Scientific Papers. Series A. Agronomy, Vol. LX, 2017
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

RESEARCH REGARDING THE INFLUENCE OF MINERAL FERTILIZATION ALONG WITH *Bradyrhizobium japonicum* ON SOYBEAN GRAIN YIELD (*Glycine max* (L.) Merrill), UNDER THE CONDITIONS OF SOUTH - EAST ROMANIA

Nicoleta CĂPĂȚÂNĂ, Ciprian BOLOHAN, Doru Ioan MARIN

University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, District 1, Bucharest, Romania

Corresponding author email: nicoleta.capatana@agro-bucuresti.ro

Abstract

The research was conducted over two agricultural years 2014/2015 and 2015/2016, and aimed to assess the influence of mineral fertilization and seed inoculation with nitrogen fixing bacteria Bradyrhizobium japonicum on soybean grain yield. The research was based on a split plot experiment placed on a chromic luvisoil, which was previously cultivated with maize.

The results presented in this paper were obtained by analyzing the following factors: Factor A – soybean varieties from different maturity groups: Adsoy, Orion, Carla, Darina, PR92B63; Factor B – mineral fertilization levels $N_0P_{60}K_0$ (Control), $N_0P_{60}K_0$ + foliar fertilization; $N_{45}P_{60}K_0$; $N_{45}P_{60}K_0$ + foliar fertilization; $N_{45}P_{60}K_{45}$; $N_{90}P_{60}K_{45}$; Factor C – soybean seeds inoculated with Nitragin Bac Soya (Bradyrhizobium japonicum); soybean seeds non-inoculated with Nitragin Bac Soya (Bradyrhizobium japonicum).

The average grain yield of the soybean varieties was 1898.5 kg/ha, varying from 1319.80 kg/ha (Orion) to 2483.43 kg/ha (PR92B63), for variants where the soybean seeds were inoculated with Bradyrhizobium japonicum. In variants were soybean seeds weren't inoculated with nitrogen - fixing bacteria the average grain yield was 1829.80 kg/ha, varying from 1277.41 kg/ha (Orion) to 2483.43 kg/ha (PR92B63).

Mineral fertilization generated a grain yield increase of 30.2%. Seed inoculation with nitrogen fixing bacteria brought an increase of the grain the yield of 3.76%.

Key words*: soybean, grain yield, mineral fertilizer, Bradyrhizobium japonicum*.

INTRODUCTION

Soybean *Glycine max* (L.) Merrill is a valuable crop, highly appreciated due to seeds' high content in proteins 40% and oil 20 % (Mello Filho, 2005; Clemente, 2009; Subramanian, 2013). The agronomic importance of the crop is sustained by both, crop nutritional value and its ability to fix the molecular nitrogen from the atmosphere (Popescu, 2008).

Biological nitrogen fixation (BNF) has a direct contribution to improve the soil fertility (Cass, 1994; Tago, 2011; Matsumiya, 2013), replaces the use of synthetic nitrogen fertilizers (Peoples, 2009; Canfield, 2010; Kovačević, 2011) and has a positive influence on crops' grain yields (Van Kessel, 2000). Soybean crop has a high demand for nitrogen (N), thus for achieving 1000 kg grains, the crop is requiring 93 - 104 kg N (Diaconescu, 1971; Deac, 2013).

At the beginning of the growing season, soybean plants are getting about 50% of the required nitrogen (N) from the soil (Deac, 2013). After the installation of the symbiosis between plants' roots and nitrogen-fixing bacteria, *Bradyrhizobium japonicum* (Cheţan, 2014), the rest of the required nitrogen (N) is achieved from the atmosphere (Deac, 2013). Specialized literature raises a lot of controversial results regarding the soybean crop nutrition with nitrogen (N) under field conditions (Kaschuk, 2016) mainly because of the plant's ability to acquire the required amounts of nitrogen from atmosphere (Salvagiotti, 2008; Caliskan, 2008). Some researches showed that nitrogen (N) fertilization is not necessary if soybean seeds are inoculated with *Bradyrhizobium japonicum* (Freeborn, 2001; Schmitt, 2001; Sogut, 2006). Other results showed that biological nitrogen fixation (BNF) is not enough, due to the fact that it can't supply the full requirements of the

crop for nitrogen (N) (Wesley, 1998; Mahna, 2005; Caliskan, 2008, Janagard, 2013), thus it is required to apply mineral nitrogen (N) fertilizers to improve yield and quality of the harvest (Ray, 2006; Osborne, 2006; Gan, 2003; Caliskan, 2008).

Essential nutrients, nitrogen (N), phosphorus (P) and potassium (K) are playing a crucial role in increasing the productive potential of the soybean crop (Mohamed, 2011; Janagard, 2013). Applying nitrogen (N) fertilizers as a starter has a positive influence on soybean grain yields (Starling, 2000; Osborne, 2006; Janagard, 2013). Increases in production between 28% - 30% were reported when mineral nitrogen (N) was applied in stages R1-R3 (blooming) (Brevedan, 1978; Osborne, 2006).

