EFFICIENCY OF BACTERIAL INOCULATION AND MINERAL NITROGEN AND PHOSPHORUS FERTILIZATION IN RAINFED SOYBEAN

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ABSTRACT

This research has been carried out on vertic argilluvial chernozem under rainfed conditions, in 1990-1991 and 1994-1998, at Turda Agricultural Research Station. Three strains of *Rhizobium* (SO-26, SO-110 and SO-122) were studied in interaction with two genotypes (Diamant and Perla) at three nitrogen fertilization levels (0, 20 and 100 kg N /ha). The most efficient genotype x bacterial strain interaction was Diamant x SO-122 under 20 kg N/ha fertilization conditions. The maximum yield increase obtained with bacterial inoculation and 20 kg N/ha fertilization was 409 kg/ha (21%). The mineral N and P fertilization caused modifications of the morphological indices and main productive elements. The rates of 70-80 kg N/ha and 80 kg P_2O_5/ha yielded 2895 kg of soybean grains and 993 kg/ha of protein.

Key words: bacterial inoculation, bacteria strains, mineral fertilization, soybean.

INTRODUCTION

Soybean is one of the very important agricultural crops due to both its multiple uses and its capacity to fix nitrogen from the air by symbiotic bacteria, being an excellent preceding crop, especially for winter cereals.

The scientific references show that soybean is a high nitrogen consumer but, at the same time, it has the possibility to supply a large part of its needs by fixing nitrogen from the air, and the application of the bacterial fertilizer, called "Nitragin", increases the fixing activity of the symbiotic bacteria, thus leading to significant yield increases (Bălan et al., 1980; Budoi et al., 1984; Prodan et al., 1985). The research results on soybean emphasize that the percentage of nitrogen fixed from the air represents 0-75% (1-168 kg/ha of fixed nitrogen) (Nutman, 1976) and Weber (1976) appreciates that a successful bacterial symbiosis supplies 40% from the total nitrogen (78 kg of the 195 kg).

Hera et al. (1985), by using the ^{15}N stable isotope, show that the nitrogen symbiotic fixation reaches up to 220 kg/ha, and its participation in nitrogen accumulation in grains represents 75% (in the whole plant 67%). Research carried out by Bălan et al. (1980) led to the conclusion that, after soybean harvest, about 45-70 kg N/ha remain in chernozem soils.

The particular importance presented by the soybean seed inoculation determined a large number of research activities. In this view there are also the research carried out by the Turda Agricultural Research Station in cooperation with the Fundulea Research Institute for Cereals and Industrial Crops whose objective was to select new bacterial strains of the *Rhizobium* genus, which be efficient in fixing the nitrogen from the air in the case of a soybean crop, as well as the study of the mineral fertilization with nitrogen and phosphorus, and the interaction of the inoculation x fertilization with increasing nitrogen rates on the production and yield quality. This research has been included in the present paper regarding the solution of the contradictions between the high need of protein on the one hand, and the rationalization of the fuel and energy consumption, on the other hand.

MATERIALS AND METHODS

The research representing the objective of this paper was carried out at the Turda Agricultural Research Station, in the forestry-steppe zone of the Transylvania Plain, on a vertic argilluvial chernozem. The topsoil is characterized by loamy-clay texture (clay content > 50%), neutral reaction (pH 6.9 - 7.1), moderate content of available phosphorus (15-20 ppm P), and high supply of mobile potassium (249 ppm K), organic matter (3.92%) and total nitrogen (0.196%). As concerns the climatic conditions of this area, the mean annual temperature is 8.6^{0}C, and the mean annual rainfall 510 mm with a peak in May-June (Figure 1). The rainfall in May-

