AGROCHEMICAL CHARACTERIZATION OF A NEW RANGE OF FOLIAR FERTILIZERS

Mihalache Daniela[1], Carmen Sirbu[1], Ana-Maria Stanescu[1], Adriana Grigore[1], Nicoleta Marin[1], Mariana Iancu[1]

[1] National Research & Development Institute for Soil Science, Agrochemistry and Environment Protection Bucharest

Keywords: Foliar fertilizer, organic substances, protein hydrolysate, agrochemical tests, mineral nutrition.

ABSTRACT

In the context of a competitive and sustainable agriculture, the development of novel fertilizers with foliar application is always a challenge for both producers and users. Worldwide, a major trend in the research, development and production of organic substances fertilizers with growth-stimulating role is noticed. Thus, these new fertilizers formulas can be used in both, conventional and organic farming (especially to protect crops from climatic stress factors and to prevent or correct nutritional deficiencies). The production of fertilizers that contain natural organic compounds embedded in NPK matrix structures has increased. As organic substances are used protein hydrolysates, amino acids and algae extracts.

In this study, in order to obtain a new range of fertilizers we defined the composition of a NPK matrix with meso- and microelements (Fe, Cu, Zn, Mn, Mg, S, Co, Mo) that was subsequently embedded with protein hydrolysate of animal origin (composed of peptides, ureide and amino acids) respectively, protein hydrolysate of vegetal origin.

The new developed fertilizers were characterized and tested in the National Network for Fertilizers Testing in order to be licensed for agriculture use. The experiments were carried out for two years on different crops by foliar application in comparison to a similar NPK matrix. The obtained results showed significant production yields (in comparison to the non-fertilized control) ranging from 20% to 40% (statistically insured), as well as changes in the photosynthesis and mineral nutrition processes.

INTRODUCTION

In the context of a competitive and sustainable agriculture, the development of novel fertilizers with foliar application is always a challenge for both producers and users. Worldwide it can be noticed a major trend in the research, development and production of organic substances fertilizers with growth-stimulating role [4, 5]. The production of fertilizers that contain natural organic compounds embedded in NPK matrix structures has increased. As organic substances are used protein hydrolysates of animal origin that contain peptides, ureide and amino acids (glycine, alanine, phenylalanine, proline, oxyproline, asparagine, glutamine, arginine, histidine, lysine, serine, threonine, valine) and algae extracts [3, 7, 8].These new fertilizers formulas can be used in both, conventional and organic farming (especially to protect crops from climatic stress factors, and to prevent or correct nutritional deficiencies) [9].

In countries such as: US, Russia, China, India, Brazil, Japan etc. can be observed a rapid development of organo-mineral and organic foliar fertilizers industry (especially of those with humic acids and/or fulvic; protein hydrolysates of plant or animal origin; algae extracts and plant products; natural or synthetic chemicals with bio-stimulation role; chelates or metal complexes) [1, 2].

Regulation (EC) No 2003/2003 relating to fertilizers does not include chemical fertilizers that contain organic substances in their structure [6, 9]. Given that these products can be used in organic farming, EU countries have their own regulations in this field [3, 10].

The organic substances with bio-stimulation role influence the growth and development processes, as well as the biochemical processes [11].

To avoid the separation of meso and micro-elements in N, P, K solutions, are used substances that enhance the mobility in plant tissues and form chelates/stable complexes (EDTA, DTPA, EDDHA, HEEDTA, $C_6H_8O_7$, $C_4H_6O_6$, $C_6H_{12}O_7$, $C_4H_6O_4$, polyphosphates, lignosulfonates, humates, amino acids). The relative efficacy of these fertilizers depends on the rate and size of nutrient transport in plant [7].

MATERIAL AND METHOD

The research activity has sought for:

- The course survey of some unconventional and non-pollutant inputs as nutrient sources for crops within the frame of a sustainable agriculture;

-The increase of soil productive potential;

-The ecological protection of cropping and environment;

-The productive and energetic efficiency of a range of new ecological fertilizers;

-The productive and energetic efficiency of some natural bio-stimulators. The fertilization influences upon quantity and quality indicators, chlorophyll assimilation and mineral nutrition.