Maximum nitrogen (N) requirements were recorded by the soybeans plants in reproductive phase (Hungria, 2006; Kaschuk, 2010; Kaschuk, 2016) and in the pods filling stage. An important role in soybean plants nutrition (Afzal, 2010; Jarecki, 2016) is owned by the availability of the macro and micro elements applied to soil or as a foliar fertilizer (Freeborn, 2001; Jarecki, 2016). Along with nitrogen (N), phosphorus (P) and potassium (K) are contributing efficiently in increasing the soybean grains yields.

Phosphorus has a positive influence on the nitrogen (N) biological fixation by increasing the number of active nodules per plant (Deac, 2013) and it improves soybean crop yield under drought conditions (Zheng, 2010; Kovačević, 2011).

Researches carried out in the West of Romania, showed the positive influence of phosphorus (P) on soybean grain yield. Applied in doses of 40 kg/ha and 80 kg/ha phosphorus (P) generated a growth between 183 kg/ha and 219 kg/ha compared to unfertilized.

Potassium (K) has a role in stimulating the plants in the vegetative growth period, increasing the plants' resistance to drought, pests, diseases and fall (Imas, 2007; Kovačević, 2011). It also has a major contribution in synthesizing the fats and depositing them in the grains (Giosan, 1986).

Potassium (K) fertilizers are more efficient when they are applied along with nitrogen (N), or with nitrogen (N) and phosphorus (P), KxN and KxNP (Burlacu, 2007). Some studies reported limitations of soybean grain yield (Imas, 2007) and a poor quality of the harvest due to the usage of potassium (K) fertilizers in inappropriate doses (Imas, 2007; Gill, 2008; Kovačević, 2011).

Absorption and assimilation of mineral fertilizers from the soil by soybean plants are highly dependent on climatic conditions during the growing season (Ranđelović, 2009; Mandić, 2015).

For correcting the nutritional deficiencies encountered by the plants during the vegetation period is recommended to apply foliar fertilizers (Ranđelović, 2009; Mandić, 2015). Application of urea as a foliar fertilizer at the beginning of the reproductive period (R2-R3) determined increases of soybean grain yields of 6-6.8% (Oko, 2003).

The purpose of this research was to determine the influence of mineral fertilization along with nitrogen fixing bacteria *Bradyrhizobium japonicum* on the grain yield of some soybean varieties, from different maturity groups *Glycine max* (L.) Merrill, in the field conditions of South-East Romania.

MATERIALS AND METHODS

The experiment was conducted at Moara Domneasca Didactic Farm, Ilfov County – (44°29'33''N, 26°15'20"E) during two agricultural years 2014/2015 - 2015/2016, placed on a chromic luvisoil. The research was based on the split plot method with three replications and the following factors tested:

Factor A – soybean variety: a_1 – Adsoy; a_2 – Orion; a_3 – Carla; a_4 – Darina;
a_5 - PR92B63;

Factor B – fertilization treatment with the following graduations: b_1 - $N_0P_{60}K_0$ (Control); b_2 - $N_0P_{60}K_0$ + Hortifor (foliar fertilizer); b_3 - $N_{45}P_{60}K_0$;b_4 - $N_{45}P_{60}K_0$ + Hortifor (foliar fertilizer); b_5 - $N_{45}P_{60}K_{45}$; b_6 - $N_{90}P_{60}K_{45}$;

Factor C — seeds inoculation before sowing: c_1 - inoculated seeds with Nitragin Bac Soya (*Bradyrhizobium japonicum*); c_2 – non-inoculated seeds.

Soybean varieties were sown at the distance of 50 cm between rows on 16th of April 2015 and on 9th of April 2016. Before sowing the

soybean seeds were inoculated with Nitragin Bac Soya in a dose of 300 g/ha.
Seedbed preparation was made one day before sowing at 5-6 cm depth, using a pre-sowing combinator. Fertilizers were applied at the seedbed preparation and in vegetation. Foliar fertilization was made with Hortifor (N 30%; P_2O_5 20%; K_2O 10%; Fe 0,04%; Mn 0,025%; Cu 0,015%, Mo 0,001%), at 62 and 77 days after sowing in 2014/2015, and 67 and 84 days after sowing in 2015/2016.
In both years of research weeds were controlled in pre-emergence using the herbicide Dual Gold (1.5 l/ha) and after emergence with Basagran (2 l/ha) and Pantera (1.2 l/ha). The control of pests (*Tetranychus urticae)* was done using the insecticide Envidor 240 SC in a dose of 0.3 l/ha. In both years of experimentation the harvesting date for soybean varieties used in the research was different due to each variety maturity:
a_1 – Adsoy 0000, 17th August 2015 (123 days after showing) and 12th August 2016 (125 days after showing);
a_2 – Orion 0, 17th August 2015 (123 days after showing) and 17th August 2016 (125 days after showing);
a_3 – Carla 000 (ISTIS 2015), 07th September 2015 (144 days after showing); 10th September 2016 (154 days after showing);
a_4 – Darina 00, 07th September 2015 (144 days after showing) 2015; 10th September 2016 (154 days after showing);
a_5 – PR92B63 0, 19th October 2015 (186 days after showing); 21th October 2016 (195 days after showing).

