ACTA ABP BIOCHIMICA POLONICA

Vol. 62, No 4/2015
669–675
http://dx.doi.org/10.18388/abp.2015_1100

Regular paper

The effect of application of micromycetes on plant growth, as well as soybean and barley yields*

Lyudmila Ignatova[1], Yelena Brazhnikova[2]✉, Ramza Berzhanova[1] and Togzhan Mukasheva[1]

[1]Faculty of Biology and Biotechnology, al-Farabi Kazakh National University, Almaty, Kazakhstan; [2]Research Institute of Biology and Biotechnology Problems, Almaty, Kazakhstan

The possibility of application of micromycetes (strains *Penicillium bilaiae* Pb14, *Aureobasidium pullulans* YA05 and *Rhodotorula mucilaginosa* YR07) to increase yields of soybean (*Glycine max* cv Almaty) and barley (*Hordeum vulgare* cv Arna) was estimated. It was shown that the most positive effect on germination energy and seed germination after seed treatment with liquid culture, supernatant and filtrate, is achieved at 1:5 dilution. In studying the influence of cell-associated and extracellular biologically active compounds of micromycetes (liquid culture and supernatant) on biometric parameters of seedlings, the maximum stimulating effect was observed in the variants with liquid culture. These strains of micromycetes were used as a bases for various compositions of preparations — application of each strain separately and application of micromycetes mixes. In microfield experiments, the increase of soybean yield ranged from 4.5 to 9.4 quintal/ha, barley — from 2.9 to 5.9 quintal/ha. A significant increase in various parameters of structure of the yield was shown in all experimental variants when compared to the control. It was found that an increase in soybean and barley yields and yield components was higher in the variant with a mix of micromycetes when compared to the separate application of each strain. The most efficient mixture was based on the mix of fungal strains (culture filtrate of *P. bilaiae* Pb14 diluted 1:5 + liquid cultures of *A. pullulans* YA05 and *Rh. mucilaginosa* YR07 in a 1:5 dilution).

Key words: bio-preparations, micromycetes, yield, yield components, soybean (*Glycine max* cv Almaty), barley (*Hordeum vulgare* cv Arna)

Received: 06 July, 2015; revised: 22 September, 2015; accepted: 02 October, 2015; available on-line: 04 November, 2015

INTRODUCTION

Barley is a valuable forage and food crop. The nutrient content of barley compares favorably with that of wheat, corn, oats, milo. Barley is the major cereal in many dry areas of the world. Barley yield depends on the growth conditions, agronomic practices, and on the properties of a cultivar. These conditions play a major role in improving the collection of production per unit area. The aboriginal cultivars play an important role (Vanova *et al.,* 2006; Ullrich, 2011; Alireza, 2015; Tiwari, 2010).

Today, in almost all the regions of Kazakhstan, the trend of soil degradation is going on; processes leading to the loss of soil fertility are developed. Under these conditions the expansion of legumes cultivation can be a significant factor in increasing productivity of agrocenoses. The symbiotic relationships between plants and microorganisms play a crucial role in the life of plants, including legumes crops, and contribute to plant mineral nutrition, adaptation to abiotic stresses, protection against pathogens and pests (Morel *et al.,* 2012; Kiers *et al.,* 2003; Franche *et al.,* 2009; Wells & Varel, 2011; Frey-Klett *et al.,* 2011). Among legume crops, soybean occupies a unique position due to the extremely versatile use. The main feature of soybean, which distinguishes it from other legumes, is the chemical composition of the grain. The protein composition of this culture is the most complete of all vegetable proteins; it has well-balanced amino acid composition (Endres, 2001). Soy is widely used as food, forage and industrial plant due to its nutrient content. Soybean ranks first in cultivation areas and gross grain harvest among legumes and oilseeds crops in the world.

The most important task is ensuring environmental cleanliness and maintaining quality and food safety of grain and grain products. Crop yield formation depends on the sowing conditions in the optimal agronomic terms and at a high level, as well as the efficient use of fertilizers and plant protection products, in particular bio-fertilizers based on plant growth-promoting microorganisms (Singh *et al.*, 2011; Pérez-Montano *et al.,* 2014).

It is known that seed treatment with rhizosphere microorganisms is capable of increasing the biomass of the roots and nutrient uptake by the root system as well as stimulating seed germination due to the production of physiologically active substances such as vitamins, auxins, gibberellins, and inhibiting the development of pathogenic organisms (Morel *et al.,* 2012).

