UDC 581.557 **https://doi.org/10.15407/biotech12.02.079**

EFFICIENCY OF SOYBEAN-RHIZOBIUM SYMBIOSES FOR SEEDS INOCULATED WITH COMPOSITIONS BASED ON *Rhizobium*, *Azotobacter* AND PHYTOLECTINS

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Received 28.02.2019
Revised 21.03.2019
Accepted 10.05.2019

The aim of the work was to estimate the action efficiency of pre-sowing soybean seed bacterization with complex inoculants based on *Bradyrhizobium japonicum* 634b and *Azotobacter chroococcum* T79 under influence of phytolectins in vegetation conditions. It was shown, that during all vegetation period the soybean plants formed vegetative mass more actively: (in 1.2–1.5 times) above-ground part and in 1.2–1.7 times root system by the the complex seed bacterization as compared to the mono-inoculation. There is a direct dependence of soybean vegetative height on the functional (nitrogen-fixing) ability of the symbioses. Advantages of the application of complex compositions for intensification of beans formations (more early terms of reproductive organs forming, greater amount of beans on plants with their mass, exceeding control in 1,1–1,7 time) are shown. The middle increase of soybean harvest to control made from 13% (binary bacterial composition on basis of rhizobium and azotobacter) to 21% (polycomposition on basis of rhizobium and azotobacter activated by the wheat lectin). The compositions based on rhizobium activated by the soybean lectin provided 18% increased seed harvest. Polycomposition containing nitrogen-fixing bacteria activated by appropriate plants lectins led to the 19% increased harvest. It is shown that the harvest increased with higher values of almost all indexes of its structure.

The compositions based on rhizobia and azotobacter activated by wheat lectin as well as the compositions based on rhizobia activated by soybean lectin are the most productive for practical use to increase the soybean yield.

Key words: soybean (*Glycine max* (L.) Merr.), rhizobia, azotobacter, phytolectins, complex inoculants.

Today, microbial biotechnology is employed in agriculture to fulfill environmental and industrial tasks [1–3]. A large segment of microbial preparations for plant husbandry [1–6] is bacterial products for bean cultures based on active, effective and competitive rhizobia presented to artificially bacterize the seeds. A promising approach is creation and application of complex bacterial preparations based on microorganisms with various specialized effects on the plant and soil, algae, arbuscular mycorrhizal fungi, biologically active substances, microelements and plant growth regulators [1; 3; 6–14]. Complex preparations are more stable in the field and have a wider range of action (poly-vector mechanisms) on the components of the plant — soil — microbes system due to the manifold functions of the biologic agents they include. They are more efficient in bringing out the productive potential of phytobacterial symbioses and associations [1; 6–8; 12; 15] compared to bacterial monocultures for seed inoculation.

Soybean is one of the strategic food cultures not only in Ukraine but in many countries worldwide [16]. According to the data of the Ukrainian Association of producers and processors of soybeans, by 2020 soybean plantations in Ukraine may reach 2.4 million hectares. Ukraine occupies the sixth place in its export, after Brazil, USA, Argentine, Paraguay and Canada. Since the world demand for non-GMO soybean increases (Europe alone requires 7 million tons soybean [17]),

developing environmentally safe ways to increase the culture's productivity is currently an urgent problem. With this in mind, we conducted research developing the possibilities of creating multi-component microbial compositions for pre-sowing inoculation of soybean seeds based on plant host-specific rhizobia, agriculturally useful microorganisms of the genus *Azotobacter* and phytoproteins (soybean lectin and wheat germ agglutinin), which are natural bioactive substances with a wide range of action [12; 14; 15].

The paper was aimed to evaluate the efficiency of pre-sowing bacterization of soybean seeds by complex inoculants based on host-specific *Bradyrhizobium japonicum* 634b and bacterium of the genus *Azotobacter* as affected by phytolectins (soybean lectin and wheat germ agglutinin).