Varieties belonging to different maturity group like Carla 000, and Darina 00, were harvested at the same date in the both years of research, 144 days after sowing in 2015 and 154 days after sowing in 2016 and for Orion 0, and Adsoy 0000 the harvest date was the same only in 2016, 125 after sowing.

RESULTS AND DISCUSSIONS

Variety influence on soybean grain yield, Moara Domnească

On average, in two years of research in variants where the soybean seeds were inoculated before sowing with Nitragin Bac Soya grain yield recorded was 1898.51 kg/ha, Table 1.
Carla, Darina and PR92B63 varieties recorded on average, positive grain yields ranging from + 3.4% to + 5.3% compared to Control (Average variety), without being statistically assured, Table 1. Adsoy and Orion varieties recorded on average the smallest grain yield values, representing 92.9% and 95% compared to Control. The highest grain yields were recorded in variants fertilized with $N_{45}P_{60}K_{45}$ + Nitragin Bac Soya and in $N_{90}P_{60}K_{45}$ + Nitragin Bac Soya with 115.29 kg/ha and 140.82 kg/ha.
Orion variety fertilized $N_{90}P_{60}K_{45}$ + Nitragin Bac Soya recorded 93.6% of Control, the difference of 155.29 kg/ha being distinct significantly negative.
The minimum grain yield was 1319.80 kg/ha (Orion, $N_0P_{60}K_0$ + Nitragin Bac Soya) and maximum was 2551.70 kg/ha (PR92B63, $N_{90}P_{60}K_{45}$ + Nitragin Bac Soya) statistically assured for both varieties (Table 1).

Table 1. Variety influence on soybean grain yield (GY, kg/ha) in variants inoculated with Soybean Nitragin Bac Soya, Average 2015-2016

	ADSOY		ORION		CARLA		DARINA		PR92B63		Average - Variety	
	GY kg/ha	Diff. %	GY kg/ha	Diff. %	GY kg/ha	Diff. %	GY kg/ha	Diff. %	GY kg/ha	Diff. %	GY kg/ha	%
$N_0P_{60}K_0$	1406.54^{ns}	96.1	1319.80^{0}	90.2	1533.01^{ns}	104.7	1523.09^{ns}	104.1	1535.94^{ns}	104.9	1463.68	Ct
$N_0P_{60}K_0$ + F	1486.34^{ns}	96.3	1397.93^{0}	90.6	1604.64^{ns}	104.0	1597.20^{ns}	103.5	1630.83^{ns}	105.7	1543.39	Ct
$N_{45}P_{60}K_0$	1705.22^{ns}	95.1	1675.93^{0}	93.4	1832.90^{ns}	102.2	1868.54^{ns}	104.2	1885.49^{ns}	105.1	1793.62	Ct
$N_{45}P_{60}K_0$+F	1825.05^{ns}	95.2	1813.25^{ns}	94.6	1956.68^{ns}	102.1	1977.50^{ns}	103.2	2008.84^{ns}	104.8	1916.26	Ct
$N_{45}P_{60}K_{45}$	2130.14^{0}	94.1	2114.86^{0}	93.4	2349.58^{ns}	103.8	2343.08^{ns}	103.5	2378.53*	105.1	2263.24	Ct
$N_{90}P_{60}K_{45}$	2265.31^{0}	94.0	2255.59^{00}	93.6	2496.20^{ns}	103.5	2485.64^{ns}	103.1	2551.70*	105.8	2410.89	Ct
Avg.	1803.10^{ns}	95.0	1762.89^{0}	92.9	1962.17^{ns}	103.4	1965.84^{ns}	103.5	1998.56^{ns}	105.3	1898.51	Ct
LSD 5% 110.18; LSD 1% 153.70; LSD 0.1% 216.68												
*Note: Ct – control, ns – not significant, * positive significance, 0 negative significance, F - Hortifor*												

In variants where only mineral fertilizers were applied, the average grain yield of varieties was 1829.80 kg/ha, lower with 68.71 kg/ha compared with variants where the seeds were inoculated with Nitragin Bac Soya before sowing (Table 2).
Compared to Control for the varieties Carla, Darina and PR92B63 the average yields increases were of 68.71 kg/ha (3.8%), 63.96 kg/ha (3.5%) and 90.96 kg/ha (5%) (Table 2). Orion and Adsoy had yield decreases between -9.1% and -3.4% (Table 2), compared with the average grain yield recorded by the tested varieties.