The use of microorganisms with plant growth-promoting abilities isolated from natural habitats is very important. These microorganisms can be used to create highly effective biological preparations for agriculture. The application of bio-fertilizers is an effective alternative to chemical fertilizers. It helps to reduce chemical pollution (Singh, 2011; Pérez-Montano *et al.,* 2014; Agamy *et al.,* 2013).

There is evidence that the mixed cultures of rhizobacteria produce large amounts of phytohormones. In nature, microorganisms live in communities, so the biosynthesis of molecules that stimulate the growth and development of both plants and microorganisms themselves is, enhanced by their interaction. It is known that the precursors of phytohormones, such as tryptophan, are allocated in the rhizosphere with plant root exudates.

✉e-mail: PoLB_4@mail.ru; Yelena.Brazhnikova@kaznu.kz
*The results were presented at the 6th International Weigl Conference on Microbiology, Gdańsk, Poland (8–10 July, 2015).

Plant metabolites excreted in the rhizosphere, contain a variety of nutrients that attract microorganisms (Stefan *et al.,* 2013; Arshad & Frankenberger, 1997; Vessey, 2003).

MATERIALS AND METHODS

Materials. Strains of micromycetes: *Penicillium bilaiae* Pb14, *Aureobasidium pullulans* YA05 and *Rhodotorula mucilaginosa* YR07 were isolated from dark chestnut soil.

The strain of filamentous fungus *P. bilaiae* Pb14 belongs to *Ascomycota*, order *Eurotiales,* family *Trichocomaceae*. The strain of yeast-like fungus *A. pullulans* YA05 belongs to *Ascomycota*, order *Dothideales*, family *Dothideaceae*. The strain of unicellular yeasts *Rh. mucilaginosa* YR07 belongs to Basidiomycota, order *Sporidiales*, family *Sporidiobolaceae*.

The strains were cultured for 5 days in Sabouraud dextrose broth with shaking (240 rpm) at 26°C. After incubation, the *A. pullulans* YA05 and *Rh.mucilaginosa* YR07 strains were centrifuged at $10\,000\times g$ for 10 min. The culture of filamentous fungus *P. bilaiae* Pb14 was filtered through filter paper No. 4 (pore diameter 20–25 microns).

Determination of the optimal dilution. The liquid culture, culture supernatant and culture filtrate were used for soaking of previously sterilized seeds. Variants without dilution and 1:1, 1:3, 1:5, 1:10 dilutions (with water) were studied. Soybean (*Glycine max* cv Almaty) and barley (*Hordeum vulgare* cv Arna) seeds were used in the experiment. After daily soaking, seeds were placed in pots filled with a mixture of sand and sawdust. Seeds soaked in water were used as a control. Seeds were germinated for 14 days. At the end of the exposure, the germination energy and seed germination were determined. Germination energy was determined as a percent of number of seeds (grains) which germinated up to the time of peak germination in a 24 hour period. Seed germination was defined as a percent of number of seeds (grains) which germinated within 14 days under optimal conditions.

Determination of plant growth-promoting effect of micromycetes. The optimal dilutions of liquid culture, culture supernatant and culture filtrate were used for seeds soaking. Seeds were germinated for 14 days. After exposure, biometric research was carried out. Length of stems and roots in the experiment and control was determined.

Microfield experiments. Microfield experiments were carried out in the Almaty region at the experimental plot of the "Turgen" agro-industrial company. Fields of the "Turgen" company are situated in the foothill steppe zone. The soil cover is represented by foothill dark chestnut soils.

Legume crop soybean (*Glycine max* cv Almaty) and grain crop barley (*Hordeum vulgare* cv Arna) were used in the experiment. Microfield experiments were conducted in small plots (1×1 m) in 4 replicates.

The experiment consisted of the following variants:

No. 1 — based on the strain of filamentous fungi *P. bilaiae* Pb14 (culture filtrate in dilution 1:5);

No. 2 — based on strains *A. pullulans* YA05 and *Rh. mucilaginosa* YR07 (liquid cultures in dilution 1:5);

No. 3 — based on a mix of micromycetes (culture filtrate of *P. bilaiae* Pb14 + liquid cultures of *A. pullulans* YA05 and *Rh. mucilaginosa* YR07 in dilution 1:5).

Control — without treatment.