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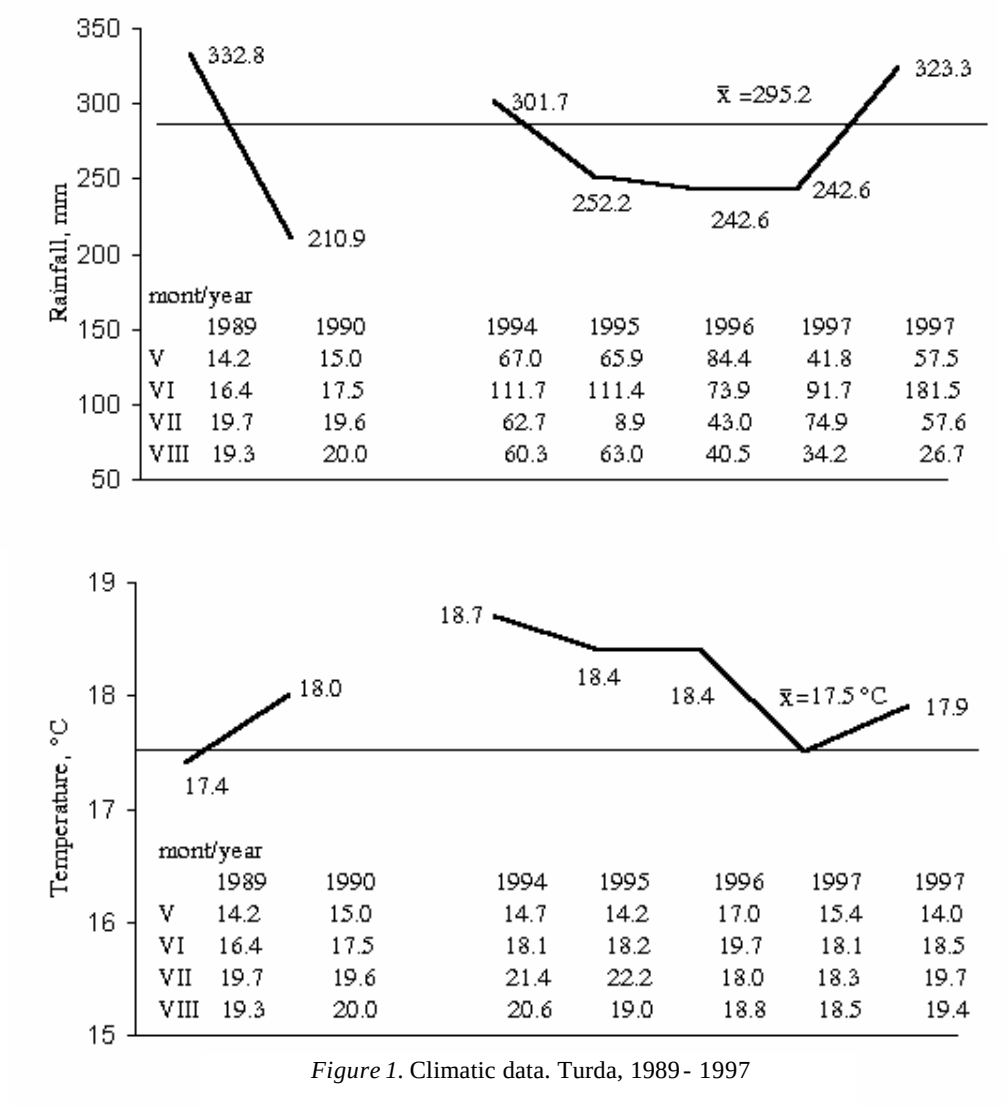

Figure 1. Climatic data. Turda, 1989 - 1997

August, in all the experimental years, ranged between 210.9 and 332.8 mm, a completely unsatisfactory amount as compared to the needs of a successful soybean crop.

The experiments regarding the interaction between the bacterial inoculation and increasing mineral nitrogen rates were of the 3 x 2 x 4 type, located according to the method of the subdivided plots, with :

- factor A - nitrogen (0, 20, 100 kg a.i./ha active ingredient) supplied as ammonium nitrate :

-factor B - cultivars (Diamant and Perla) and

-factor C - seed treatment (non-inoculated, inoculated with SO-26, SO-110 and SO-122).

In the second experiment of the same type, the nitrogen was supplied as urea. The nitrogen rates were completely applied before sowing, and the phosphorus was uniformly applied in autumn, by plough up the soil, at a rate of 80 kg P_2O_5/ha. The experiment concerning the mineral fertilization influence was bifactorial of the stationary type with 25 treatments having as factors :

- factor A - phosphorus with five rates (0, 40, 80, 120, 160 kg P_2O_5/ha and

- factor B - nitrogen with five rates (0, 25, 50, 75, 100 kg N a.i./ha).

To reach the purpose, observations and determinations were carried out and the results regarding the utilizable yield, as synthetic index to evaluate the fertilization and inoculation efficiency, were interpreted by the method of variance analysis.

RESULTS AND DISCUSSIONS

a) Inoculation efficiency under mineral nitrogen fertilization conditions

The experiments carried out at the Turda Agricultural Research Station tried to elucidate the relationship between the fertilization with nitrogen applied as ammonium nitrate and urea, and the biological fixation of nitrogen from the air in the case of two soybean cultivars, Diamant and Perla, aiming at supplying at the optimum level the nitrogen needs of plants.

The opportunity of the nitrogen fertilizer application, especially before sowing, is still a much discussed problem, and the obtained results are often contradictory due to the high diversity of the climatic and soil conditions under which the research has been carried out. The symbiosis presumes the installation of a very fragile equilibrium between the partners, dependent on the numerous endogenous and exogenous factors.

Some authors state that the application, in the early stages, of some low "starter" nitrogen rates (20-30 kg/ha) may have synergic effects on the nitrogen fixation (Eaglesham et al., 1983). Hera et al. (1976) show that the maximum soybean yield was obtained without mineral nitrogen on chernozems, and with a moderate nitrogen rate (30 kg/ha) on the poorer soils under inoculation with *Rhizobium* spp. conditions. The research carried out on this experiment approached the complex aspect determined by the compatibility between the inoculated strains, cultivars and decreasing nitrogen rates, aiming at obtaining higher yields.

According to the data presented in the variance analysis table (Table 1), the soybean yields obtained in the two experimental years are very significant and positively influenced by the climatic conditions, cultivated cultivars, *Rhizobium* strains used for inoculation and non-significantly influenced by the nitrogen rates, irrespective of the used fertilizer, urea or ammonium nitrate. It has been observed that the calculated F sample has the highest value in the case of the "cultivars" factor (164.25 and 94.99) followed by the climatic conditions of years (92.26 and 41.84).