Matherials and Methods

The object of our research was symbiotic systems consisting of soybean plants (*Glycine max* (L.) Merr.) of the early-ripening variety Annushka and *B. japonicum* 634b by introduction of rhizosphere diazotrophs *A. chroococcum* T79 on the seeds under the effect of wheat and soybean lectins in complex inoculants. Annushka is an early-ripening variety (National standard of Ukraine) which was included in the State Register of plant varieties suitable for dissemination in Ukraine in 2007, in Russia in 2008, in Europe in 2009, certified as "Organic". It was created by the scientific breeding seed-growing firm "Soievyi vik" (Kropyvnytskyi, Ukraine).

Bacterial cultures (strain collection of symbiotic and associated diazotrophs of the Department of symbiotic nitrogen fixation of the Institute of Plant Physiology and Genetics (IPPG), NAS of Ukraine, Kyiv, Ukraine) were grown on yeast mannitol agar and Ashby's culture medium [18] for 10 and 3 days, respectively, at 28 °C. The rhizobium cells titer was 10^9 cells/ml, *Azotobacter* 10^8 cells/ml. Bacterial compositions were prepared by incubation (i) and mixing the components (*v:v*, stated for the individual experiments) with the rhizobium load kept even for different inoculums.

To activate rhizobia in the inoculum we used 5 µg/ml soybean lectin (SBL, LECTINOTEST, Lviv, Ukraine) [19]. Our pilot studies showed that 5 µg/ml SBL enhanced the symbiotic properties of plant host-specific rhizobia and the level of productivity potential for soybean-rhizobium symbiosis [19]. We also found that such amounts of lectin, unlike the higher concentrations we tried (50 and 500 µg/ml), did not cause accumulation of lectin proteins (allergenic factors) in the soybean yield, which is an advantageous quality of seeds. Rhizobium were incubated with lectin at 28 °C for one day. The trial also included co-incubation (1:1) of *Azotobacter* with wheat germ agglutinin (WGA, LECTINOTEST, Lviv, Ukraine) at 10 µg/ml. Protein-modified diazotrophic microbes were used to prepare inoculation suspensions.

The efficiency of mono- and complex inoculation of soybean seeds was evaluated in vegetation experiments carried out in 2012–2014 at a plantation of the IPPG in natural light and temperature conditions, replicated five times (every variant) in ten-kg Wagner vessels on sand or soil with Gelrigel nutrient mixture (0.25 mineral nitrogen requirement) as follows:

1. No inoculation (water treatment, absolute control group — AC).

2. Inoculation with *Bradyrhizobium japonicum* 634b + water (1:1) (strain-control, *monoinoculant*).

Binar inoculants:

3. Inoculation (*B. japonicum* 634b + *A. chroococcum* T79)i (1:1, bacterial composition).

4. Inoculation (*B. japonicum* 634b + SBL)i (1:1, lectin-bacterial composition).

Poly-inoculants:

5. Inoculation *B. japonicum* 634b + (*A. chroococcum* + WGA)i, 1: (1:1).

6. Inoculation (*B. japonicum* 634b + SBL)i + *A. chroococcum* T79, (1:1):1.

7. Inoculation (*B. japonicum* 634b + SBL)i + (*A. chroococcum* + WGA)i, (1:1):1.

Note: i — the components were incubated at 28 °C for 22–24 hr.

The sand culture experiment included variants No 1–4 and 6, soil culture — No 2–7.

The efficiency of soybean -rhizobium symbioses was evaluated by the growth of the plant vegetative mass, reproductive organ formation and the yield of soybean seeds; at the stages of the primordial, one and three true leaves, and flowering — start of beans inception, active beans formation, and seed full ripeness (Tables 1, 2).

The results were statistically treated using Statgraphics Plus (V. 3.0) software. The mean values and standard errors are provided in the Tables ($M \pm m$). The P-value was calculated after Dospekhov [20]. Dispersion analysis of the soybean yield was done using DAD software [21].

