Volume 16(4), 63- 66, 2012
JOURNAL of Horticulture, Forestry and Biotechnology
www.journal-hfb.usab-tm.ro

Nitrogen content in lettuce under the influence of magnetic nanofluids

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Abstract Our research focussed on the modification of total and nitric nitrogen content in lettuce, under the influence of treatments with magnetic nanofluids. We used water-based magnetic fluid (WMF/H_2O), with saturation magnetization $Ms = 32\ Gs$. The magnetic nanofluid was applied at foliar level, in four concentrations: 0.05%, 0.1%, 0.5% and 1%, and were compared to the control variant. Magnetic nanofluid treatments influenced the content of total and nitric nitrogen in lettuce. Total nitrogen ranged from 4.960 to 3.740 ± 0.291 % N_{tot} in the treated variants, as compared to 3.350 ± 0.291 % N_{tot} in the control variant. Nitric nitrogen is reduced in the treated variants, ranging from 1252.00 to 1068.00 ± 397.40 ppm $-NO_3^-$, while in the control variant we identified 3101.00 ppm $N - NO_3^-$. Variable distribution analysis through cluster analysis place the experimental data into two groups: the group of variables with magnetic fluid, split, in its turn, into two subgroups according to their magnetite concentration (subgroup WMF 0.1% - WMF 0.5% - WMF 1% with higher magnetite concentration and variant WMF 0.05% with lower concentration). The control is found in the second group (without magnetite). Multiple criteria data analysis helped establish the groups of variables with positive reaction regarding the change in the nitrogen content in relation to the nitrogen treatments.

Key words

magnetic nanofluids, magnetite, lettuce, total nitrogen, nitric nitrogen

Magnetic nanofluids or ferrofluids are ultrastable complex biphasic media, composed of fine magnetic nanoparticles (ϕ ≅ 20 - 200 nm) found in colloidal suspension in a base liquid, sensitive to the magnetic field; this mixture behaves as a homogenous liquid, Malchenko et al. 1992, Nakatani et al. 1992 (a, b).

The effects of ferrofluids in vegetal organisms and microorganisms represents an important application field of special interest.

Together with the development of nanoscience interest in the vegetal field, the investigation techniques have been diversified regarding the penetration and circulation of magnetic nanoparticles in vegetal tissues and structures, Gonzalez et al. 2007.

Researchers have studied the influence of magnetic fluids on certain metabolic processes such as seed germination, plant growth and development in incipient vegetation stages, Sala F., 1999.

A number of studies have focussed on the penetration of magnetic nanoparticles in various vegetal structures (cells, tissues, organs) and their translocation in plants, Cifuentes et al. 2010, Corredor et al. 2010.

Research has been made on the influence of ferrofluids on the content of chlorophyll in cereals, (*Zea mays*), highlighting some stimulating effects of ferrofluids on chlorophyll a, b and carotenoids, Mihaela Răcuciu and Dorina-Emilia Creangă, 2007.

Recent studies look into the control of chemical substances for plant protection and nutrients through nanotechnologies that use magnetic nanoparticles, Remya Nair et al. 2010.

Other researchers have found cytogenetic modifications and chromosomal aberrations in plants under the influence of magnetic fluids, Angela Pavel and Dorina-Emilia Creangă, 2005, Mihaela Răcuciu and Dorina Creangă 2007. Phytotoxic effects have been reported of different types of magnetic nanoparticles on plant germination and growth in early vegetation stages, for *Cucurbita pepo*, Stampoulis et al. 2009 and for *Cucumis sativum* Peng Zhang et al. 2012.

Having in mind the tendencies of approaching the relation nanoparticles/magnetic nanofluids - vegetal organism, we focused on the influence of nanomagnetic fluids on the total nitrogen(N_{tot}) and nitric nitrogen ($N - NO_3^-$) in lettuce.

Material and Methods

The research was conducted on lettuce, in protected environment, in a greenhouse. We tested the bioactive influence of magnetic nanofluids in different concentrations on the nitrogen content in lettuce, looking for the values of total nitrogen and nitric nitrogen as well.

We used water-based magnetic fluid (WMF/H_2O), with saturation magnetization $Ms = 32\ Gs$. The magnetic nanofluid was used in four concentrations: 0.05%, 0.1%, 0.5% and 1%, together with a control variant. The treatment solutions were water-based.

The biologic material was represented by the species *Lactuca sativa,* capitata variety.