In variants fertilized with $N_{90}P_{60}K_{45}$ and $N_{45}P_{60}K_{45}$ Orion recorded a grain yield of 2063.27 kg/ha and 2194.79 kg/ha, with a difference distinctly negative compared to Control.
The maximum grain yield was achieved by PR92B63, 2483.43 kg/ha, in variants fertilized with $N_{90}P_{60}K_{45}$ and the lowest value was recorded by Orion in $N_0P_{60}K_0$, 1277.41 kg/ha. Compared to Control varieties recorded on average grain yield differences between -131.85 kg/ha and +90.96 kg/ha, Table 2.

Table 2. Variety influence on soybean grain yield (GY, kg/ha), in variants non-inoculated with Nitragin Bac Soya
Average 2015/2016

	ADSOY		ORION		CARLA		DARINA		PR92B63		Average – Variety	
	GY Kg/ha	%	GY Kg/ha	%	GY Kg/ha	%	GY Kg/ha	%	GY Kg/ha	%	GY Kg/ha	%
$N_0P_{60}K_0$	1358.21 ns	96.6	1277.41 0	90.9	1464.62 ns	104.2	1444.57 ns	102.8	1482.55 ns	105.5	1405.47	Ct
$N_0P_{60}K_0$ + F	1404.06 ns	95.1	1366.94 0	92.5	1535.58 ns	104.0	1523.47 ns	103.1	1555.16 ns	105.3	1477.04	Ct
$N_{45}P_{60}K_0$	1605.80 ns	95.3	1562.62 0	92.8	1746.43 ns	103.7	1744.23 ns	103.5	1764.34 ns	104.7	1684.68	Ct
$N_{45}P_{60}K_0$+F	1767.04 ns	95.5	1722.63 0	93.1	1922.55 ns	103.9	1910.51 ns	103.3	1927.18 ns	104.2	1849.98	Ct
$N_{45}P_{60}K_{45}$	2088.94 0	94.3	2063.27 00	93.2	2299.79 ns	103.8	2310.48 ns	104.3	2311.88 ns	104.4	2214.87	Ct
$N_{90}P_{60}K_{45}$	2204.11 0	93.9	2194.79 00	93.5	2422.07 ns	103.2	2429.29 ns	103.5	2483.43 *	105.8	2346.74	Ct
Avg.	1738.02 ns	95.0	1697.95 0	92.8	1898.51 ns	103.8	1893.76 ns	103.5	1920.76 ns	105.0	1829.80	Ct

LSD 5% 108.76; LSD 1% 150.61; LSD 0.1% 209.81
*Note: Ct – control, ns – not significant, * positive significance, 0 negative significance, F – Hortifor*

Fertilization influence on soybean grain yield, Moara Domneasca

Table 3 presents the influence of fertilization on the grain yield, compared to Control $N_0P_{60}K_0$ + Bac Nitragin Soya.
The five varieties tested recorded an average grain yield increase between 5.4% and 64.7%. Fertilization with nitrogen doses of 45 kg/ha and 90 kg/ha, the usage of NPK complex fertilizers and foliar fertilizers had a very significant positive influence on the soybean varieties grain yield.
Regarding the treatment with $N_0P_{60}K_0$ + Hortifor + Nitragin Bac Soya the grain yield varied from 71.63 kg/ha (4.7%) and 94.88 kg/ha (6.2%), statistically unassured.
Fertilization with nitrogen in doses of 90 kg/ha brought yield increases of 858.76 kg/ha (Adsoy) and 1015.76 kg/ha (PR92B63) compared with Control (Table 3).
For variants where applied foliar treatments and nitrogen fertilizers in doses of 45 kg/ha were applied the average increase of yields was of 54.6%.
On average the mineral fertilizer along with Nitragin Bac Soya generated a grain yield increase of 29.7% for the soybean varieties tested at Moara Domneasca Didactic Farm.

Table 3. Fertilization influence on soybean varieties grain yields (GY, kg/ha) in variants inoculated with Nitragin Bac Soya, Average 2015-2016

	ADSOY		ORION		CARLA		DARINA		PR92B63		Average - Variety	
	GY Kg/ha	%	GY Kg/ha	%	GY Kg/ha	%	GY Kg/ha	%	GY Kg/ha	%	GY Kg/ha	%
$N_0P_{60}K_0$	1406.54^{ns}	Ct.	1319.80^{ns}	Ct.	1533.01^{ns}	Ct.	1523.09^{ns}	Ct.	1535.94^{ns}	Ct.	1463.68^{ns}	Ct.
$N_0P_{60}K_0$ + F	1486.34^{ns}	105.7	1397.93^{ns}	105.9	1604.64^{ns}	104.7	1597.20^{ns}	104.9	1630.83^{ns}	106.2	1543.39^{ns}	105.4
$N_{45}P_{60}K_0$	1705.22***	121.2	1675.93***	127.0	1832.90***	119.6	1868.54***	122.7	1885.49***	122.8	1793.62***	122.5
$N_{45}P_{60}K_0$+F	1825.05***	129.8	1813.25***	137.4	1956.68***	127.6	1977.50***	129.8	2008.84***	130.8	1916.26***	130.9
$N_{45}P_{60}K_{45}$	2130.14***	151.4	2114.86***	160.2	2349.58***	153.3	2343.08***	153.8	2378.53***	154.9	2263.24***	154.6
$N_{90}P_{60}K_{45}$	2265.31***	161.1	2255.59***	170.9	2496.20***	162.8	2485.64***	163.2	2551.70***	166.1	2410.89***	164.7
Avg.	1803.10***	128.2	1762.89***	133.6	1962.17***	128.0	1965.84***	129.1	1998.56***	130.1	1898.51***	129.7
*LSD 5% 98.23; LSD 1% 130.33; LSD 0.1% 168.89; Note: Ct – control, ns – not significant, * positive significance, 0 negative significance; F - Hortifor*												