Results and Discussion

We found that in sand culture, the plants in experimental designs with complex seed inoculation actively formed vegetative mass during the whole vegetation period (Table 1). During practically all studied development stages (excluding the early ontogenesis) statistically significant difference was seen between the inoculated and control plants.

A significant difference in aboveground biomass, which was 1.3–1.6 times larger than AC, and 1.5–1.8 times larger than in case of rhizobium seeds monoiculation, was noted for complex bacterization variants at the stages of flowering, active bean formation and full seed maturity. A significant difference to strain control (1.2 times larger aboveground biomass) during flowering was recorded for variant No. 4 (rhizobium + lectin)i, with a symbiotic system also characterized then by the maximal nitrogenase activity of the root nodules [22]. A tendency for increase of aboveground and root biomass by 14 and 10% was noted in variant No. 6 (the preparation dose of lectin was half of that in variant No. 4) compared to variant No. 2 (monoinoculation). At the stage of active bean formation, the plants in variants No. 3 and 4 had aboveground mass 1.2 times larger than control (variant No. 2) (Table 1), and the difference in nitrogenase activity was 1.5–3.1 and 1.2–2.3 times, respectively [22], which suggests a direct link between the development of the photosynthetic apparatus and nitrogenase activity of the rhizobium nodules in legumes. At this same ontogenetic stage there was noted a significant difference in root mass in plants which had been inoculated before sowing; root mass was larger 1.3–1.8 times in relation to AC, and 1.2 and 1.4 times (for variants No. 3, 4) — to strain control (variant No. 2) (Table 1).

In soil culture (in two-year experiments), active root nodule formation with high nitrogen fixation levels [22] in variants with complex seed inoculation also had a positive effect on development of plants which actively formed vegetative mass (Table 2), especially on the root system which is the bacterial habitat [23]. Root mass (mean values) during flowering was 18–70% greater in rhizobium-inoculated seeds (No. 2) or remained at the same level (at the stages of one true leaf and active bean formation). The aboveground mass of soya (mean values) significantly (14 to 59%) exceeded the parameters of control plants. In variants No. 3–5 the symbiotic systems were characterized by a high level of nitrogenase activity during soybean vegetation [22] and the plants substantially differed from the control in vegetative mass (Table 2). Therefore, activation of the plants' development and vegetative mass accumulation in these variants occurs, most probably, due to their improved nitrogen nutrition. Meanwhile, the symbiotic ability to fix nitrogen was low in variants

Table 1. **Vegetative mass (g) formation by soya plants at seed inoculation by complex compositions (absolute dry mass, sand culture)**

Experiment variant, No	Soybean development stage							
	One true leaf		*Flowering — early bean formation*		*Active bean formation*		*Fully mature seeds*	
	AP	R	AP	R	AP	R	AP	R
1	0.93 ± 0.05	0.16 ± 0.01	1.44 ± 0.09	0.30 ± 0.02	1.75 ± 0.12	0.29 ± 0.02	1.54 ± 0.04	0.33 ± 0.01
2	0.96 ± 0.06	0.17 ± 0.01	1.80 ± 0.17*	0.31 ± 0.02	2.68 ± 0.19*	0.38 ± 0.04*	2.09 ± 0.05*	0.48 ± 0.01*
3	1.01 ± 0.05	0.17 ± 0.01	1.95 ± 0.15*	0.32 ± 0.02	3.11 ± 0.32*	0.46 ± 0.03*^	2.08 ± 0.11*	0.43 ± 0.02*
4	1.01 ± 0.06	0.17 ± 0.01	2.24 ± 0.19*^	0.33 ± 0.03	3.20 ± 0.18*^	0.52 ± 0.04*^	2.22 ± 0.07*^	0.51 ± 0.03*
6	1.05 ± 0.06	0.18 ± 0.01	2.05 ± 0.11*	0.34 ± 0.02	2.58 ± 0.19*	0.43 ± 0.04*	2.04 ± 0.10*	0.48 ± 0.03*