A. Experimental fertilizers

Three experimental fertilizers were developed in the Testing and Quality Control of Fertilizers Laboratory as follows:

- **NUTRIFERT** – a fertilizer with a classic NPK with meso and micronutrients matrix;
- **NUTRIFERT PLUS** - a fertilizer with a NPK with meso and micronutrients matrix that was embedded with a protein hydrolysate of animal origin. The protein hydrolysate is composed of peptides, ureide and amino acids (glycine, alanine, phenylalanine, proline, oxyproline, asparagine, glutamine, arginine, histidine, lysine, serine, threonine, valine).
- **NUTRIFERT VEGETAL** - a fertilizer with a NPK with meso and micronutrients matrix that was embedded with a protein hydrolysate of vegetal origin

Chemical characteristics of the experimental fertilizers are shown in Table 1.

Table 1

Composition of the experimental fertilizers

COMPOSITION	NUTRIFERT		NUTRIFERT PLUS		NUTRIFERT VEGETAL	
	Estimated value	Determinated value	Estimated value	Determinated value	Estimated value	Determinated value
	(g/L)		(g/L)		(g/L)	
Total nitrogen, N	120	122,51	120	121,60	215	216,79
Phosphorus,, P_2O_5	70	69,42	70	71		
Potassium, K_2O	60	60,28	60	61,60		
Boron, B	0,30	0,31	0,30	0,28	0,15	0,20
Cobalt, Co	0,01	0,001	0,01	0,01	0,005	0,005
Copper, Cu	0,20	0,24	0,20	0,21	0,15	0,12
Iron, Fe	0,50	0,52	0,50	0,48	0,30	0,35
Magnesium, Mg	0,25	0,26	0,25	0,24	0,25	0,22
Manganese, Mn	0,30	0,32	0,30	0,28	0,20	0,18
Molybdenum, Mo	0,01	0,01	0,01	0,01	0,005	0,005
Sulfur, SO_3	2,50	3,25	2,50	3,05	1,10	1,70
Zinc, Zn	0,15	0,14	0,15	0,13	0,10	0,11
Protein hydrolysate of animal origin	-	-	13,70	13,70	-	-
Free amino acids	-	-	0,64	0,64	10,50	10,50
Vegetal hydrolysate (proteins)	-	-	-	-	277	277

The agrochemical testing of the fertilizers was performed in the National Network for Fertilizers Testing for different crops in order to obtain the authorization/license and RO-ÎNGRĂȘĂMÂNT label for agriculture use and distribution in Romania in accordance with 6/22/2004 Order(Annex 1) [6].

B. Location and experimental design

The experiments presented in this study were conducted in 2014-2015 on tomato (Precos variety), apple (Idared variety), and apricot (Fortuna variety) at Vasile Adamachi Didactic and Experimental Station, USAMV Iasi (Ezăreni and Iasi field farms).

This study consisted in one factor experiments established in a randomized block design with four replications.

The soil was a hortic anthrosol. Under the condition of irrigated greenhouse this type of soil has a medium to high fertility and production potential. In orchards the soil has a medium fertility and production potential, but they can decrease when summer is excessively dry.

C. Treatments

The experiments were carried out on a soil which received no fertilization ($N_0P_0K_0$). The fertilizers were applied in form of a 5% solution, as follows:

- On tomato: two weeks after planting, before flowering, and at the begining of the ripenning.
- On apple trees: at shoot growth, after flowering, and at fruit developing.
- On apricot trees: after flowering, at fruit set, at fruit developing.

The spraying of the fertilizing solutions was made in the morning, in a wind-free atmosphere, at below 25 ^oC, using a manual pump.

RESULTS AND DISCUSSIONS

<u>Productive and energetic efficiency</u>

The productive and energetic efficiencies for tomato, apple and apricot production after foliar fertilization are presented in Tables 2 - 4.

