CHEMICAL ENGINEERING TRANSACTIONS
VOL. 88, 2021
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.cetjournal.it
Guest Editors: Petar S. Varbanov, Yee Van Fan, Jiří J. Klemeš

ISBN 978-88-95608-86-0; **ISSN** 2283-9216
DOI: 10.3303/CET2188216

Nanopreparations Impact on Soybeans Growth and Development under Conditions of Piedmont Zone of East Kazakhstan

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The article provides the outcomes of field experiments related to studying influence of plant growth stimulant “Fullerenol” (foliar application) when soybeans are cultivated under conditions of piedmont zone of East Kazakhstan on agricultural lands. The obtained results of soybeans foliar application by fullerene derivatives C60 enabled to identify the range of its concentration that have positive effect on biometric characteristics of soybeans herbage growth and indicate the need for further researches for improvement of concentrates compositions in order to strengthen growth stimulating functions. It has been observed that leaves, stems, and roots herbage are increased on 27-30 %, and when Fullerenol concentration 0.002 g/dm^3 was used (from the entire range of concentrations), soybeans crop yield is increased by 8.51 %.

1. Introduction

The value of land as the main means of agricultural production depends on its fertility. Fertility is the ability to meet the needs of plants in nutrients, air, water, heat, biological and physical-chemical environment. Soil fertility depends on its content of nitrogen, phosphorus, potassium salts and other substances. The required ratio of the listed minerals in the soil allows farmers to obtain environmentally friendly agricultural products.
Degraded soil is a serious modern problem. Soil degradation occurs due to overuse of land, overuse of chemical fertilizers, deforestation and land clearing. The authors (Maneeintr et al., 2020) proposed the use of coal-fired power plant products in agriculture to improve soil quality. They found that flue gas desulfurization wastes can change the acidic conditions in the soil.
To develop and apply highly-effective and ecologically safe preparations for increasing productiveness and stability of agricultural crops and ecosystems is a relevant objective of modern science. Foreign (Shamsuddin et al., 2020) and national researches (Aitbaev et al., 2018) prove that when different stimulators of plants growth are used as well as biological ones, it is possible to speed up and improve seeds germinating ability and also to influence crop yield and quality of the obtained products (Arbizu-Milagro et al., 2021). According to the data of Research institute of organic agriculture (FIBL), 179 out of 230 world countries are involved into production of organic farm products (Rushchitskaya, 2019). The characteristic feature of organic farming is minimized impact on the environment and natural resources (Khasanova and Grashorn, 2015), so the term “ecological” farming is often used. In this connection the methods of “Fullerenols” plant growth regulators use, as environmentally safe preparations for soybeans cultivation by Ltd. “Research farms of oil crops” in East Kazakhstan are relevant. Basic approaches in this scientific field are in the use of biological materials exclusively, in avoiding synthetic substances for maintaining soils fertility and ecological balance and minimal environmental impact.

Paper Received: 13 May 2021; Revised: 12 September 2021; Accepted: 3 October 2021
Please cite this article as: Rakhymberdina M.Y., Sadenova M.A., Kulenova N.A., Asangaliyev Y.A., Shaimardanova B.K., Toguzova M.M., Varbanov P.S., Shaimardanov Z.K., 2021, Nanopreparations Impact on Soybeans Growth and Development under Conditions of Piedmont Zone of East Kazakhstan, Chemical Engineering Transactions, 88, 1297-1302 DOI:10.3303/CET2188216

It should be noted that carbon nanomaterials, in particular fullerenols and their derivatives are related to innovation research area in searching the alternative for pesticides, herbicides and other preparations. Fullerenols are mixtures of polyoxyhydroxylated water soluble fullerene derivatives. The researches for fullerenols impact on plants growth and development has just been initiated and there are very few works related to this issue. Fullerenols find their application in very different science and technology fields (Langa and Nierengarten, 2007). Positive impact from the use of polyoxyhydroxylated fullerenols is indicated in the work (Kole et al., 2013), where bitter melon seeds treatment by the solution resulted in increasing biomass output up to 54 %, water content – by 24 %, fruits length – up to 20 %, fruits number – by 59 %, fruits mass – by 70 %, fruits yield – up to 128 %. The work (Bityutskii et al., 2021) indicates fullerenol addition activated reaction centres of PSII in the Fe-deprived plants. The results of work suggest for the first time that fullerenol can protect cucumber plants against Fe deficiency through increased utilisation of root apoplastic Fe.

