significantly increase in oil and protein in Rape seeds (25% in oil and 20% in protein) in compared with control.

In contrast the results reported in watermelon (Li et al., 2013) and Chinese mung bean (Hong-Xuan et al., 2011) showed that treatments with magnetite NPs of 9 and 18 nm, was not significantly effect on chlorophyll content compared to control.

Analysis of variance showed that plant height, length of main root, root volume and chlorophyll content in wheat plants were significantly influenced (at the probability level of 5% and 1%, respectively) by the applied treatments (Table 4).

Table 4. Analysis of variance for the physiological characteristics studied in wheat

Source of variance	FD	Height of plants		Length of main root		Root volume		Chlorophyll content	
		Mean square	F factor and significance	Mean square	F factor and significance	Mean square	F factor and significance	Mean square	F factor and significance
Treatments	2	1849	12.38**	1022.11	187.73***	0.0661	14.60**	46.77	60.14***
Error	4	149.33		5.44		0.0045		0.77	

Wheat plants treated with iron oxide solution had a smaller height of plants, by 13 mm compared to the untreated control, (Table 5).
The applied treatments had a positive effect on the root volume and the chlorophyll content, the values for the root volume being 0.54 cm^3 for the treatment with nanoparticles with iron oxides and 0.41 cm^3 for the treatment with hydroxyapatite compared to only 0.25 cm^3 for the control. The highest chlorophyll content was recorded in plants treated with hydroxyapatite nanoparticles (Table 5).
Similar results were obtained in lettuce plants treated with Fe/Fe3O4 NPs treatment, the chlorophyll content increased with respect to the control by 12% (Trujillo-Reyes et al., 2014).

Table 5. The effect of treatment with nHA and nIO on studied physiological traits

Variants	Height of plants		Length of main root		Root volume		Chlorophyll content	
	mm	Differences	mm	Differences	cm^3	Differences	SPAD units	Differences
Control	273	0	175	0	0.25	0	30	0
T1. Hydroxyapatite (nHA)	289	+16	180	+5	0.41	+16	37	+7
T2. Iron oxide (nIO)	260	-13	167	-8	0.54	+29	34	+4

The applied treatments had a very significant positive effect on dry matter content (Table 6).

Table 6. Analysis of variance for dry matter

Source of variance	FD	Mean square	F factor and significance
Treatments	2	0.292	19.58***
Error	4	0.014	

The analysis of the correlations showed that between the dry matter and the root volume there is a positive correlation (r = -0.98***, figure 4), and also with chlorophyll content (r = 0.75*, figure 5).
From our observations it was seen that there was a compensation of the reduction of the length by increasing the density of the root system, respectively the winter wheat plants treated with iron oxide had more adventitious roots.
This and the higher chlorophyll content may explain the positive effect of the treatments applied on the height of plants.

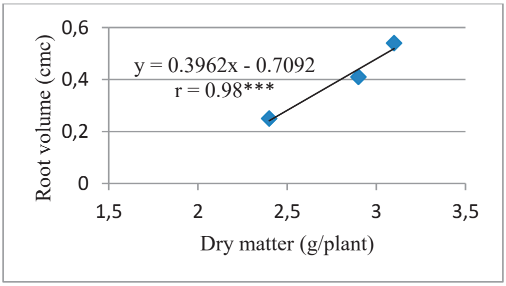

Figure 4. Relationship between dry matter and root volume

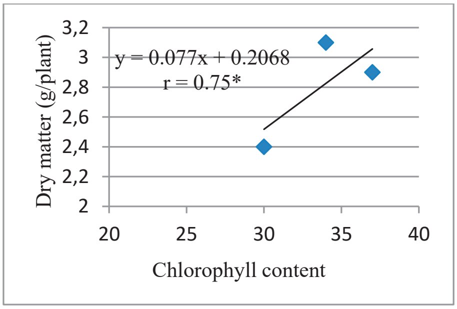

Figure 5. Relationship between dry matter and chlorophyll content

CONCLUSIONS

The results show that hydroxyapatite and irone oxide nanoparticle treatments had a positive effect on chlorophyll content of maize and winter wheat plants.

In the case of treatments with solutions of iron oxides nanoparticles, although negative effects were reported on the plant height and root length, a compensating effect was found by increasing root density. but also by higher chlorophyll content. This and also the higher chlorophyll content, led to a positive effect on height of maize and winter wheat plants.

The results suggested that use of treatments with hydroxyapatite and iron oxide nanoparticle in agriculture could be possible.

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