Table 2

Productive and energetic efficiency of foliar fertilization to tomato crop

Experimental variants	**Average production** (kg/ha)	**Productive efficiency**			**Energetic efficiency** (Mcal/ha)					
		Dif. kg/ha	**%**	**Sign.**	**Output**	**Input**	**Balance**	**Energy yield**		
								Dif.	**%**	**Sign.**
Control $N_0P_0K_0$	32642	-	100	-	8813	3085	5728	-	100	-
NUTRIFERT PLUS 0,5%	44798	12156	137	xxx	12095	4838	7257	1529	127	xxx
NUTRIFERT VEGETAL 0,5%	41677	9035	128	xxx	11252	4500	6752	1024	118	xxx
NUTRIFERT 0,5%	42033	9391	129	xxx	11348	4539	6809	1081	119	xxx

DL 5% 2814 kg/ha
DL 1% 4576 kg/ha
DL 0,1% 5838 kg/ha

DL 5% 256 Mcal/ha
DL 1% 374 Mcal/ha
DL 0,1% 502 Mcal/ha

Table 3

Productive and energetic efficiency of foliar fertilization to apple tree

Experimental variants	Average production (kg/ha)	Productive efficiency			Energetic efficiency (Mcal/ha)					
		Dif. kg/ha	%	Sign.	Output	Input	Balance	Energy yield		
								Dif.	%	Sign.
Control $N_0P_0K_0$	15213	-	100	-	11410	3993	7417	-	100	-
NUTRIFERT 0,5%	20014	4801	132	xxx	15010	6004	9006	1589	142	xxx
NUTRIFERT VEGETAL	19845	4632	130	xxx	14883	5953	8930	1513	120	xxx
NUTRIFERT PLUS 0,5%	21321	6108	140	xxx	15990	6396	9594	2177	129	xxx

DL 5% 1852 kg/ha
DL 1% 2481 kg/ha
DL 0,1% 3675kg/ha

DL 5% 586Mcal/ha
DL 1% 873Mcal/ha
DL 0,1% 1036Mcal/ha

Table 4

Productive and energetic efficiency of foliar fertilization to apricot tree

Experimental variants	Average production (kg/ha)	Productive efficiency			Energetic efficiency (Mcal/ha)					
		Dif. kg/ha	%	Sign.	Output	Input	Balance	Energy yield		
								Dif.	%	Sign.
Control 1000 l/ha water	13256	-	100	-	7821	3128	4693	-	100	-
NUTRIFERT 0,5%	17700	4444	134	xxx	10443	4177	6266	1573	134	xxx
NUTRIFERT VEGETAL	16591	3335	125	xxx	9789	3915	5874	1181	125	xxx
NUTRIFERT PLUS 0,5%	18242	4986	138	xxx	10762	4304	6458	1765	138	xxx

DL 5% 1525 kg/ha
DL 1% 2463 kg/ha
DL 0,1% 3027 kg/ha

DL 5% 547Mcal/ha
DL 1% 781Mcal/ha
DL 0,1% 1063Mcal/ha

The outcome energy indicators (OUTPUT and energy balance) show higher values than those of INPUT, resulting thus significant yields as concerns the energy and crop production. As shown in Tables 2-4, the production yields obtained after fertilization for all crops were higher than those obtained for the non-fertilized control.

Quality indicators: photosynthesis

The use of foliar fertilizers to tomato (Precos variety), apple (Idared variety), and apricot (Fortuna variety) crops stimulated the photosynthetic assimilation process leading to significant yields for each assimilatory pigment, as well as of the total content of assimilatory pigments (Tables 5-7).