Note. Here in after: *1.* No of the variant (pre-sowing seed treatment) — 1. No inoculation (AC, absolute control); 2 — rhizobium (strain control); 3 — (rhizobium + *Azotobacter*)i; 4 — (rhizobium + SBL)i; 5 — rhizobium + (*Azotobacter* + WGA)i; 6 — (rhizobium + SBL)i + *Azotobacter*; 7 — (rhizobium + SBL)i + (*Azotobacter* + WGA) i; *2.* * — statistically significant difference ($P \leq 0.05$) with AC (variant No 1); ^ — significant difference ($P \leq 0.05$) with strain control (variant No 2), where P is the significance level [20].

Table 2. **Soybean plants vegetative mass at complex seed inoculation (soil culture), g**

Variant No	Aboveground biomass			Root		
	experiment I	experiment II	mean	Experiment I	Experiment II	mean
One true leaf stage						
2	1.07±0.04	2.60±0.25	1.84±0.77	0.34±0.02	0.43±0.02	0.39±0.05
3	1.10±0.06	2.10±0.15	1.60±0.51	0.36±0.02	0.39±0.02	0.38±0.01
4	1.18±0.05^	2.49±0.07	1.84±0.66	0.36±0.02	0.45±0.03	0.41±0.05
5	1.18±0.05^	2.50±0.19	1.84±0.67	0.35±0.02	0.51±0.03^	0.43±0.08
6	1.22±0.08^	3.03±0.19	2.13±0.91	0.39±0.02^	0.47±0.03	0.43±0.04
7	1.34±0.06^	2.39±0.13	1.87±0.53	0.38±0.02	0.42±0.01	0.40±0.02
Full flowering — start of bean formation stage						
2	3.30±0.15	5.61±0.50	4.46±1.17	1.79±0.20	2.21±0.30	2.00±0.21
3	4.85±0.36^	5.64±0.39	5.25±0.40	2.25±0.11^	2.44±0.33	2.35±0.10
4	4.00±0.26^	8.94±0.69^	6.47±2.50	2.61±0.21^	4.17±0.36^	3.39±0.79
5	4.03±0.25^	8.51±0.60^	6.27±2.26	2.66±0.10^	3.51±0.40^	3.09±0.43
6	3.63±0.12^	7.27±0.43^	5.44±1.82	1.79±0.27	2.98±0.18^	2.39±0.60
7	3.43±0.33	8.94±0.45^	6.19±2.78	1.57±0.11	3.25±0.47^	2.41±0.85
Active bean formation stage						
2	5.19±0.26	9.79±0.60	7.49±2.32	2.39±0.09	3.79±0.33	3.09±0.71
3	5.95±0.52^	11.15±0.95	8.55±2.63	3.74±0.38^	3.66±0.37	3.70±0.04
4	5.52±0.43	13.09±0.34^	9.31±3.82	2.57±0.11	3.79±0.28	3.18±0.62
5	5.04±0.40	13.36±0.45^	9.20±4.20	2.51±0.24	2.78±0.16	2.65±0.14
6	5.90±0.40^	13.00±0.99^	9.45±3.58	3.00±0.18^	3.55±0.37	3.28±0.28
7	5.83±0.35^	12.70±0.92^	9.27±3.47	2.61±0.07^	2.48±0.20	2.55±0.07

No. 6 and 7 compared to variants No. 4 and 5 [22] while plant biomass exceeded the control by 22% and 39% (flowering stage), 24% and 26% (active bean formation), suggesting that polycompositions No. 6 and 7 manifest to a larger extent as growth factor agents than as regulators of symbioses' nitrogen-fixing ability. Both in sand and in soil, complex compositions were more efficient compared to monoinoculant for the vegetative mass formation.