The study of the 24 experimental treatments - combinations of ranking the experimental factors (Table 2) - shows that, on an average for two years, the nitrogen (as ammonium nitrate) application (20 kg/ha) determined a maximum yield increase of 12.5 per cent in the case of the Diamant cultivar. Higher nitrogen rates (100 kg a.i./ha) did not significantly influenced the yield of the Diamant soybean cultivar, and in the case of the Perla soybean cultivar they determined even a slight yield reduction. The same effect of fertilization was also recorded when the urea was used as nitrogen fertilizer (Table 3), obtaining 6.1 per cent maximum yield increase by fertilization with 20 kg N/ha in the case of the Diamant cultivar.

Compared with the control, the inoculated seed produced significant yield increases. Generally, the yields obtained in the treatments inoculated with different bacterial strains and fertilized with 20 kg N/ha are higher than those obtained on non-fertilized plots or in plots fertilized with rates of 100 kg N/ha.

The nitrogen excess in soil, as a result of high nitrogen rates applied before sowing, inhibits the bacterial activity, and the application of low "starter" nitrogen rates allows crop nutrition in the early stages when the

Table 1. Variance analysis

Variability cause	UREA					AMMONIUM NITRATE				
	SP	GL	s^2	F sample		SP	GL	s^2	F sample	
				calculated	theoretical				calculated	theoretical
Total	11576259	143				11409012	143			
Years	5168044	1	5168044	92.26***	6.83	4141564	1	4141564	41.84***	6.83
Nitrogen	146064	2	73032	3.10	4.75	404045	2	202022	2.88	4.75
Cultivars	2537118	1	2537118	164.25***	6.83	1477642	1	1477642	94.99***	6.83
Rhizobium strains	1015725	3	338575	21.49***	3.91	1171275	3	390425	19.39***	3.91

Table 2. Bacteria inoculation x mineral (Ammonium nitrate) fertilization interaction in soybean and its effect on grain yield (kg/ha). Turda, 1989-1990

Nitrogen rate (amonium nitrate) kg a.i./ha (A)	Non-inoculated		Bacteria strain (B)						Average of nitrogen levels in inoculated treatments		% as compared to non-fertilized	
			SO-26		SO-110		SO-122					
	Diamant	Perla	Diamant	Perla	Diamant	Perla	Diamant	Perla	Diamant	Perla		
0	1923	2311	2048	2509	2189	2453	2185	2433	2086	2426	100	100
20	2117	2160	2299	2467	2469	2428	2506	2466	2347	2380	112.5	98.1
100	2050	2261	2140	2387	2210	2356	2119	2457	2130	2365	102.1	97.5
Average on bacteria strains	2030	2244	2163	2454	2289	2412	2270	2452				
% as compared to non-inoculated	100	100	106.5	109.3	112.7	107.4	112.8	109.2				
			A		B		A X B					
	LSD 5% LSD 1% LSD 0.1%		124 kg 181 kg 272 kg		66 kg 88 kg 114 kg		136 kg 197 kg 293 kg					

Table 3. Bacteria inoculation x mineral (urea) fertilization interaction in soybean and its effect on grain yield (kg/ha) Turda, 1989-1990

Nitrogen rate (ammonium nitrate) kg a.i./ha (A)	Non-inoculated		Bacteria strains (B)						Average of nitrogen levels in inoculated treatments		% as compared to non-fertilized	
			SO-26		SO-110		SO-122					
	Diamant	Perla	Diamant	Perla	Diamant	Perla	Diamant	Perla	Diamant	Perla		
0	1923	2311	2048	2509	2189	2453	2185	2433	2086	2426	100	100
20	2005	2223	2341	2495	2181	2546	2332	2459	2214	2430	106.1	100.1
100	1980	2353	2154	2421	2217	2365	2185	2360	2134	2374	100.3	97.9
Average on bacteria strains	1969	2295	2181	2475	2196	2454	2234	2417				
% as compared to non-inoculated	100	100	110.7	107.8	111.5	106.9	113.4	105.3				
			A		B		A x B					
	LSD 5% LSD 1%		72 kg/ha 105 kg/ha		58 kg/ha 78 kg/ha		113 kg/ha 156 kg/ha					

symbiotic system is still nonfunctional. The analysis of the fertilization x inoculation interaction shows that the yield gains produced by each of the three bacterial strains, compared with the non-inoculated average, varied from 6.5 per cent to 12.7 per cent when the utilized fertilizer was ammonium nitrate, and from 6.8 per cent to 13.4 per cent when urea was used as fertilizer.

The biometric determinations regarding the formation and development of nodules in different fertilization (ammonium nitrate or urea) and inoculation (Tables 4 and 5) treatments show that the number of nodules did not vary very much in terms of strains used for inoculation, neither in terms of the nitrogen rate applied before sowing. A slight increase of nodules number in the inoculated

Table 4. Influence of fertilization with increasing nitrogen (Ammonium nitrate) rates on the number of nodules formed on soybean roots inoculated with different bacteria strains. Turda, 1989-1990