Table 5

Influence of foliar fertilization on the tomato leaves photosynthesis

Experimental variants	Chlorophyll a				Chlorophyll b				Carotene				Total pigments			
	mg/g	Dif.	%	sig	mg/g	Dif.	%	sig	mg/g	Dif.	%	sig	mg/g	Dif.	%	sig
Control	0,9451	-	100	-	0,7741	-	100	-	0,5968	-	100	-	2,3160	-	100	-
NUTRIFERT 0,5%	1,2589	0,3138	133	xxx	1,0410	0,2669	134	xxx	0,7908	0,1940	133	xxx	3,0907	0,7747	133	xxx
NUTRIFERT VEGETAL 0,5%	1,2488	0,3037	132	xxx	1,0324	0,2583	133	xxx	0,7834	0,1866	131	xxx	3,0646	0,7486	132	xxx
NUTRIFERT PLUS 0,5%	1,3374	0,3923	142	xxx	1,1048	0,3307	143	xxx	0,8362	0,2394	140	xxx	3,2784	0,9624	142	xxx

DL 5% 0,1006mg/g
DL 1% 0,1534mg/g
DL0,1% 0,2016mg/g

DL5% 0,0921mg/g
DL 1% 0,1407mg/g
DL0,1% 0,1733mg/g

DL 5% 0,0531mg/g
DL 1% 0,0862mg/g
DL0,1% 0,1125mg/g

DL 5% 0,2523mg/g fresh subst.
DL 1% 0,3746 mg/g fresh subst.
DL0,1% 0,5017mg/g fresh subst.

Table 6

Influence of foliar fertilization on the apple tree leaves photosynthesis

Experimental variants	Chlorophyll a				Chlorophyll b				Carotene				Total pigments			
	mg/g	Dif.	%	sig	mg/g	Dif.	%	sig	mg/g	Dif.	%	sig	mg/g	Dif.	%	sig
Control	0,7816	-	100	-	0,6245	-	100	-	0,5351	-	100	-	1,9412	-	100	-
NUTRIFERT 0,5%	1,0693	0,2877	137	xxx	0,8584	0,2339	137	xxx	0,7253	0,1902	136	xxx	2,653	0,7118	137	xxx
NUTRIFERT VEGETAL 0,5%	1,0517	0,2701	135	xxx	0,8452	0,2207	135	xxx	0,7141	0,1790	133	xxx	2,6110	0,6698	135	xxx
NUTRIFERT PLUS 0,5%	1,1351	0,3535	145	xxx	0,9162	0,2917	147	xxx	0,7712	0,2361	144	xxx	2,8225	0,8813	145	xxx

DL 5% 0,1112mg/g
DL 1% 0,1563mg/g
DL 0,1% 0,2231mg/g

DL5% 0,0981mg/g
DL 1% 0,1426mg/g
DL 0,1% 0,2057mg/g

DL 5% 0,0736mg/g
DL 1% 0,1121mg/g
DL 0,1% 0,1542mg/g

DL 5% 0,2631mg/g fresh subst.
DL 1% 0,3276 mg/g fresh subst
DL 0,1% 0,5104mg/g fresh subst

Table 7

Influence of foliar fertilization on the apricot tree leaves photosynthesis

Experimental variants	Chlorophyll a				Chlorophyll b				Carotene				Total pigments			
	mg/g	Dif.	%	sig	mg/g	Dif.	%	sig	mg/g	Dif.	%	sig	mg/g	Dif.	%	sig
Control	0,6532	-	100	-	0,5614	-	100	-	0,4754	-	100	-	1,6900	-	100	-
NUTRIFERT 0,5%	0,9108	0,2576	139	xxx	0,7760	0,2146	138	xxx	0,6540	0,1786	138	xxx	2,3408	0,6508	139	xxx
NUTRIFERT VEGETAL 0,5%	0,8580	0,2048	131	xxx	0,7339	0,1725	131	xxx	0,6150	0,1396	129	xxx	2,2069	0,5169	131	xxx
NUTRIFERT PLUS 0,5%	0,9264	0,2732	142	xxx	0,7877	0,2263	140	xxx	0,6614	0,1860	139	xxx	2,3755	0,6855	141	xxx

DL 5% 0,0771mg/g
DL 1% 0,1286mg/g
DL 0,1% 0,1664mg/g

DL5% 0,0672mg/g
DL 1% 0,0918mg/g
DL 0,1% 0,1543mg/g

DL 5% 0,0607mg/g
DL 1% 0,0842mg/g
DL 0,1% 0,1214mg/g

DL 5% 0,22501mg/g fresh subst.
DL 1% 0,3624 mg/g fresh subst.
DL 0,1% 0,5027mg/g fresh subst.