Evaluating reproductive organs formation on soybean plants at the active bean formation stage confirmed the advantages of complex compositions compared to traditional monoinoculation of the seeds with rhizobium (Table 3). We saw an earlier start of bean formation on the plants ($BEAN^+$ plants) in variants with the complex seeds bacterization (Table 3). At the stage of active bean formation the number of beans formed exceeded that in the variant with monoinoculation using rhizobium, and the mass of the beans was 1.3–1.7 times greater than for soybean monoinoculated with rhizobium.

At the stage of full seed maturity, bean mass statistically significantly increased 1.1-1.3 times in variants with complex inoculation compared to monoinoculation rhizobium (Table 3).

Thus, using complex compositions for pre-sowing treatment of seeds helps to intensify the formation of soya's reproductive organs.

At the stage of full maturity of soybean beans we evaluated the efficiency of complex inoculants based on plant seeds yield (Table 4).

In soil culture (for two seasons, 2013 and 2014), mean yield increase was 13% (binary composition of rhizobium + *Azotobacter*) to 21% (polycomposition based on rhizobium and *Azotobacter* activated by WGA). In variants № 4, 6 (rhizobium activated by SBL) seed yield increase was 18%. In variant No. 7 (bacterium activated by lectins of the respective plants), seed yield increased by 19%. We found that yield increase occurred due to improvements

Table 3. **Soya bean formation at complex seed bacterization (soil culture)**

Variant No	BEAN$^+$ plants, % of all plants in the vessel		Number of seeds formed on a plant	Bean mass per plant, g	1 bean mass, g
	Start of bean formation stage	*Active bean formation stage*			
2	0	100	7.9±1.1	1.44±0.22	0.26±0.02
3	14.3	100	7.5±0.4	2.50±0.20^	0.36±0.03^
4	66.7	100	13.5±0.9^	2.38±0.18^	0.25±0.02
5	62.5	100	11.3±0.9^	2.45±0.24^	0.27±0.02
6	62.5	100	14.4±1.8^	1.97±0.21^	0.27±0.01
7	37.5	100	14.6±0.7^	1.87±0.13^	0.25±0.03
Full seed maturity stage					
2	100		8.4±0.8	2.90±0.16	0.39±0.01
3	100		8.8±0.1	3.36±0.09^	0.41±0.00
4	100		9.0±0.1	3.69±0.07^	0.43±0.01^
5	100		8.7±0.2	3.29±0.12^	0.40±0.01
6	100		9.7±0.2^	3.25±0.11^	0.34±0.02
7	100		8.6±0.6	3.27±0.08^	0.43±0.01^

in practically all its structural parameters (Table 4).

Conducting the dispersion analysis in DAD software [21], we isolated the effects of the composition constituents (*Azotobacter* — Factor A, rhizobium modified by SBL — Factor B, and *Azotobacter* activated by WGA — Factor C) and calculated the influence of every component (Table 5) on the soybean yield (Table 6). We took seeds inoculated with rhizobium as control.

The maximal effect was seen for Factor B (15%) — rhizobium modified with SBL (2013), and Factor C (42%) — *Azotobacter* modified with WGA, and a complex of B and C (24%) — bacterium modified with the respective lectins (2014). The effect of Factor A was 3%.

Thus, the dispersion analysis showed how soybean yield was shaped by compositions containing phytolectins as exogenous regulators of bioactivity of diazotrophs and natural regulators of plant growth [15] (variants No. 4–7).

Clearly, a higher efficiency as reflected in all studied parameters was seen throughout vegetation in complex compositions compared to monoinoculant, as evident by the active growth of vegetative mass, reproductive organs and seed yield.