Table 4. Fertilization influence on soybean varieties grain yield (GY kg/ha) in variants non-inoculated with Nitragin Bac Soya (Moara Domnească, Average 2014-2015)

	ADSOY		ORION		CARLA		DARINA		PR92B63		Average – Variety	
	GY Kg/ha	%	GY Kg/ha	%	GY Kg/ha	%	GY Kg/ha	%	GY Kg/ha	%	GY Kg/ha	%
$N_0P_{60}K_0$	1358.21	Ct.	1277.41	Ct.	1464.62	Ct.	1444.57	Ct.	1482.55	Ct.	1405.47	Ct.
$N_0P_{60}K_0$ + F	1404.06***	103.4	1366.94***	107.0	1535.58***	104.8	1523.47***	105.5	1555.16***	104.9	1477.04***	105.1
$N_{45}P_{60}K_0$	1605.80***	118.2	1562.62***	122.3	1746.43***	119.2	1744.23***	120.7	1764.34***	119.0	1684.68***	119.9
$N_{45}P_{60}K_0$+F	1767.04***	130.1	1722.63***	134.9	1922.55***	131.3	1910.51***	132.3	1927.18***	130.0	1849.98***	131.6
$N_{45}P_{60}K_{45}$	2088.94***	153.8	2063.27***	161.5	2299.79***	157.0	2310.48***	159.9	2311.88***	155.9	2214.87***	157.6
$N_{90}P_{60}K_{45}$	2204.11***	162.3	2194.79***	171.8	2422.07***	165.4	2429.29***	168.2	2483.43***	167.5	2346.74***	167.0
Avg.	1738.02***	128.0	1697.95***	132.9	1898.51***	129.6	1893.76***	131.1	1920.76***	129.6	1829.80***	130.2
LSD 5% 109.62 kg/ha; LSD 1% 145.43 kg/ha; LSD 0.1% 188.46 kg/ha *Note: Ct – control, ns – not significant, * positive significance, 0 negative significance, F – Hortifor*												

For non-inoculated variants, Table 4, the average grain yield recorded values between 1405.47 kg/ha ($N_0P_{60}K_0$, Ct.) and 2346.74 kg/ha ($N_{90}P_{60}K_{45}$).

Treatment with complex fertilizers $N_{90}P_{60}K_{45}$ determined a very significantly positive increase in yield, of 845.90 kg/ha (Adsoy) and 1000.88 kg/ha (PR92B63) (Table 4). All the tested varieties recorded increased grain yields very significantly positive between 45.85 kg/ha (+3.4%) and 89.53 kg/ha (+7%), in variants treated with $N_0P_{60}K_0$ + Hortifor. In variants treated with $N_{45}P_{60}K_0$+Hortifor grain yields varied compared to control from +30% to +34.9% (Table 4). The positive influence of fertilization on the grain yield was significant for all the five soybean varieties tested.

Inoculation with Bradyrhizobium japonicum (Nitragin Bac Soya) influence on soybean grain yields, Moara Domneasca

Inoculation with Nitragin Bac Soya before sowing, for the five varieties tested in South-East of Romania between 2014/2015 - 2015/2016 brought grain yield increases between 2.18% and 6.47%. The data in Table 4 highlights the influence of the treatment with Nitrogen Bac Soya inoculant, *Bradyrhizobium japonicum*, compared to non-inoculated, Control (Ct.). On average the seed inoculation with Nitragin Bac Soya, with nitrogen - fixing bacteria *Bradyrhizobium japonicum* generated a grain yield increase of 68.71 kg/ha (3.76%), statistically assured (Table 5).