We applied two treatments with solutions based on magnetic nanofluids. The first treatment in the stage of three pairs of leaves, and the second 10 days later.

The treatments were applied by spraying the leaves with an atomizer pump.

The growth medium for lettuce had the following characteristics: pH_{H_2O} = 7.92, $H = 6.46\%$, $P_{mobil} = 365\ ppm$, $K_{mobil} = 1798\ ppm$, $N_{total} = 0.40\%$, $Fe_{total} = 30755\ ppm$, $Zn_{total} = 91.9\ ppm$, $Mn_{total} = 448\ ppm$.

We determined the total nitrogen content (N_{tot}) and nitric nitrogen ($N - NO_3^-$) in lettuce plants. The plants were harvested 25 days after the second treatment, when they had reached maturity for consumption.

The determinations were made by specific laboratory methods: total nitrogen was determined by wet digestion with sulphuric acid followed by distillation; nitric nitrogen was determined through colorimetry, in extract of acetic acid 2% with phenoldisulphonic acid.

The results were processed through adequate statistical methods: statistic analysis, correlations, variance - covariance and spatial distribution of variables through cluster analysis.

Results and Discussions

The experimental conditions facilitated plant reaction to treatment and we registered variationa of the nitrogen content (both total and nitric) in salad, under the influence of magnetite nanoparticles.

Table 1 presents the experimental data on the concentration of magnetite administered and the nitrogen content.

We distinguish here the existence of the effect of magnetic nanofluid on the regime of nitrogen in plants, in terms of variation in the nitrogen content, in both forms, total (N_{tot}) and nitric (NO_3^-).

Table 1

Variation of the nitrogen content in lettuce (*Letuca sativa*) under the influence of magnetic nanofluid treatments

Experimental variants	Quantity of magnetite in colution (g/100 ml)	Nitrogen content: $N_{tot.}$ (%)	Nitrogen content: $N - NO_3^-$ Ppm
Mt	-	3.350 ± 0.29	3101.000 ± 397.40
WMF 0.05%	0.0510	4.960 ± 0.29	1252.000 ± 397.40
WMF 0.1%	0.1020	4.620 ± 0.29	1076.000 ± 397.40
WMF 0.5%	0.5100	4.023 ± 0.29	1089.000 ± 397.40
WMF 1%	1.0201	3.740 ± 0.29	1068.000 ± 397.40

In the control variant, total nitrogen was identified in quantities of 3.350 ± 0.29 % N_{tot} and in higher concentrations in the plants treated with nanofluids, 4.960 - 3.740 ± 0.29 % N_{tot} respectively. The highest content of total nitrogen in treated plants was identified for variant WMF 0.05% and the lowest for variant WMF 1%.

Though higher in nanofluid-treated plants, total nitrogen content was in an inverse relationship with the concentration of magnetic liquid administered.

Because of the risks it poses, nitric nitrogen is much more closely studied; its values were smaller in all nanofluid-treated variants, as compared to the control variant. Nitric nitrogen content was 3101.000 ± 397.40 ppm $N - NO_3^-$ in the control variant, and it ranged within quite close limits in the treated variants, between 1252.000 ± 397.40 ppm $N - NO_3^-$ for variant WMF 0.05% and 1068.000 ± 397.40 ppm $N - NO_3^-$ for variant WMF 1%. It is worth mentioning that the values were smaller than those of the control variant.

When we analysed the results through multiple correlations among variables, we distinguished two distinct groupings: the control, over 1.5 units on X axis away from the origin, and over 2 units away from the treated variants, outside the 95% confidence interval. The second grouping includes the nanofluid-treated variants (WMF 0.05 ÷ WMF 1%), placed 0,4 units away from the origin on the x axis, in the 95% confidence interval.

The second category of variables, namely total nitrogen and nitric nitrogen, display two directions that are distinctly different from the independent variables.

Nitric nitrogen ($N - NO_3^-$), as a determined parameter, has a geometrical position which is lateral to the 95% confidence interval. The other variable parameter, N_{tot} is geographically positioned in the confidence interval, having a tendency to come closer to the perimeter of the interval defined by the high concentration variants of nanoparticles, Fig. 1.