A single-row arrangement of replicates was used in order to maximize the removal of similar plots. Soybean seeding depth was 3–5 cm, barley seeding depth — 4–6 cm. The vegetative growth period of soybean (*Glycine max* cv Almaty) is 100–105 days. The vegetative growth period of barley (*Hordeum vulgare* cv Arna) is 75–85 days.

Analysis of the structure of soybean yield was carried out based on the following elements: plant height, number of pods and seeds per plant, seed weight per plant, weight of 1000 seeds.

The structure of the barley yield was evaluated based on the following components: plant height, ear length, number of grains per ear, grain weight per ear, weight of 1000 grains.

Plant height was determined by measuring the length of the main stem of each plant.

Ear length was determined by measuring ear length of the main stem from the base of the first spikelet excluding awns.

Two samples of 500 pieces from fraction of conditioned air-dry seeds were counted to determine the weight of 1000 seeds (grains). Each sample was weighed to the nearest 0.01 g and multiplied by two, and then the average weight of 1000 seeds to the nearest 0.1 g was calculated. The definition of the weight of 1000 seeds (grains) in terms of dry matter was carried out by the formula:

$$A=B\times(100-C)/100,$$

where A — the absolute mass of seeds, g; B — weight of 1000 air-dry seeds, g; C — seed moisture, %.

RESULTS

Determination of the optimal dilution of liquid culture, culture supernatant and culture filtrate for seed treatment

Active strains of micromycetes *P. bilaiae* Pb14, *A. pullulans* YA05 and *Rh. mucilaginosa* YR07, previously selected in the studies for their biological properties, were used in experiments. These strains possess plant growth-promoting and antagonistic activity (Ignatova *et al.,* 2015).

In the study of morphological characteristics of micromycetes, it was shown that the *A. pullulans* YA05 and *Rh. mucilaginosa* YR07 strains grow as single yeast cells, and the *P. bilaiae* Pb14 strain grows in the form of filaments. Accordingly, the following variants were used for seed treatment: liquid culture and culture supernatant of *A. pullulans* YA05 and *Rh. mucilaginosa* YR07 strains and culture filtrate of *P. bilaiae* Pb14.

The concentration of the biologically active compounds is important in the seed treatment with microorganisms. In studying optimal dilution of liquid culture and culture supernatant of the *A. pullulans* YA05 and *Rh. mucilaginosa* YR07 strains, it was shown that germination energy and seed germination achieved maximum at 1:5 dilution and were higher by 13–15% in a variant with soybean, and by 13–16% in a variant with barley when compared to the control. Similar results were recorded for the culture filtrate of *P. bilaiae* Pb14. The greatest positive effect was noted in the variant with 1:5 dilution (Table 1).

Plant growth-promoting activity of micromycetes strains

Determination of plant growth-promoting effect of micromycetes was carried out by seed soaking method. The influence of the filtrate of *P. bilaiae* Pb14 in 1:5 dilution, cell-associated and extracellular biologically active

Table 1. Influence of various options of dilution on germination energy and seed germination.
Liquid cultures and culture supernatants of the *A. pullulans* YA05 and *Rh. mucilaginosa* YR07 strains and culture filtrate of *P. bilaiae* Pb14 were diluted 1:1, 1:3, 1:5, 1:10 to determine the optimal dilution for seed treatment. The germination energy and germination of soybean and barley seeds were determined.

Variant of experiment	Soybean (*Glycine max* cv Almaty)		Barley (*Hordeum vulgare* cv Arna)	
	Germination energy (%)	Seed germination (%)	Germination energy (%)	Seed germination (%)
Control (water)	85	87	84	85
A. pullulans YA05				
Supernatant without dilution	87	91	86	90
Supernatant in 1:1 dilution	90	91	91	92
Supernatant in 1:3 dilution	89	93	91	91
Supernatant in 1:5 dilution	97	98	95	97
Supernatant in 1:10 dilution	87	89	88	91
Liquid culture without dilution	89	92	88	90
Liquid culture in 1:1 dilution	91	93	89	93
Liquid culture in 1:3 dilution	91	94	90	90
Liquid culture in 1:5 dilution	98	99	96	99
Liquid culture in 1:10 dilution	86	87	86	91
Rh. mucilaginosa YR07				
Supernatant without dilution	88	91	87	89
Supernatant in 1:1 dilution	89	90	90	91
Supernatant in 1:3 dilution	90	93	90	93
Supernatant in 1:5 dilution	96	98	95	99
Supernatant in 1:10 dilution	88	90	89	93
Liquid culture without dilution	89	91	88	91
Liquid culture in 1:1 dilution	92	93	90	90
Liquid culture in 1:3 dilution	90	95	91	94
Liquid culture in 1:5 dilution	97	99	96	98
Liquid culture in 1:10 dilution	85	88	90	92
P. bilaiae Pb14				
Filtrate without dilution	88	92	89	92
Filtrate in 1:1 dilution	90	92	89	93
Filtrate in 1:3 dilution	91	94	90	91
Filtrate in 1:5 dilution	97	99	95	98
Filtrate in 1:10 dilution	85	88	87	90