Table 5. Mineral fertilization along with Nitragin Bac Soya inoculant influence on soybean varieties grain yield (GY kg/ha) (Moara Domnească, Average 2014-2015)

	Non – Inoculated (a_1)			Inoculated (a_2)		Diff.	
	GY Kg/ha	%	Signf.	GY Kg/ha	%	a2-a1 Kg/ha	Signf.
$N_0P_{60}K_0$	1405.47	100.00	Ct	1463.68	104.14	58.21	-
$N_0P_{60}K_0$ + F	1477.04	100.00	Ct	1543.39	104.49	66.34	+
$N_{45}P_{60}K_0$	1684.68	100.00	Ct	1793.62	106.47	108.93	++
$N_{45}P_{60}K_0$+F	1849.98	100.00	Ct	1916.26	103.58	66.28	+
$N_{45}P_{60}K_{45}$	2214.87	100.00	Ct	2263.24	102.18	48.37	-
$N_{90}P_{60}K_{45}$	2346.74	100.00	Ct	2410.89	102.73	64.15	+
Avg.	1829.80	100.00	Ct	1898.51	103.76	68.71	+
LSD 5% 58.94 kg/ha; LSD 1% 82.53 kg/ha; LSD 0.1% 121.22 kg/ha *Note: Ct – control, ns – not significant, * positive significance, 0 negative significance, F – Hortifor*							

The five varieties tested recorded a maximum grain yield statistically assured of 108.93 kg/ha (6.4%), and a minimum of 48.37 kg/ha, uninsured statistically.

Correlation between doses of active fertilizers on soybean grain yield

The grain yield of the five varieties tested was strongly influenced by the mineral fertilizers and by Nitragin Bac Soya inoculant, *Bradyrhizobium japonicum*.

The high positive correlation between fertilizer doses (a.s.) is supported by a coefficient with the value r = 0.98635, the increased grain yields are due in a proportion of 98% to the doses of active substance fertilizers applied, supported by the determination coefficient R^2 = 0.9729 (r*** = 0.98635 very significant positive) (Figure 1).

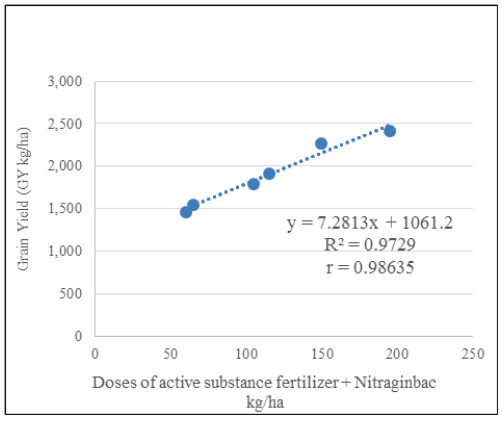

Figure 1. Correlation between the grain yield (GY kg/ha) of soybeans varieties and the doses of active substance fertilizers along with Nitragin Bac Soya (kg/ha)

Influence of active doses of fertilizer on the grain yields for the tested varieties (Figure 2) in non-inoculated variants is supported by a correlation coefficient with a value r*** = 0.9715 very significant positive.

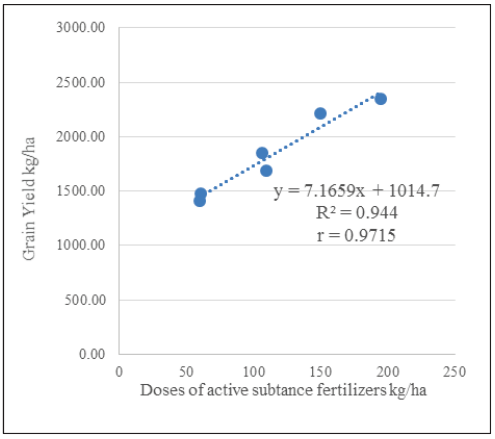

Figure 2. Correlation between the grain yield (GY kg/ha) of soybeans varieties and the doses of active substance (kg/ha) in variants non-inoculated, Nitragin Bac Soya

The relationship between grain yield and the amount of active substance applied is described by the regression line having a positive slope (Figure 2).

The increased grain yield was influenced in a proportion of 94% by the doses of active substance fertilizers applied, supported by the determination coefficient R^2 = 0.944.

CONCLUSIONS

Research conducted in South - East of Romania at Moara Domneasca Didactic Farm, Ilfov

County, during two agricultural years 2014/2015 - 2015/2016 highlights the positive influence of different doses of fertilizers along with inoculation with *Bradyrhizobium japonicum*, on the grain yields of five soybean varieties from different maturity groups.

Mineral fertilization along with inoculation with Nitragin Bac Soya, *Bradyrhizobium japonicum*, generated grain yields between 1319.80 kg/ha (Orion, $N_0P_{60}K_0$ + Nitragin Bac Soya) - 2551.70 kg/ha (PR92B63, $N_{90}P_{60}K_{45}$ + Nitragin Bac Soya). For non-inoculated variants, the grain yields ranged between 1277.41 kg/ha (Orion, $N_0P_{60}K_0$) - 2483.43 kg/ha (PR92B63, $N_{90}P_{60}K_{45}$).

For variants fertilized with $N_{45}P_{60}K_0$ + Nitrogen Bac Soya the five varieties tested recorded an average increase of grain yield of 108.93 kg/ha, compared with non-inoculated variants. Inoculation with Nitragin Bac Soya, nitrogen - fixing bacteria *Bradyrhizobium japonicum* generated a grain yield increase of 68.71 kg/ha (3.76%), statistically assured.