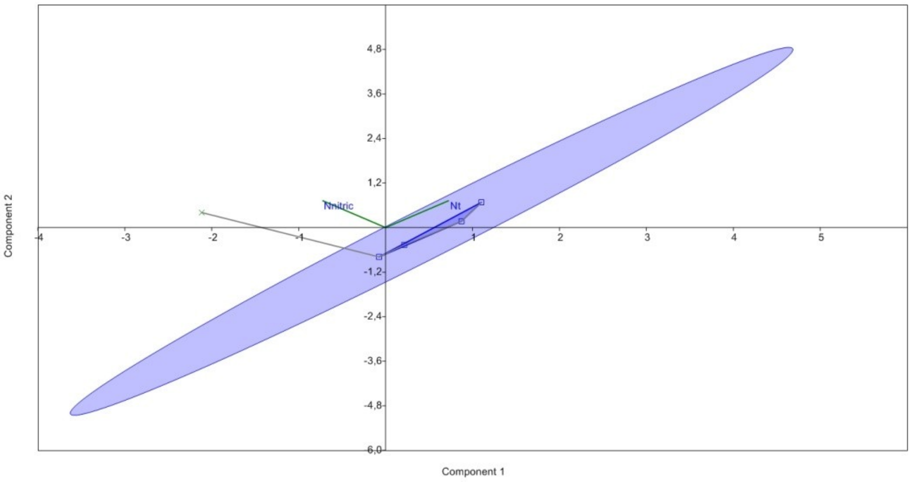

Fig. 1. Geometrical representation of correlations between the distribution of experimental variants and the total and nitric nitrogen contents in lettuce under the influence of magnetic nanofluids

Analysis of the grouping and distribution of variants based on Euclidian distances, through cluster analysis, also defined two large groups of variables: the control variant and the treated variants. The latter group is split into two other groups: one given by the lowest nanofluid concentration, WMF 0.05% and another that includes the variants with moderate-high variants, namely WMF 0.1%, WMF 0.5% and WMF 1%, as shown in Fig. 2.

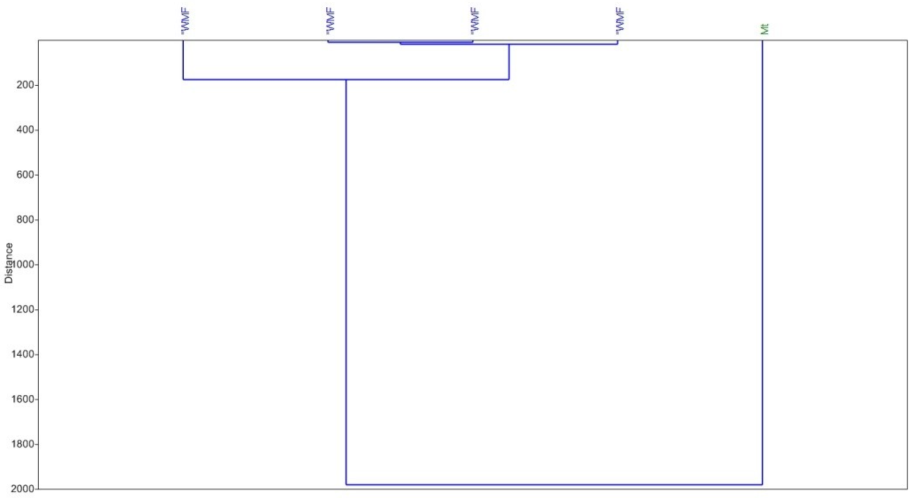

Fig. 2. Grouping of experimental variants according to Euclidian distribution, cluster analysis.

Acknowledgments

The magnetic fluid used for tests was made and provided by the Magnetic Fluid Laboratory at the National Centre for Engineering of Systems with Complex Fluids, Politehnica University, Timişoara.

Conclusions

Water-based magnetic nanofluids (WMF/H_2O), with saturation magnetization Ms - 32 Gs, influenced the total nitrogen content and the nitric nitrogen content ($N_{tot}; N - NO_3^-$) in lettuce (*Lactuca sativa,* var. capitata).

Total nitrogen is found in higher concentrations in the plants that were subjected to treatments than in the control, but in an inverse relationship with the concentration of magnetite administered.

Nitric nitrogen is lower in the treated plants as compared to the control; the decrement gradient in nitrate concentration in relation to the concentration of magnetite used is 1.16 – 0.98.

Statistical analysis of the type variance-covariance, correlations and cluster analysis place the experimental data into two groups according to the magnetite concentration and the way it affects the indices determined: the control in an independent position and the group of treated variables, with one subgroup with high magnetite concentration (WMF 0.1%, WMF 0.5% and WMF 1%) for the highest dilution WMF 0.05%.

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