compounds of the *A. pullulans* YA05 and *Rh. mucilaginosa* YR07 strains (liquid culture and supernatant in 1:5 dilution) was studied.

It has been observed that the stimulating effect of micromycetes could be detected at the earliest stages of plant development, starting from seed germination.

In variants with *A. pullulans* YA05 and *Rh. mucilaginosa* YR07, it was noted that stem length of soybean increased 1.2–1.5 fold, and root length 1.2–2.6 fold when compared to the control seedlings. A 1.3–1.5 fold increase in stem length and 1.1–1.3 fold increase in root length was observed in experiments with barley (Table 2). The best results were obtained by seed treatment with liquid cultures. The maximum stimulating effect was achieved in a variant with a mix of "*A. pullulans* YA05 + *Rh. mucilaginosa* YR07" (Fig. 1).

Statistically significant increase in biometric parameters of two-week seedlings (the increase of shoot and root length) was observed after seed treatment with filtrate of *P. bilaiae* Pb14. The data presented in Table 2 show that length of stems and roots of barley increased 1.5-fold when compared to the control. A 1.5-fold increase in stem length and 2.6-fold increase in root length were obtained in variants with soybean seedlings.

Evaluation of the properties of biological preparations in microfield experiments

Liquid cultures of micromycetes strains: *A. pullulans* YA05 + *Rh. mucilaginosa* YR07, and fungal filtrate of *P. bilaiae* Pb14 diluted 1:5 were used to create test samples of bio-preparations.

The results of microfield studies indicated that soybean yield ranged from 26.4±0.6 quintal/ha to 35.8±1.1 quintal/ha depending on the variant of the experiment. The increase of yield in the experimental variants ranged from 4.5 to 9.4 quintal/ha. The highest soybean yield was obtained in the variant No. 3 — 35.8±1.1 quintal/ha (Fig. 2).

Table 2. Influence of seed treatment with micromycetes strains on seedling growth.
Liquid cultures and culture supernatants of the *A. pullulans* YA05 and *Rh. mucilaginosa* YR07 strains (each strain separately and their mixture) and fungal filtrate of *P. bilaiae* Pb14 were used for seed treatment to determine their plant growth-promoting effect. Stem and root length of soybean and barley seedlings was measured in experiments and control (treatment with water).

Variant of experiment	Length of stems (mm)	Length of roots (mm)
Soybean (*Glycine max* cv Almaty)		
Control	47.2±1.5	30.5±1.1
Culture supernatant		
A. pullulans YA05	60.7±2.5	36.4±1.1
Rh. mucilaginosa YR07	63.3±2.8	38.2±1.5
Mix *(A. pullulans* YA05+ *Rh. mucilaginosa* YR07)	68.2±1.5	42.6±0.8
Liquid culture		
A. pullulans YA05	68.5±2.5	77.2±1.5
Rh. mucilaginosa YR07	70.3±3.1	80.2±3.5
Mix *(A. pullulans* YA05+ *Rh. mucilaginosa* YR07)	73.3±2.7	86.4±3.2
Filtrate		
P. bilaiae Pb14	71.4±2.5	81.2±3.8
Barley (*Hordeum vulgare* cv Arna)		
Control	73.3±2.1	19.2±0.5
Culture supernatant		
A. pullulans YA05	95.2±3.5	22.1±0.2
Rh. mucilaginosa YR07	97.4±4.1	23.2±0.4
Mix *(A. pullulans* YA05+ *Rh. mucilaginosa* YR07)	104.2±3.5	25.2±0.6
Liquid culture		
A. pullulans YA05	101.7±3.5	24.5±0.7
Rh. mucilaginosa YR07	106.8±5.1	25.5±0.5
Mix *(A. pullulans* YA05+ *Rh. mucilaginosa* YR07)	115.4±4.5	29.1±0.8
Filtrate		
P. bilaiae Pb14	107.1±4.2	28.2±0.5

As can be seen from the data presented in Table 3, there were significant differences between plant heights in the experimental variants and the untreated one. The maximum plant height was recorded in variants No. 1 and No. 3, where it reached 83.4±1.5 and 85.2±1.8 cm respectively.