Nitrogen rate (ammonium nitrate) kg a.i./ha (A)	Non-inoculated		Bacteria strains (B)						Average of nitrogen levels	
			SO-26		SO-110		SO-122			
	Diamant	Perla	Diamant	Perla	Diamant	Perla	Diamant	Perla	Diamant	Perla
0	20.2	22.1	27.0	19.0	30.3	20.0	21.3	18.0	24.7	19.8
20	22.3	23.0	16.9	20.5	21.4	17.2	22.0	20.0	20.6	20.2
100	18.9	18.5	17.2	13.5	19.6	14.3	12.1	10.3	17.0	14.2
Average of strains	20.5	21.2	20.4	17.7	23.8	17.2	18.5	16.1	-	-

	A	B	A x B
LDS 5%	1.7	2.4	3.4
LSD 1%	2.3	3.1	4.8
LSD 0.1%	3.1	3.9	6.8

Table 5. Influence of fertilization with increasing nitrogen (urea) rates on the number of nodules formed on soybean roots inoculated with different bacteria strains. Turda, 1989-1990

Nitrogen rate (ammonium nitrate) kg a.i./ha (A)	Non-inoculated		Bacteria strain (B)						Average of nitrogen levels	
			SO-26		SO-110		SO-122			
	Diamant	Perla	Diamant	Perla	Diamant	Perla	Diamant	Perla	Diamant	Perla
0	18.9	19.3	27.0	19.0	30.3	20.0	21.3	16.0	26.2	18.3
20	17.3	16.7	22.5	19.6	20.1	17.8	19.1	19.4	20.5	18.9
100	15.1	14.9	13.5	12.7	13.6	12.0	13.5	14.9	13.5	13.2
Average of strains	17.1	16.9	21.0	17.1	21.3	16.6	17.9	16.8	-	-

	A	B	A x B
LSD 5%	1.5	2.3	3.3
LSD 1%	2.1	3.0	4.9
LSD 0.1%	2.9	3.8	6.9

treatments was observed as compared with treatments without inoculation, and a reduction from 20 kg/ha nitrogen rate to 100 kg/ha nitrogen rate. A high number of nodules was also observed in the treatments without inoculation, due to the multiplication of native nitrogen fixing bacteria as a result of applying for several years a three year crop rotation with legumes : soybean, bean or peas.

The statistic computation by the variance analysis shows the very significant influence of the climatic conditions on soybean yield development as well as the very significant action of the nitrogen and phosphorus fertilization (Table 6). The calculated F sample has the highest value in the case of the "climatic conditions" factor (166.31).

Fertilizers, along with other technological factors, represent one of the basic factors which contribute to the increase of soybean yield.

The research results obtained at the Turda Agricultural Research Station in 1994-1998 show that the yield gains obtained with non-inoculated soybean, but fertilized with 25-100 kg N/ha and 40-60 kg P_2O_5/ha, are of 14-23% (Table 7). The nitrogen rate of 75 kg N/ha, applied under 80 kg P_2O_5/ha fertilization conditions, produces the highest soybean yield. The nitrogen fertilizers increased the soybean yield with 418-515 kg/ha (18-23%) depending on the applied rate, and, in interaction with phosphorus, the yield increased with up to 869 kg/ha (43%).

Table 6 . Variance analysis

Variability cause	SP	GL	s^2	F sample	
				calculated	theoretical
Total	81233992	374			
Years	46737616	4	11681404	166.31***	3.32
Phosphorus	5689577	4	1422394	18.92***	3.32
Years x phosphorus	899498	16	563218	0.75	1.99
Nitrogen	12236928	4	3059232	65.74***	3.32
Years x nitrogen	1009934	16	63120	1.36	1.99

Table 7. Influence of nitrogen and phosphorus fertilization on soybean yield. Turda, 1994-1998

P and N kg a.i./ha	N_0	N_{25}	N_{50}	N_{75}	N_{100}	Average	Difference	%
P_0	2026	2293	2456	2561	2468	2361	-	100
P_{40}	2241	2482	2614	2771	2670	2556	195	108
P_{80}	2323	2536	2723	2812	2763	2631	270	111
P_{120}	2365	2648	2801	2895	2733	2688	327	114
P_{160}	2406	2584	2770	2895	2816	2694	333	114
Average	2272	2509	2673	2787	2690	-	-	-
Difference	-	237	401	515	418	-	-	-
%	100	110	118	123	118	-	-	-

	N	P	N x P
LSD 5%	69 kg/a	90 kg/ha	155 kg/ha
LSD 1%	91 kg/ha	120 kg/ha	204 kg/ha
LSD 0.1%	117 kg/ha	158 kg/ha	263 kg/ha

Table 8. The influence of increasing nitrogen and phosphorus rates on number of nodules formed on soybean roots Turda, 1997

P and N kg a.i./ha	N_0	N_{25}	N_{50}	N_{75}	N_{100}	Average	Difference
P_0	15.2	17.8	14.3	10.9	9.8	13.0	-
P_{40}	17.3	19.3	17.5	11.4	9.3	14.96	1.36
P_{80}	19.7	19.9	18.1	13.5	10.1	16.32	2.72
P_{120}	19.3	19.1	17.7	13.1	10.1	15.86	2.26
P_{160}	18.1	19.3	18.3	14.3	10.3	16.06	2.46
Average	17.92	19.08	17.18	12.64	9.98		
Difference	-	1.16	-0.74	-5.28	-7.94		

The application, at the sowing time, of some high nitrogen rates, especially under rainfed conditions, leads to undesirable effects and generating the exaggerated development of plants and the reduction of the utilizable product.