The goal of the research is to study plant growth stimulant “Fullerenol” (foliar application) impact when soybeans are cultivated under conditions of piedmont zone of East Kazakhstan on agricultural lands. In this connection carbon nanostructures (water soluble fullerene derivatives) are considered as perspective forms used in biomedicine and pharmacology. However, the mechanisms of fullerene influence on agricultural crops growth and production are not described much in literature.

To date, most of the preparations used for foliar treatment are also recommended for the treatment of plant seeds. There is a known technology for pre-sowing seed treatment with environmentally safe multicomponent polyfunctional nanosystems - nanochips, which include modified natural components (derivatives of modified minerals, active carbons, oligo-, poly- and aminoaccharides, oligochitosans and preparations based on them) (Voropaeva et al., 2014) and other physiologically active substances (Ruban et al., 2012).

2. Materials and methods

The object of the research is agricultural lands where soybeans are grown. The researches were carried out on experimental field of Ltd. “Research farms of oil crops located 7 km north from Ust-Kamenogorsk, piedmont zone of East Kazakhstan. The climate of this region is characterized by sharp continentality and weather variability. The soil of the experimental field refers to ordinary, medium-humic, medium, leached chernozems.

The plot allocated for a field experiment corresponds to the typical soil properties and climatic conditions and homogeneity in fertility. The initial stage of work when setting up a field experiment is a soil survey.

In order to define qualitative and quantitative soils composition of the considered territory, soils underwent agrochemical survey. To assess the fields fertility, samples were taken. Soils samples were taken by envelope method. WINTEX 1000S sampler was used for it. Soils sampling depth was from 0 to 0.30 m of plough-layer. Soils combined samples were taken in surface elements. The area of surface element (section) is 5 ha. One combined sample is taken from one surface element, which contains 10-25 individual samples. Then the combined sample was placed into a packing container, and information about it was indicated on the label. Collected samples further go to agrochemical laboratory to define the content of 6 basic factors: humus content, pH, total nitrogen, sulphur, phosphorus and potassium.

Chemical analysis of soil was carried out in the accredited laboratory of soils agrochemical analysis of D. Serikbaev EKTU. Humus in soil samples was defined by Tyurin method; aqueous extract pH was defined with pH-meter; the amount of total nitrogen was defined by Kjeldahl method; nitrogen concentrate in the form of nitrate was defined by ion-selective method; the amount of total phosphorus and potassium was defined by Machigin method. Field tests were carried out with the use of plant growth stimulant “Fullerenol” when soybeans were cultivated. Aqueous emulsions of nanopreparations were prepared by dissolving a certain amount of fullerenol and lysine in water. The experimental sites were treated with nanopreparation emulsion solutions from 6 to 7 a.m. The control plots were not treated with anything. Additional watering of experimental and control plots was not carried out.

3. Results and discussion

The initial stage in field test establishment is to carry out soil survey. It has been found out that mainly calcium cation predominates among the total amount of absorbed minerals. Humus content was 3.85 %, total reserves of phosphorus P (0.09-0.20 %), total nitrogen N 0.24 %. The content of mobile phosphorus P_2O_5 – 13.4 mg/100 g of soil, exchangeable potassium K_2O 70.5 mg, easy hydrolysable nitrogen was NO_3 from 9.0 to 11.5 mg/100 g of soil respectively.

According to the content of phosphorus and nitrogen, soil of experimental area refers to medium-saturated soil, according to the content of potassium, it refers to high-saturated soils. Before soybeans dropping, preceding crop grown on this field was maize.