Quality indicators: mineral nutrition

The influence of foliar fertilization on mineral nutrition is summarized in Tables 8-10. The foliar fertilization improved the macronutrients content (N, P, K) involved in the foliar metabolism, with significant yields registered for all crops (tomato, apple and apricot).

Table 8

Influence of foliar fertilization on the mineral nutrition of tomato leaves

Experimental variants	Total nitrogen, Nt (%)				Total phosphorus, P_2O_5 (%)				Potassium, K_2O (%)			
	%	Dif.	%	sig	%	Dif.	%	sig	%	Dif.	%	sig
Control	0,4583	-	100	-	0,2517	-	100	-	0,2031	-	100	-
NUTRIFERT 0,5%	0,6218	0,1635	136	xxx	0,3382	0,0865	134	xxx	0,2711	0,0680	134	xxx
NUTRIFERT VEGETAL 0,5%	0,6086	0,1503	133	xxx	0,3304	0,0787	131	xxx	0,2655	0,0624	131	xxx
NUTRIFERT PLUS 0,5%	0,6605	0,2022	144	xxx	0,3618	0,1101	144	xxx	0,2890	0,0859	142	xxx

DL 5% 0,0471% DL 1% 0,0653% DL 0,1% 0,1025%

DL 5% 0,0251% DL 1% 0,0314% DL 0,1% 0,0501%

DL 5% 0,0177% DL 1% 0,0211% DL 0,1% 0,0354%

Table 9

Influence of foliar fertilization on the mineral nutrition of apple tree leaves

Experimental variants	Total nitrogen, Nt (%)				Total phosphorus, P_2O_5 (%)				Potassium, K_2O (%)			
	%	Dif.	%	sig	%	Dif.	%	sig	%	Dif.	%	sig
Control	0,4421	-	100	-	0,2362	-	100	-	0,1843	-	100	-
NUTRIFERT 0,5%	0,6119	0,1698	138	xxx	0,3296	0,0934	140	xxx	0,2533	0,0690	137	xxx
NUTRIFERT VEGETAL 0,5%	0,6023	0,1602	136	xxx	0,3243	0,0881	137	xxx	0,2493	0,0650	135	xxx
NUTRIFERT PLUS 0,5%	0,6469	0,2048	146	xxx	0,3484	0,1122	148	xxx	0,2674	0,0831	145	xxx

DL 5% 0,0616% DL 1% 0,0867% DL 0,1% 0,1253%

DL 5% 0,0153% DL 1% 0,0327% DL 0,1% 0,0514%

DL 5% 0,0211% DL 1% 0,0304% DL 0,1% 0,0423%

Table 10

Influence of foliar fertilization on the mineral nutrition of apricot tree leaves

Experimental variants	Total nitrogen, Nt (%)				Total phosphorus, P_2O_5 (%)				Potassium, K_2O (%)			
	%	Dif.	%	sig	%	Dif.	%	sig	%	Dif.	%	sig
Control	0,4726	-	100	-	0,2881	-	100	-	0,3154	-	100	-
NUTRIFERT 0,5%	0,6629	0,1903	140	xxx	0,3978	0,1097	138	xxx	0,4395	0,1241	139	xxx
NUTRIFERT VEGETAL 0,5%	0,6260	0,1534	132	xxx	0,4759	0,0878	130	xxx	0,4152	0,0998	132	xxx
NUTRIFERT PLUS 0,5%	0,6820	0,2094	144	xxx	0,4112	0,1231	143	xxx	0,4527	0,1373	135	xxx

DL 5% 0,0693% DL 1% 0,0835% DL 0,1% 0,1387%

DL 5% 0,0288% DL 1% 0,0413% DL 0,1% 0,0635%

DL 5% 0,0377% DL 1% 0,0486% DL 0,1% 0,0755%

ACKNOWLEGMENTS

The researches carried out for the elaboration of the present paper were financed by ANCSI in PN 16 07, GRISGSOL, Contract No. 16N/10.03.2016.