The presence of bacteria and the intensity of their development even under non-inoculation conditions are emphasized by the occurrence of nodules and their number on plant roots (Table 8). The application of nitrogen rates higher than 40-50 kg a.i./ha, before sowing, inhibits the bacterial activity, the nodules keep small and in low number. The number of nodules per plant in the fertilized treatment with 100 kg N/ha is with 7.94 lower than in the control. If the presence of high nitrogen rates hinders the bacterial activity, the phosphorus fertilizers have a direct role in the symbiotic activity of the bacteria, stimulating their formation and facilitating the possibility of the nitrogen fixation from the air.

The modification of some morphological properties and productivity elements under the nitrogen mineral fertilization influence represented the objective of some determinations carried out on the occasion of the soybean harvest (Tables 9 and 10). The height of plants was higher in all treatments fertilized with nitrogen as compared with the control without fertilization. Thus, if the average height of the control plants was of 72.6 cm, by fertilization with 100 kg N/ha it

Table 9. Influence of nitrogen fertilization on some soybean morphological properties. Turda, 1997-1998

N kg a.i./ha	Plant height cm	First pod height cm	Plant weight g	Dry weight root g	No. of branches	No. of nodes
0	54.3	8.3	13.8	1.23	0.8	15.6
25	63.6	8.2	17.5	1.13	1.1	16.1
50	68.0	10.4	18.5	0.97	1.2	16.8
75	70.6	11.3	19.9	1.10	1.2	17.3
100	72.6	10.8	20.3	1.08	1.4	17.7
Average	65.6	9.8	18.0	1.10	1.14	16.7

Table 10. Influence of nitrogen fertilization on the main productivity elements of soybean. Turda, 1997-1998

N kg a.i./ha	No. of pods/plant	No. of grains/pod	No. of grains/plant	Seed weight /plant -g	1000 - seed weight -g	Utilizable yield %
0	31.1	2.0	6.22	6.04	113.2	43.7
25	33.2	2.1	69.7	8.39	120.4	47.9
50	34.9	2.1	73.3	9.38	128.0	50.7
75	36.4	2.2	80.1	9.86	123.2	49.5
100	35.7	2.1	75.0	9.63	123.0	47.4
Average	34.3	2.1	72.1	8.66	121.6	47.8

Table 11. Effect of nitrogen and phosphorus mineral fertilizers on the chemical composition of soybean grain

Kg/ha		N	Protein				P
P_2O_5	N	%	%	kg/ha	difference	%	%
	0	5.03	31.43	637	0	100	0.730
	25	5.14	32.12	736	99	115	0.728
0	50	5.31	33.18	781	144	123	0.718
	75	5.54	34.62	887	250	139	0.697
	100	5.73	35.81	884	247	139	0.723
	0	5.02	31.37	703	66	110	0.738
	25	5.18	32.37	803	166	126	0.720
40	50	5.29	33.06	864	227	136	0.698
	75	5.52	34.50	955	318	150	0.716
	100	5.70	35.62	966	329	150	0.718
	0	5.12	32.0	743	106	117	0.757
	25	5.20	32.50	887	250	137	0.700
80	50	5.31	33.18	863	226	135	0.731
	75	5.55	34.68	975	338	153	0.728
	100	5.72	35.75	987	350	154	0.725
	0	5.01	31.31	740	103	116	0.751
	25	5.23	32.68	974	337	153	0.733
120	50	5.32	33.25	910	273	143	0.718
	75	5.19	34.31	993	356	156	0.697
	100	5.73	35.81	978	341	153	0.701
	0	5.05	31.56	759	122	119	0.750
	25	5.26	32.87	849	212	133	0.728
160	50	5.34	33.37	933	296	146	0.723
	75	5.46	34.12	987	369	157	0.715
	100	5.71	35.40	992	360	156	0.719

become with 18.3 cm higher. As plants grow higher, the number of plant nodes increases (from 13.8 g to 20.3 g) against the control, in the treatment fertilized with 100 kg N/ha.

The average number of branches per plant is an element influenced by fertilization. Its increase ranged from 0.8 in the case of the control to 1.4 by fertilization with 100 kg N/ha.

If the aerial part of the plant (height, weight) is positively influenced by nitrogen fertilization, as concerns the root system, the determinations emphasize the reduction of its

weight, in the fertilized treatments from 1.23 g/plant to 0.97 g/plant. The plants in the fertilized treatments explore less the soil mass for nutrients and thus the root system remains more slightly developed than in the case of the treatments without fertilization. The nitrogen fertilization determined also modifications of the main productivity elements (Table 10).

The average number of pods per plant was 31.1 in the case of the control, and by fertilization it exceeded 35-36 pods. As the number of pods grows higher, the number of seeds per plant increases as well as the weight of seeds per plant. The average number of seeds in a pod was less influenced by fertilization.

An increase of the utilizable yield (%) was observed in all the fertilized treatments as against the control. Also, it was observed that, if in the case of the control the utilizable yield represents 43 per cent, under 50 kg N/ha fertilization conditions it increases up to 50.7 per cent. If the moderate nitrogen rates (50-60 kg a.i./ha) are preponderantly used in the metabolic process of the accumulated substances in seed, on the contrary, high nitrogen rates (100 and even more than 100 kg a.i./ha) are involved in the vegetative growing process, determining the plant development and finally the reduction of the seed production.