The largest number of pods and seeds per plant were formed under the influence of biological preparation based on the mix of micromycetes and amounted to 73.6±1.6 and 179.5±5.6, respectively. Application of the tested compositions of bio-preparations promoted the formation of higher seed weight per plant and provided an increase in weight by 18–24% compared with an untreated variant. The seed weight values ranged from 26.5±0.6 g to 32.9±0.7 g. The maximum positive effect was recorded in variant No. 3. There was a significant increase in the weight of 1000 seeds in all experimental variants compared to the control. The highest weight of 1000 seeds was observed during treatment with bio-preparation No. 3, where the value of this parameter reached 230.7±5.7 (Table 3).

In conducting the microfield research, the yield of barley amounted to 19.4±0.5 quintal/ha in the control variant. The maximum yield was registered for the variant No. 3, where the increase in yield was 5.9 quintal/ha compared to the variant without treatment (Fig. 3).

Maximum height of barley plants was characterized in variants No. 1 and No. 3 — 89.5±2.5 and 90.4±1.5 cm respectively. The ear length ranged from 6.1±0.1 cm in the variant without treatment to 7.7±0.3 cm in variant No. 3. The increase in the ear length by 10–26% depending on the composition of bio-preparations was observed in all experimental variants (Table 4).

Investigated plants significantly differed in the number of grains per ear, this parameter ranged from 15.4±0.5 to 19.3±0.7 pc. Data analysis allows us to conclude that application of preparations increases grain weight by 20–24% per ear. The grain weight amounted to 0.9±0.04 g per ear in the variant without treatment, while it was significantly higher in the experimental variants with maximum values in variant No. 3 — 1.1±0.02 g. Weight of 1000 grain amounted to 37.9±1.3 g in the untreated variant, which was lower by 16–21% compared to the experimental variants. In variant No. 3, the weight of 1000 grains reached the maximum of 45.5±0.5 g (Table 4).

Three various compositions of bio-preparations were applied: No. 1 — based on the strain of filamentous fungi *P. bilaiae* Pb14 (culture filtrate in dilution 1:5); No. 2 — based on the *A. pullulans* YA05 and *Rh. mucilaginosa* YR07 strains (liquid cultures in dilution 1:5); No. 3 — based on the mix of micromycetes (culture filtrate

Table 3. The structure of the soybean (*Glycine max* cv Almaty) yield.
Three various compositions of bio-preparations were applied: No. 1 — based on the strain of filamentous fungi *P. bilaiae* Pb14 (culture filtrate in dilution 1:5); No. 2 — based on the *A. pullulans* YA05 and *Rh. mucilaginosa* YR07 strains (liquid cultures in dilution 1:5); No. 3 — based on the mix of micromycetes (culture filtrate of *P. bilaiae* Pb14 + liquid cultures of *A. pullulans* YA05 and *Rh. mucilaginosa* YR07 in dilution 1:5). The yield components of soybean were studied.

Variant	Plant height (cm)	Number of pods per plant	Number of seeds per plant	Seed weight per plant (g)	Weight of 1000 seeds (g)
No. 1	83.4±1.5	70.7±0.6	169.5±5.6	31.2±0.7	219.5±5.6
No. 2	79.5±0.6	69.3±0.5	167.7±4.9	31.5±0.3	215.9±6.9
No. 3	85.2±1.8	73.6±1.6	179.5±5.6	32.9±0.7	230.7±5.7
Control (without treatment)	65.7±0.5	58.4±2.6	138.6±2.5	26.5±0.6	202.2±7.2