CONCLUSIONS

- Foliar fertilization with NUTRIFERT, NUTRIFERT PLUS and NUTRIFERT VEGETAL led to production yields, ranging from 20% to 40% (statistically insured) in comparison to the non-fertilized control for all the crops, as well as to changes in the photosynthesis and mineral nutrition processes.
- As a result of foliar fertilization, the outcome energy indicators (OUTPUT and energy balance) show higher values than those of INPUT, resulting thus significant yields as concerns the energy and crop production.
- The application of foliar fertilizers increased the quality indicators, i.e. assimilatory pigments and macronutrients (NPK) content in leaves.

BIBLIOGRAPHY

1. **Cioroianu, Tr. M., Dumitru, M., Sîrbu, C**., 2012 - Fertilizant cu hidrolizate proteice cu aplicare extraradiculară, procedeu de obţinere şi metodă de aplicare, RO 126939/2012.
2. **Cioroianu, Tr. M., Sîrbu, C.**, 2011 - Unconventional fertilizers- Extraradicular fertilizers with proteic substances, Ed. Estfalia, Bucuresti.
3. **Dorneanu, A., Dumitru, M., Cioroianu, Tr. M., Dorneanu, E., Sîrbu, C**., 2008 - *Fertilizant complex cu aplicare radiculară sau foliară și metoda de aplicare a acestuia,* RO 121814 B1/2008.
4. **Mihalache, D., Sirbu, C., Cioroianu, Tr. M., Gațe, O**., 2015 - *Fertilizers formulas with extraroot application. Physico-chemical and agrochemical characteristics*, Scientific Papers. Series A. Agronomy, Vol. LVIII, 2015 ISSN 2285-5785; ISSN CD-ROM 2285-5793.
5. **Mihalache, D., Sîrbu, C., Grigore, A., Cioroianu, Tr. M., 2014** - *Protein hydrolysates and amino-acids fertilizers – physicochemical characteristics*, Lucrări Ştiinţifice, seria Agronomie, vol. 57, Nr. 2, IAȘI, ISSN 1454-7414, pagina 47.
6. Regulation (EC) no 2003/2003 of the European Parliament and of the Council from 13 October 2003 relating to fertilisers (accessed 01.10.2016);
7. **Sîrbu, C., Cioroianu, Tr. M.,** 2011 – Caracterizarea și testarea agrochimică a unor fertilizanți extraradiculari cu substanșe humice, *Ed. SITECH, Craiova.*
8. **Sîrbu, C., Cioroianu, Tr. M., Cojocaru I., Trandafir, V., Albu, M., G.,** 2009 - *The fertilizers with the protein chelated structures with the biostimulator role*, vol. 60.
9. **Sirbu, C., Cioroianu, Tr. M., Dumitru, M.,** 2012 – *Fertlizanți cu substanțe proteice, Ed. SITECH, Craiova.*
10. **Soare, M., Cioroianu, Tr. M., Dumitru, M., Sîrbu, C., Mărin, N.**, 2012 - Fertilizant extraradicular, procedeu de obţinere şi metodă de aplicare, RO 127400/2012.
11. **Soare, M., Dana, D., Anton, I., Sârbu, C., Mihalache, D., Cioroianu, Tr. M., Mărin N.,** 2009 - The influence of nitrogen chemical sources on the penetration, uptake and distribution of nitrogen in different organs of sunflower plants, Lucrari ştiintifice, vol 52, seria Agronomie, ISSN 1454-7415.