Soil of experimental soil was worked according to the type of early plough with the use of agricultural technological tools for working the land – combined multipurpose aggregates AKM-6,3 VI for 10 - 21 cm depth. According to technological requirements in crop production, soybeans dropping was carried out by sowing machine «Kuzbass-D». Basing on the obtained experimental data, an agrochemical map of agricultural areas was developed. The agrochemical map is an accurate (attached to the coordinate system), easy-to-handle, and qualitative map chart of fields comprising the results of laboratory analyses (Figure 1).

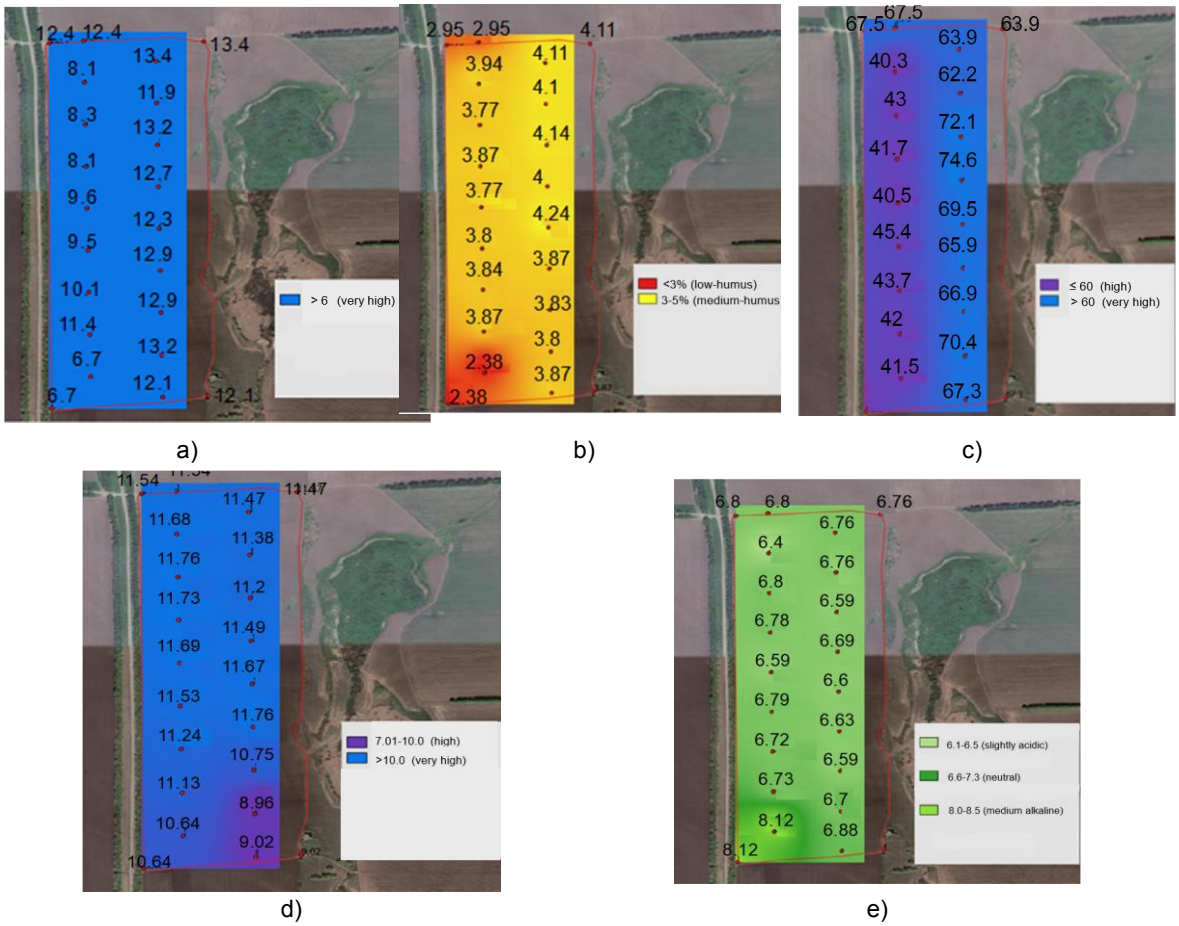

Figure 1: Agrochemical map charts of elements content in soil: the mapchart of soilssaturated with mobile phosphorus, mg/100 g of soil (a); the mapchart of humus content (u); the mapchart of soils saturated with exchangeable potassium, mg/100 g of soil (c); the mapchart of soils saturated with easy hydrolysable nitrogen, mg/100 g of soil (d); the mapchart of pH acidity in soils (e)