Such effect is linked to the activating influence of additional components, agriculturally useful bacterium of the genus *Azotobacter*, whose exometabolites contain a various biologically active substances [24; 25] as well as phytolectins with a growth factor effect, which are directly involved in the hormonal regulation of plant's growth and development [15]. The growth of soybean vegetative mass and yield is probably stimulated on one hand due to the ability of both rhizobia and *Azotobacter* to synthesize substances of growth factor activity, in particular hormones of citokinine and auxin nature [24; 25]. Phytolectin, exogenously applied, also increases the production of auxin and citokinine hormones by soil microbes and activates their development [15], and also benefits the development and increased yield of the plants [19] by regulating their hormonal balance among other things [15]. On the other hand, the effect can be explained by high nitrogen fixation ability of symbiotic systems and rhizosphere microbiota in the variants with complex bacterization of the seeds [22], which forms a richer-in-nitrogen nutrition regime and higher productivity of symbioses between soybean plants and the complex inoculants.

The presented results show that the presowing treatment of soybean seeds by specific rhizobium combined with introduction of diazotrophic microbes belonging to the genus *Azotobacter* under the effect of phytolectins in complex inoculants is more effective than seed bacterization with a rhizobium monoculture due to a higher level of symbiotic potential realization. In particular, the effect was seen for nodulation and nitrogenase activity (for the

Table 4. **Yield structure of soybean at complex seeds bacterization (soil culture, mean values for two seasons, 2013 and 2014)**

No	Yield per vessel, g	Number of beans per node	Number of beans per plant	Mass of beans per plant, g	Mass of 1 bean, g	Number of seeds per bean	Mass of seeds per bean, g	Number of seeds per plant	Mass of seeds per plant, g	Mass of 1000 seeds, g	IH K%
2	13.52± 2.35	1.5± 0.2	6.4± 2.1	2.41± 0.50	0.41± 0.02	2.1± 0.1	0.29± 0.04	11.2± 3.1	1.57± 0.33	125.49± 14.63	0.20± 0.01
3	15.31± 1.58 (113)	1.7± 0.2 (113)	6.8± 2.0 (106)	2.91± 0.45 (121)	0.47± 0.06 (115)	2.2± 0.0 (107)	0.32± 0.05 (110)	13.3± 3.3 (119)	1.85± 0.29 (118)	125.50± 15.35 (100)	0.21± 0.01 (105)
4	15.92± 1.45 (118)	1.7± 0.1 (113)	7.2± 1.8 (113)	3.11± 0.59 (129)	0.47± 0.04 (115)	2.2± 0.0 (107)	0.31± 0.03 (107)	14.1± 3.5 (126)	1.95± 0.34 (124)	126.74± 12.66 (101)	0.21± 0.02 (105)
5	16.37± 2.26 (121)	1.6± 0.1 (107)	7.1± 1.7 (111)	3.01± 0.28 (125)	0.48± 0.08 (117)	2.2± 0.1 (107)	0.32± 0.05 (110)	14.2± 4.0 (127)	1.95± 0.42 (124)	130.89± 11.30 (104)	0.21± 0.01 (105)
6	15.91± 1.70 (118)	1.7± 0.3 (113)	7.4± 2.4 (117)	2.92± 0.33 (121)	0.44± 0.10 (107)	2.1± 0.1 (100)	0.30± 0.07 (103)	13.8± 3.7 (123)	1.94± 0.32 (124)	132.79± 16.05 (106)	0.24± 0.02 (120)
7	16.03± 1.77 (119)	1.5± 0.2 (100)	6.7± 1.9 (105)	2.87± 0.40 (119)	0.48± 0.05 (117)	2.3± 0.0^ (112)	0.34± 0.05 (117)	13.7± 3.9 (122)	1.94± 0.35 (124)	134.09± 15.24 (107)	0.24± 0.03 (120)

Note. 1. (in parentheses) —% to strain control (№ 2).
2. Variant №: 2 — rhizobium; 3 — (rhizobium + *Azotobacter*)i; 4 — (rhizobium + SBL)i; 5 — rhizobium + (*Azotobacter* + WGA)i; 6 — (rhizobium + SBL)i + *Azotobacter*; 7 — (rhizobium + SBL)i + (*Azotobacter* + WGA)i. 3. IH — index Harvest.

composition based of rhizobia and *Azotobacter*, activated by wheat lectin) as well as growth regulation effect (for the poly-inoculant based on rhizobium activated by soybean lectin with *Azotobacter*, and the composition based on rhizobia and *Azotobacter* activated by the respective lectins), leading to increased soybean productivity.