The fertilization may modify, under certain limits, the chemical composition of the soybean grains. The nitrogen content of grains increased proportionally with the applied nitrogen rate, both in the case of the unilaterally application and in the case of the combined application of nitrogen with phosphorus (Table 11). Thus, the nitrogen content of grains varies from 5.03 per cent (control) up to 5.73 per cent (treatment fertilized with maximum nitrogen rate - 100 kg a.i./ha).

As concerns the protein, the quantitative increases represent the joint effect of both the grain yield and the qualitative increase of the grain protein content. The maximum effect is obtained with rates of 75 kg N/ha and 120 kg P_2O_5/ha, reaching 993 kg raw protein/ha, with 356 kg/ha more than the control. The obtained raw protein production proves the positive effect of the two elements, nitrogen and phosphorus, in achieving high yields of superior quality. The phosphorus content of grain is positively influenced by the applied phosphorus fertilizers, and the nitrogen has a diminishing action of the phosphorus quantity in the soybean grain.

CONCLUSIONS

The correct bacterial inoculation applied under the vertic argilluvial chernozem conditions, from the Turda Agricultural Research Station resulted in significant yield gains, i.e. 21 percent (409 kg/ha) with Diamant cultivar under nitrogen fertilization conditions, with a 20 kg/ha rate.

The application of the lower "starter" nitrogen rates secures the nutrition in the early stages when the symbiotic system is still unfunctional.

The bacterial strains SO-26, SO-110 and SO-122 revealed a good efficiency in fixing the nitrogen from the air, being active and virulent. The best genotype x bacterial strain combination proved to be the combination between the Diamant cultivar and SO-122 strain. To obtain high and qualitatively superior soybean yields it is necessary to apply moderate nitrogen rates, 20-30 kg N/ha when the seed is inoculated and 70-80 kg/ha without inoculation, and under equilibrated phosphorus regime conditions.

The mineral fertilization with nitrogen and phosphorus produced modifications of the morphological indices and of the main productivity elements. The fertilization favourably influences the fructification process, which is demonstrated by the higher values of the production elements per plant in the fertilized treatments as compared with the control, determined at the harvest.

To increase the productivity of the soybean and, generally, of legumes, and to ensure the yield stability, it is recommended to use the combination of the two nitrogen nutrition ways - biological and mineral - avoiding thus the deficiencies of one or other way taken separately.

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Table 8. The influence of increasing nitrogen and phosphorus rates on number of nodules formed on soybean roots

Turda 1997

P and N kg/ha a.i.	N 0	N 25	N 50	N 75	N 100	Average	Difference
P 0	15.2	17.8	14.3	10.9	9.8	13.0	-
P 40	17.3	19.3	17.5	11.4	9.3	14.96	1.36
P 80	19.7	19.9	18.1	13.5	10.1	16.32	2.72
P 120	19.3	19.1	17.7	13.1	10.1	15.86	2.26
P 160	18.1	19.3	18.3	14.3	10.3	16.06	2.46
Average	17.92	19.08	17.18	12.64	9.98		
Difference	-	1.16	-0.74	-5.28	-7.94		

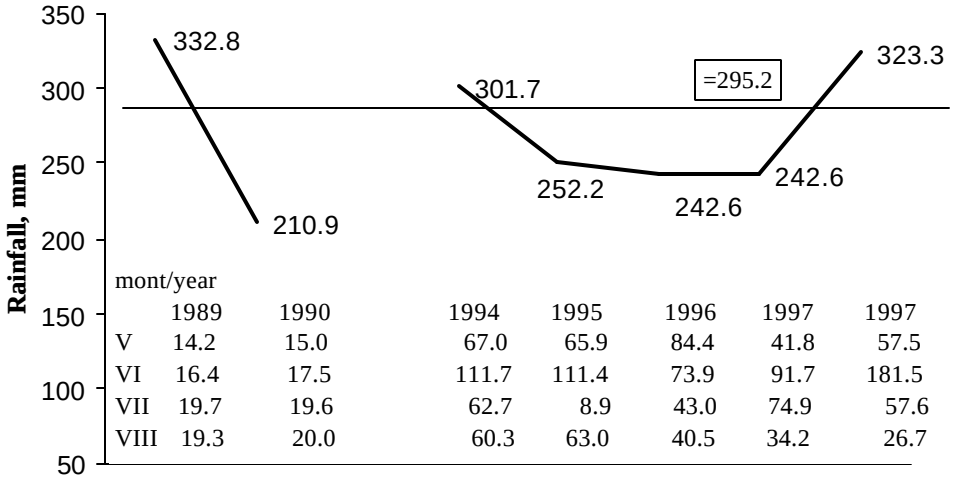
Table 10. Influence of nitrogen fertilization on the main productivity elements of soybean