The results of agrochemical examination of soils were further used to develop agrotechnical measures and form recommendations. Fullerenol and fullerene C60 adducts were used in the research to study the effect of nanopreparations on the processes that determine net productivity, production process and growth in soybean plants. Non-root fertilizing was carried out on June 25-26, 2019 in the 1st-in the phase of the beginning of tillering-stem formation of soybean plants. Foliar application was carried during the period of soybeans stems formation. The tests were intended for 4-time replication. Plot area is 10 m^2. All records and observations were in accordance with methodology of B.A. Dospekhov's field tests (Dospekhov, 1985). Table 1 shows the names and concentrations of nanopreparations used in soybean treatments.

Weather conditions (precipitations, temperature) were observe during the experiments; there were phenol logical observations; observations over plants height dynamics, plants population dynamics, soil moisture; chemical composition of herbage. Economic efficiency was assessed on the basis of the compiled technological maps, reference-design norms in crop science taking into account prices for energy sources, seeds and many others.

Table 1: Names of nanopreparations used for soybean treatment and their concentrations

№ fields (option)	1	2	3	4	5	6	7
Nano-preparation	Control	Fullerenol + lysine	Fullerenol + lysine	Fullerenol	Fullerenol	Fullerenol	Fullerenol
Concentration of nanopreparation in emulsion, g/dm^3	0	0.005 + *0.005*	0.01+ *0.01*	0.002	0.005	0.01	*0.02*

The stimulating effect of the nanopreparations used on the growth of soybeans during non-root processing was revealed in the production conditions at the experimental sites of "Experimental Farm of Oilseeds" LLP (Table 2). Thus, it was noted that soy leaves biomass, stems, roots increased by 27-30 %.

Table 2: Results of introducing different concentrates during foliar feeding of soybeans on the experimental plot of "Experimental farm of Oilseeds" LLP

№ fields (option)	Soy weight							
	g	Deviation from reference, %	g	Deviation from reference, %	g	Deviation from reference, %	g	Deviation from reference, %
Replication	1		2		3		4	
1	289	-	264	-	319	-	221	-
2	157	-45.67	221	-16.29	318	-0.31	166	-24.89
3	199	-31.14	263	-0.38	364	+14.11	243	+9.95
4	296	+2.42	308	+16.67	351	+10.03	231	+4.52
5	118	-59.17	281	+6.44	271	-15.05	256	+15.84
6	264	-8.65	251	-4.92	266	-16.61	245	+10.86
7	116	-59.86	207	-21.59	266	-16.61	221	0

It can be seen from the diagram, that soy mass increase is observed only when fullerenol is used in concentration 0.002 g/dm^3 among the 4 s table replications (Figure 2).

Also, it should be noted that deviation of soy weight values between replications proves that there are differences in micro relief on the considered field. It is reflected firstly in slope, difference of microelements content in soil, moisture etc., all these have impact on plant growth and development. Normalized vegetation index NDVI (Vannoppen and Gobin, 2021) was used for monitoring the most important indicators of plants growth and development. NDVI is a standard index that indicates the presence and state of vegetation (relative biomass) (Komarova et al., 2016).

This index uses the contrast of two channels characteristics from the set of multispectral raster data - chlorophyll absorption by the pigment in red channel and high reflective capacity of plants in infrared (IC) channel (NIR). NDVI can be defined on the basis of space images (Shinkarenko and Malyshko, 2019) and survey materials from UAV equipped with multispectral camera.

Photographic operations resulted in determining the fields where NDVI value was higher in comparison with the control field, and that can be seen from aerial images (Figure 3).