Therefore, the higher level of the productive potential's realization for phytobacterial systems, established by soya plants inoculated with *B. japonicum* 634b and *Azotobacter* under the effect of phytolectins in complex inoculants compared to seed inoculation with rhizobium, was caused both by the higher level of symbiotic potential realization of the systems and by growth regulation activity of the biological agents participating in the inoculation compositions.

Introduction of additional biological agents (*Azotobacter chroococcum* T79, soybean lectin, wheat germ agglutinin) into the inoculation suspension led to yield increase compared to monoinoculation with rhizobium by 13% (*Azotobacter*), by 18% (rhizobium activated by soybean lectin), by 21% (*Azotobacter*, activated by wheat germ agglutinin) and by 19% (rhizobium and *Azotobacter*, activated by SBL and WGA, respectively). Compositions, most productive for practical use as biotechnology for soybean yield improvement were based on rhizobium and *Azotobacter* activated by wheat lectin (variants No. 5 and No. 7), and based on rhizobium activated by soybean lectin (variants No. 4 and No. 7).

Table 5. **Effect of the inoculation composition components on soybean yield**

Factor	2013		2014	
	Factor strength, %	HCP	Factor strength, %	HCP
A	3	1.06	3	0.53
B	15	1.06	1	0.53
C	4	1.06	42	0.53
AB	5	1.50	1	0.75
AC	3	1.50	3	0.75
BC	5	1.50	24	0.75
ABC	5	2.13	1	1.05
Other	58	–	27	–
Experiment precision,%	5.10		1.97	
Data variation,%	11.36		5.75	

Note. Factor A — *Azotobacter*; B — rhizobium activated by SBL; C — *Azotobacter* activated by WGA

Table 6. **Soybean yield (g/vessel) at seeds inoculation of compositions based on rhizobium, *Azotobacter* and phytolectins**

№	2013					2014				
	Replications			Mean	Crop increase ± %	Replications			Mean	Crop increase ±%
	I	II	III			I	II	III		
2	10.44	11.43	11.70	11.19	0	16.18	15.52	15.84	15.85	0
3	14.31	12.87	14.04	13.74	+23	16.19	17.93	16.48	16,87	+6
4	12.69	15.12	15.66	14.49	+29	16.98	18.43	16.65	17.35	+9
5	13.41	11.88	16.02	14.13	+26	18.00	18.71	19.10	18.60	+17
6	14.04	14.04	14.58	14.22	+27	17.67	18.31	16.78	17.59	+11
7	15.39	13.14	14.31	14.28	+28	17.79	17.63	17.92	17.78	+12

Acknowledgements

This research was carried out in the framework of Departmental Theme of the NAS of Ukraine for 2011–2015 No. III-12-11 "To study the effectiveness of symbiotic nitrogen fixation in legume plants, depending on strains of inoculants and the action of individual environmental factors (Code of program classification of expenditures is КПКВК 6541030).

The author expresses her gratitude to the Senior research fellow of the Flax Selection Laboratory of the Department of Selection of the Institute of Oilseed Crops of the National Academy of Agrarian Sciences of Ukraine, PhD A. N. Levchuk for help in statistical treatment of experimental data.