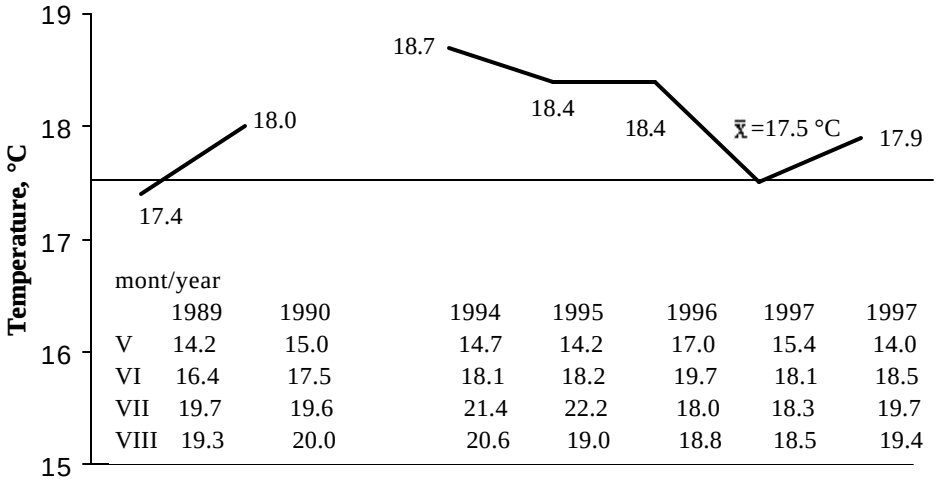
Turda 1997-1998

N kg/ha a.i.	No. of pods/plant	No. of grains/pod	No. of grains/plant	Seed weight/plant -g-	1000-seed weight -g-	Utilizable yield %
0	31.1	2.0	6.22	6.04	113.2	43.7
25	33.2	2.1	69.7	8.39	120.4	47.9
50	34.9	2.1	73.3	9.38	128.0	50.7
75	36.4	2.2	80.1	9.86	123.2	49.5
100	35.7	2.1	75.0	9.63	123.0	47.4
Average	34.3	2.1	72.1	8.66	121.6	47.8

Table 11. Effect of nitrogen and phosphorus mineral fertilizers on the chemical composition of soybean grain

Kg/ha		N		Protein			P
P_2O_5	N	%	%	Kg/ha	Difference	%	%
0	0	5.03	31.43	637	0	100	0.730
	25	5.14	32.12	736	99	115	0.728
	50	5.31	33.18	781	144	123	0.718
	75	5.54	34.62	887	250	139	0.697
	100	5.73	35.81	884	247	139	0.723
40	0	5.02	31.37	703	66	110	0.738
	25	5.18	32.37	803	166	126	0.720
	50	5.29	33.06	864	227	136	0.698
	75	5.52	34.50	955	318	150	0.716
	100	5.70	35.62	966	329	150	0.718
80	0	5.12	32.0	743	106	117	0.757
	25	5.20	32.50	887	250	137	0.700
	50	5.31	33.18	863	226	135	0.731
	75	5.55	34.68	975	338	153	0.728
	100	5.72	35.75	987	350	154	0.725
120	0	5.01	31.31	740	103	116	0.751
	25	5.23	32.68	974	337	153	0.733
	50	5.32	33.25	910	273	143	0.718
	75	5.19	34.31	993	356	156	0.697
	100	5.73	35.81	978	341	153	0.701
160	0	5.05	31.56	759	122	119	0.750
	25	5.26	32.87	849	212	133	0.728
	50	5.34	33.37	933	296	146	0.723
	75	5.46	34.12	987	369	157	0.715
	100	5.71	35.40	992	360	156	0.719





mont/year	1989	1990	1994	1995	1996	1997	1997
V	14.2	15.0	14.7	14.2	17.0	15.4	14.0
VI	16.4	17.5	18.1	18.2	19.7	18.1	18.5
VII	19.7	19.6	21.4	22.2	18.0	18.3	19.7
VIII	19.3	20.0	20.6	19.0	18.8	18.5	19.4

Table 1. Variance analysis

Variability cause	SP	GL	s^2	F sample		SP	GL	s^2	F sample	
				calculated	theo-retical				Calculated	theo-retical
Total	11576259	143				11409012	143			
Years	5168044	1	5168044	92.26***	6.83	4141564	1	4141564	41.84***	6.83
Nitrogen	146064	2	73032	3.10	4.75	404045	2	202022	2.88	4.75
Cultivars	2537118	1	2537118	164.25***	6.83	1477642	1	1477642	94.99***	6.83
Rhizobium strains	1015725	3	338575	21.49***	3.91	1171275	3	390425	19.39***	3.91
	UREA					AMMONIUM NITRATE				

Table 2. Bacterial inoculation X mineral (Ammonium nitrate) fertilization interaction in soybean and its effect on grain yield (kg/ha) Turda 1989-1990

Nitrogen rate (a monium nitrate) kg/ha a.i.	Non-inoculated		B bacterial strain						Average of nitro		% as compa	
			SO-26		SO-110		SO-122		gen levels in inoculated treatments		red to non-fertilized	
	Diamant	Perla	Diamant	Perla	Diamant	Perla	Diamant	Perla	Diamant	Perla		
0	1923	2311	2048	2509	2189	2453	2185	2433	2086	2426	100	100
20	2117	2160	2299	2467	2469	2428	2506	2466	2347	2380	112.5	98.1
100	2050	2261	2140	2387	2210	2356	2119	2457	2130	2365	102.1	97.5
Average on bacterial strains	2030	2244	2163	2454	2289	2412	2270	2452				
% as com-pared to non-inoculated	100	100	106.5	109.3	112.7	107.4	112.8	109.2				
			A		B		A X B					
	LSD 5% LSD 1% LSD 0.1%		124 kg 181 kg 272 kg		66 kg 88 kg 114 kg		136 kg 197 kg 293 kg					