REFERENCES

Afzal A., Bano A., Fatima M., 2010. "Higher soybean yield by inoculation with N-fixing and P-solubilizing bacteria." *Agronomy for Sustainable Development 30* 487-495.

Brevedan R.E., Egli D.B., Leggett. J.E., 1978. "Influence of N nutrition on flower and pod abortion and yield of soybeans." *Agronomy journal, 70(1)* 81-84.

Burlacu G., Popescu. A., Maravela. V., 2007. "Rezultate ale cercetărilor in domeniul folosirii raționale a îngrășămintelor." *I.N.C.D.A. Fundulea, VOL. LXXV. Fertilizarea și nutriția plantelor. Volum Jubiliar* 287-307.

Caliskan S., Ozkaya I., Caliskan M., E., Arslan M. 2008. "The effects of nitrogen and iron fertilization on growth, yield and fertilizer use efficiency of soybean in a Mediterranean-type soil." *Field Crops Research, 108(2)* Field Crops Research, 108(2), 126-132.

Cass A., Gusli. S., Mac D., 1994. "Sustainability of Soil Structure Quality in Rice Paddy-Soya-Bean Cropping Systems in South Sulawesi Indonesia." *Soil and Tillage Research 31(4)* 339-52.

Cheţan F., Rusu T., Chetan C., Simon A., Ignea M., Deac V., 2014. "Rezultate de producţie obţinute la soia în sistemul de lucrări minime ale solului în perioada 2007-2012, la S.C.D.A. Turda." *I.N.C.D.A. Fundulea VOL. LXXXI* 216-226.

Clemente T.E., Cahoon E.B., 2009. "Soybean oil: genetic approaches for modification of functionality and total content." *Plant physiology, 151(3)* 1030-1040.

Deac V., Rotar I., Mălinaș A., 2013. "Basic Fertilization With Mineral Fertilizers in Soybean crop." *Bulletin UASMV serie Agriculture 70(1)/2013* 218-222.

Diaconescu O., Miclea E., 1971. *Soia.* Bucureşti: Ceres.

Freeborn J.R., Holshouser., D.L. Alley M.M., Powell N.L., Orcutt D.M., 2001. "Soybean yield response to reproductive stage soil-applied nitrogen and foliar-applied boron." *Agronomy Journal, 93(6)* 1200-1209.

Galloway J.N., Schlesinger W.H., Levy H., Micaels A., Schnoor J.L., 1995. "Nitrogen fixation: Atmospheric enhancement-environmental response." *Global Biogeochem Cycles, Vol. 9* 235-252.

Gan Y., Stulen I., Van Keulen H., Kuiper P.J. 2003. "Effect of N fertilizer top-dressing at various reproductive stages on growth, N 2 fixation and yield of three soybean (Glycine max (L.) Merr.) genotypes." *Field Crops Research, 80(2)* 147-155.

Gill M.S., Singh V.K., Shukla A.A, 2008. "Potassium Management for Enhancing. Productivity in Soybean-based Cropping System." *Indian J. of Fertilizers, Vol. 4* 13-22.

Giosan N., Nicolae, I., Sin Gh., 1986. *Soia.* Bucureşti: Ed. Academiei Române.

Hungria M., Franchini J.C., Campo R.J., Crispino C.C., Moraes J.Z., Sibaldelli R.N., Arihara J., 2006. "Nitrogen nutrition of soybean in Brazil: contributions of biological N2 fixation and N fertilizer to grain yield." *Can. J. Plant Sci., 86* 927–939.

Imas P., Magen H., 2007. "Role of potassium nutrition in balanced fertilization for soybean yield and quality-Global perspective." *World, 92(220.55)* 2-38.

ISTIS. 2015. *Catalogul oficial al soiurilor de plante de cultura din Romania.* Bucuresti: I.S.T.I.S.

Janagard M.S., Raei Y., Gasemi G.K., Aliasgarzad N. 2013. "Soybean response to biological and chemical fertilizers." *International Journal of Agriculture and Crop Sciences, 5(3)* 261.

Jarecki W., Buczek J., Bobrecka-Jamro D. 2016. "Response of soybean (Glycine max (L.) Merr.) to bacterial soil inoculants and foliar fertilization." *Plant Soil and Enviroment, 62(9)* 422-427.

Kaschuk G, Hungria. M., Leffelaar P.A., Giller K.E., Kuyper T.W., 2010. "Differences in photosynthetic behaviour and leaf senescence of soybean (Glycine max [L.] Merrill) dependent on N2 fixation or nitrate supply." 60-69.

Kaschuk G., Nogueira M.A., de Luca., M.J., Hungria M., 2016. "Response of determinate and indeterminate soybean cultivars to basal and topdressing N fertilization compared to sole inoculation with Bradyrhizobium." *Field Crops Research, 195* 21-27.

Kinugasa T., Takashi Sato, T., Oikawa S., Hirose T., 2012. "Demand and supply of Nin seed production of soybean (Glycine max) at different N fertilization levelsafter flowering." *J. Plant Res. 15* 275-281.