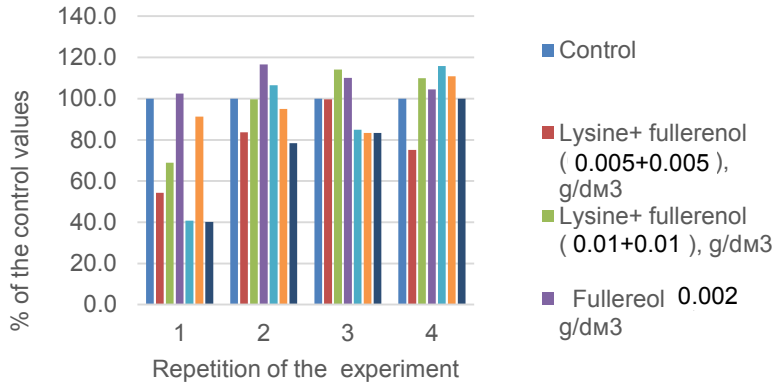

Figure 2: The diagram of soy mass increase when different options of foliar application is used

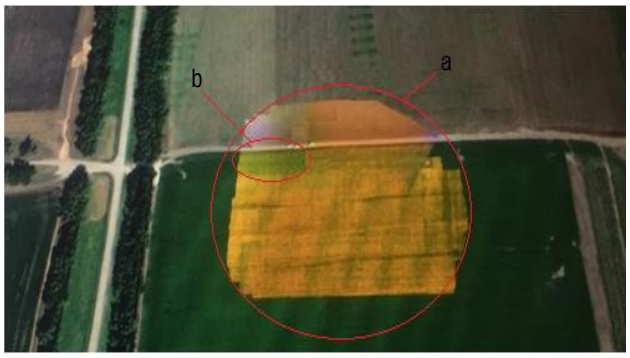

Figure3: Field not treated with fullerenol (a); area field treated with fullerenol (b)

If average value is considered in 4 replications, it is observed that there is increase of plants treated with fullerenol 0.002 g/dm^3 in relation to reference value (Table 3).

Table 3: Average value of soy biological mass in comparison with the reference value

The option of foliar application	Soy weight	
	Average value, g	Deviation from reference, %
Control	273.25	-
Lysine+ fullerenol (0.005 + 0.005), g/dm^3	215.5	-21.13
Lysine + fullerenol (0.01 + 0.01), g/dm^3	267.25	-2.20
Fullerenol 0.002 g/dm^3	296.5	+8.51
Fullerenol 0.005 g/dm^3	231.5	-15.28
Fullerenol 0.01 g/dm^3	256.5	-6.13
Fullerenol 0.02 g/dm^3	202.5	-25.89

4. Conclusions

The obtained results of assessment of soy foliar application with fullerene C60 enabled to identify the range of its concentration that have positive effect on biometric characteristics of soybeans herbage growth and indicate the need for further researches for improvement of concentrates compositions in order to strengthen growth stimulating functions. The option – fullerenol 0.002 g/dm^3 has the highest value in comparison with the reference,

it is 8.51 % higher (the average value is 296.5 g/dm^3) than the reference value 273.5 g/dm^3 (average value). This proves soy crop yield. It has been found out that timely pre-seeding treatment of seed grains with the preparations that provide better pest control, and plants competitiveness increase at early stages of their development, plays an important role. As a result of the development and application of new forms of drugs with a complex of useful functions based on nanomaterials of water-soluble polyhydroxylated fullerenols for the treatment of agricultural crops, it is possible to provide a significant increase in the efficiency and controllability of agricultural production of high-quality plant products.

Acknowledgements

This research has been supported by the Project IRN BR10965186 “Development and implementation of geo information support for "smart" agriculture to improve the management of the agro-industrial complex”, funded by the Science Committee of The Ministry of Education and Science of the Republic of Kazakhstan and the EU project "Sustainable Process Integration Laboratory -SPIL", project No. CZ.02.1.01/0.0/0.0/15_003/0000456 funded by EU as "CZ Operational Programme Research, Development and Education", Priority1: Strengthening capacity for quality research and the collaboration agreement with the D. Serikbayev East Kazakhstan Technical University.

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