Table 3. Bacterial inoculation x mineral (urea) fertilization interaction in soybean and its effect on grain yield (kg/ha) Turda 1989-1990

Nitrogen rate (ammonium nitrate)	Non-inoculated		B bacterial strains						Average of nitrogen levels in inoculated treatments		% as compared to non-fertilized	
			SO-26		SO-110		SO-122					
kg/ha a.i.	Diamant	Perla	Diamant	Perla	Diamant	Perla	Diamant	Perla	Diamant	Perla		
0	1923	2311	2048	2509	2189	2453	2185	2433	2086	2426	100	100
20	2005	2223	2341	2495	2181	2546	2332	2459	2214	2430	106.1	100.1
100	1980	2353	2154	2421	2217	2365	2185	2360	2134	2374	100.3	97.9
Average on bacterial strains	1969	2295	2181	2475	2196	2454	2234	2417				
% as compared to non-inoculated	100	100	110.7	107.8	111.5	106.9	113.4	105.3				
	LSD 5% LSD 1%		A 72 kg/ha 105 kg/ha		B 58 kg/ha 78 kg/ha		A x B 113 kg/ha 156 kg/ha					

Table 4. Influence of fertilization with increasing nitrogen (Ammonium nitrate) rates on the number of nodules formed on roots of soybean inoculated with different bacterial strains

Turda 1989-1990

Nitrogen rate (ammonium nitrate) A	Non-inoculated		Bacterial strains B						Average of nitrogen levels	
			SO-26		SO-110		SO-122			
	Diamant	Perla	Diamant	Perla	Diamant	Perla	Diamant	Perla	Diamant	Perla
0	20.2	22.1	27.0	19.0	30.3	20.0	21.3	18.0	24.7	19.8
20	22.3	23.0	16.9	20.5	21.4	17.2	22.0	20.0	20.6	20.2
100	18.9	18.5	17.2	13.5	19.6	14.3	12.1	10.3	17.0	14.2
Average of strains	20.5	21.2	20.4	17.7	23.8	17.2	18.5	16.1	-	-
	LDS 5% LSD 1% LSD 0.1%		A 1.7 2.3 3.1		B 2.4 3.1 3.9		A x B 3.4 4.8 6.8			

Table 5. Influence of fertilization with increasing nitrogen (urea) rates on the number of nodules formed on roots of soybean inoculated with different bacterial strains

Turda 1989-1990

Nitrogen rate (ammonium nitrate) A	Non-inoculated		Bacterial strain B						Average of nitrogen levels	
			SO-26		SO-110		SO-122			
	Diamant	Perla	Diamant	Perla	Diamant	Perla	Diamant	Perla	Diamant	Perla
0	18.9	19.3	27.0	19.0	30.3	20.0	21.3	16.0	26.2	18.3
20	17.3	16.7	22.5	19.6	20.1	17.8	19.1	19.4	20.5	18.9
100	15.1	14.9	13.5	12.7	13.6	12.0	13.5	14.9	13.5	13.2
Average of strains	17.1	16.9	21.0	17.1	21.3	16.6	17.9	16.8	-	-
	LSD 5%		A 1.5		B 2.3		A x B 3.3			

	LSD 1% LSD 0.1%	2.1 2.9	3.0 3.8	4.9 6.9		

Table 7. Influence of nitrogen and phosphorus fertilization on soybean yield Turda 1994-1998

P and N - kg/ha a.i.	N 0	N 25	N 50	N 75	N 100	Aver-age	Differ-ence	%
P 0	2026	2293	2456	2561	2468	2361	-	100
P 40	2241	2482	2614	2771	2670	2556	195	108
P 80	2323	2536	2723	2812	2763	2631	270	111
P 120	2365	2648	2801	2895	2733	2688	327	114
P 160	2406	2584	2770	2895	2816	2694	333	114
Average	2272	2509	2673	2787	2690	-	-	-
Difference	-	237	401	515	418	-	-	-
%	100	110	118	123	118	-	-	-

	N	P	N x P
LSD 5%	69 kg/a	90 kg/ha	155 kg/ha
LSD 1%	91 kg/ha	120 kg/ha	204 kg/ha
LSD 0.1%	117 kg/ha	158 kg/ha	263 kg/ha

Table 9. Influence of nitrogen fertilization on some soybean morphological properties Turda 1997-1998

N kg/ha a.i.	Plant height - cm -	First pod height - cm -	Plant weight - g -	Dry root weight - g -	N0. of branches	No. of nodes
o	54.3	8.3	13.8	1.23	0.8	15.6
I 25	63.6	8.2	17.5	1.13	1.1	16.1
50	68.0	10.4	18.5	0.97	1.2	16.8
I 75	70.6	11.3	19.9	1.10	1.2	17.3
100	72.6	10.8	20.3	1.08	1.4	17.7
Average	65.6	9.8	18.0	1.10	1.14	16.7