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ЕФЕКТИВНІСТЬ СОЄВО-РИЗОБІАЛЬНОГО СИМБІОЗУ ЗА ІНОКУЛЯЦІЇ НАСІННЯ КОМПОЗИЦІЯМИ НА ОСНОВІ РИЗОБІЙ, АЗОТОБАКТЕРА ТА ФІТОЛЕКТИНІВ

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Метою роботи було оцінити ефективність дії передпосівної бактеризації насіння сої комплексними інокулянтами на основі *Bradyrhizobium japonicum* 634б та *Azotobacter chroococcum* Т79 під впливом фітолектинів за вегетаційних умов. Встановлено, що за комплексної бактеризації насіння рослини протягом вегетації активніше формували вегетативну масу: надземну частину (в 1,2–1,5 раза) й кореневу систему (в 1,2–1,7 раза). Відзначимо пряму залежність вегетативного росту сої від функціональної (азотфіксувальної) здатності симбіозів. Показано переваги застосування комплексних інокулянтів для інтенсифікації плодоутворення (більш ранні строки формування репродуктивних органів рослинами, більша кількість бобів із масою, яка в 1,1–1,7 раза перевищувала контроль). Середнє збільшення врожаю сої до штаму-контролю становило від 13% (бінарна композиція на основі ризобій і азотобактера) до 21% (полікомпозиція на основі ризобій та азотобактера, активованого лектином пшениці). Композиції на основі бульбочкових бактерій, активованих лектином сої, забезпечили збільшення врожаю на 18%. Полікомпозиція, яка містить азотфіксувальні бактерії, активовані лектинами відповідних рослин, сприяла збільшенню врожаю на 19%. Встановлено, що зростання врожаю отримано за рахунок збільшення майже всіх показників його структури.

Для практичного застосування розробленої біотехнології з метою підвищення врожаю сої найбільш продуктивними є композиції на основі ризобій і азотобактера, активованого лектином пшениці, а також на основі ризобій, активованих лектином сої.

Ключові слова: соя (*Glycine max* (L.) Merr.), ризобії, азотобактер, фітолектини, комплексні інокулянти.

ЭФФЕКТИВНОСТЬ СОЕВО-РИЗОБИАЛЬНОГО СИМБИОЗА ПРИ ИНОКУЛЯЦИИ СЕМЯН СОИ КОМПОЗИЦИЯМИ НА ОСНОВЕ РИЗОБИЙ, АЗОТОБАКТЕРА И ФИТОЛЕКТИНОВ

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Целью работы была оценка эффективности действия предпосевной бактеризации семян сои комплексными инокулянтами на основе *Bradyrhizobium japonicum* 634б и *Azotobacter chroococcum* Т79 под влиянием фитолектинов в вегетационных условиях. Установлено, что при комплексной бактеризации семян по сравнению с моноинокуляцией растения на протяжении всего вегетационного периода активнее формировали вегетативную массу: надземную часть (в 1,2–1,5 раза) и корневую систему (в 1,2–1,7 раза). Отмечена прямая зависимость вегетативного роста сои от функциональной (азотфиксирующей) способности симбиозов. Показаны преимущества применения комплексных композиций для интенсификации плодообразования (более ранние сроки формирования репродуктивных органов, большее количество бобов на растениях с массой, превышающей контроль в 1,1–1,7 раза). Средняя прибавка урожая сои к штамму-контролю составила от 13% (бинарная бактериальная композиция на основе ризобий и азотобактера) до 21% (поликомпозиция на основе ризобий и азотобактера, активированного лектином пшеницы). Композиции на основе клубеньковых бактерий, активированных лектином сои, обеспечили 18% прибавки урожая семян. Поликомпозиция, содержащая азотфиксирующие бактерии, активированные лектинами соответствующих растений, способствовала повышению урожая на 19%. Установлено, что прибавка урожая получена за счет увеличения значений практически всех показателей его структуры.

Для практического применения разработанной биотехнологии с целью повышения урожая сои наиболее продуктивными являются композиции на основе ризобий и азотобактера, активированного лектином пшеницы, а также на основе ризобий, активированных лектином сои.

Ключевые слова: соя (*Glycine max* (L.) Merr.), ризобии, азотобактер, фитолектины, комплексные инокулянты.