Kovačević V., Sudarić A., Antunović M., 2011. *Mineral nutrition.* Croatia: InTech Publisher.

Mahna S.K., 2005. "Soybean cultivation and BNF in China. Nitrogen Fixation in Agriculture, Forestry, Ecology and the Environment." 43-66. Netherlands, 2005: Springer.

Mandić V., Simić A., Krnjaja V., Bijelić Z., Tomić Z., Stanojković A., Ruzić-Muslić D., 2015. "Effect of foliar fertilization on soybean grain yield." *Biotechnology in Animal Husbandry, 31(1)* 133-143.

Matsumiya Y., Horii S., Matsuno T., Kubo M., 2013. *Soybean as a Nitrogen Supplier.* Croatia: INTECH Open Access Publisher.

Mello Filho O.L.D, Sediyama C.S., Moreira M.A., Reis M.S., Massoni G.A., Piovesan N.D. 2005. "Grain yield and seed quality of soybean selected for high protein content." *Pesquisa Agropecuária Brasileira, 39(5)* 445-450.

Mohamed A.M., Ananthi T., Subramanian K.S., Muthukrishnan P., 2011. "Influence of mycorrhiza, nitrogen and phosphorus on growth, yield and economics of hybrid maize." *Madras Agric. J. 98 (1-3)* 62-66.

Oko B.F.D., Eneji A.E., Binang W., Irshad M., Yamamoto S., Honna T., Endo T., 2003. "Effect of foliar application of urea on reproductive abscission and grain yield of soybean." *Journal of plant nutrition, 26(6)* 1223-1234.

Osborne S.L., Riedell W.E., 2006. "Starter nitrogen fertilizer impact on soybean yield and quality in the Northern Great Plains." *Agronomy Journal, 98(6)* 1569-1574.

Popescu E.M., Roman GH.V., 2008. "Cercetări privind biologia şi productivitatea culturii intercalate porumb-soia în condiţiile sistemului de agricultură ecologic." *Lucrări Ştiinţifice – vol. 51, seria Agronomie* 341-350.

Ranđelović V., Prodanović S., Prijić L., Glamočlija Đ., Živanović L., & Kolarić L. 2009. "Uticaj folijarnog prihranjivanja u stresnim uslovima na dve sorte soje različitih grupa zrenja." *Zbornik naučnih radova Instituta PKB Agroekonomik, 15* 1-2.

Ray J.D., Fritschi F.B., Heatherly L.G. 2006. "Large applications of fertilizer N at planting affects seed protein and oil concentration and yield in the Early Soybean Production System." *Field crops research, 99(1)* 67-74.

Salvagiotti F., Cassman K.G., Specht J.E., Walters D.T., Weiss A., Dobermann A. 2008. "Nitrogen uptake: fixation and response to fertilizer N in soybeans: areview." *Field Crops Res. 108* 1-13.

Schmitt M.A., Lamb J.A., Randall G.W., Orf J.H., & Rehm G.W., 2001. "In-season fertilizer nitrogen applications for soybean in Minnesota." *Agronomy Journal, 93(5),* 983-988.

Sogut T., 2006. "Rhizobium inoculation improves yield and nitrogen accumulation in soybean (Glycine max) cultivars better than fertiliser." *New Zealand journal of crop and horticultural science, 34(2)* 115-120.

Starling M.E., Wood C.W., Weaver D.B., 2000. "Late-planted soybeans respond to nitrogen starter." *Fluid J, 28* 26-30.

Subramanian S., Smith D.L., 2013. *A proteomics approach to study soybean and its symbiont Bradyrhizobium japonicum-a review.* INTECH Open Access Publisher.

Tago K., Ishii S., Nishizawa T., Otsuka S., Senoo K., 2011. "Phylogenetic and Functional Diversity of Denitrifying Bacteria Isolated from Various Rice Paddy and Rice-Soybean Rotation Fields." *Microbes and Environments, 26(1)* 30-5.

Van Kessel C., Hartley C., 2000. "Agricultural management of grain legumes: has it led to an increase in nitrogen fixation?" *Field Crops Research, 65(2)* 165-181.

Wesley T.L., Lamond R.E., Martin V.L., Duncan S.R., 1998. "Effects of late-season nitrogen fertilizer on irrigated soybean yield and composition." *Journal of Production Agriculture, 11(3)* 331-336.

Zambiazzi E.V., Bruzi A.T., de Carvalho M.L.M., Soares I.O., Zuffo A.M., de Rezende P.M., Miranda D.H. 2014. "(2014). Potassium fertilization and physiological soybean seed quality." *Agricultural Sciences, 5(11), 984* 984-990.

Zheng H., Chen L., Han X., Ma Y., Zhao X., 2010. "Effectiveness of phosphorus application in improving regional soybean yields under drought stress: A multivariate regression tree analysis." *African Journal of Agricultural Research, 5(23)* 3251-3258.