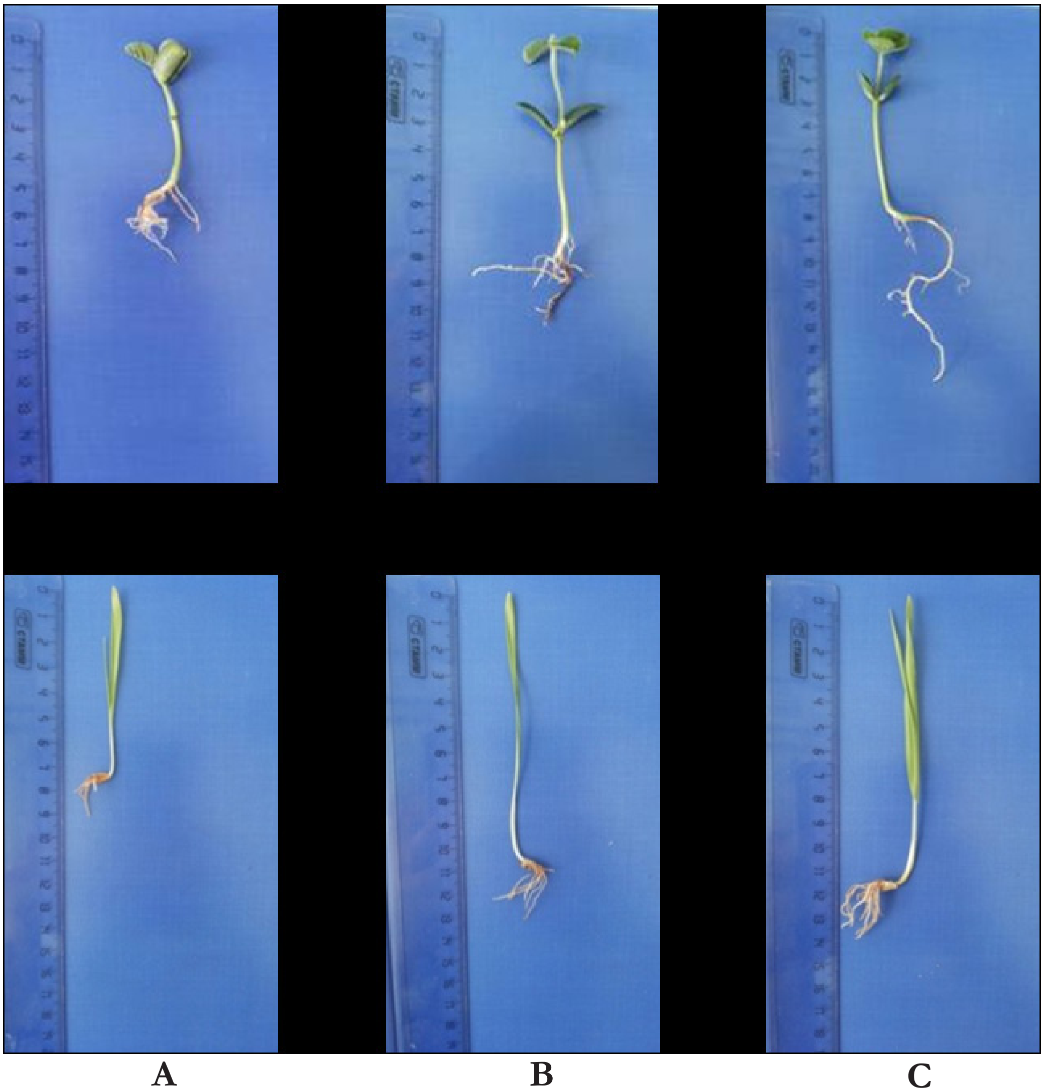

Figure 1. Plant growth-promoting effect of a fungal mixture (*A. pullulans* YA05 + *Rh. mucilaginosa* YR07) on seedlings.
The stem and root length of soybean and barley seedlings was measured at different variants of seed treatment: **A** — seed treatment with water (control), **B** — treatment with supernatant of two strains (*A. pullulans* YA05 + *Rh. mucilaginosa* YR07), **C** — treatment with liquid culture of two strains (*A. pullulans* YA05 + *Rh. mucilaginosa* YR07).

of *P. bilaiae* Pb14 + liquid cultures of *A. pullulans* YA05 and *Rh. mucilaginosa* YR07 in dilution 1:5). The soybean yield at the stage of full maturity was determined.

Three various compositions of bio-preparations were applied: No. 1 — based on the strain of filamentous fungi *P. bilaiae* Pb14 (culture filtrate in dilution 1:5); No. 2 — based on the *A. pullulans* YA05 and *Rh. mucilaginosa* YR07 strains (liquid cultures in dilution 1:5); No. 3 — based on the mix of micromycetes (culture filtrate of *P. bilaiae* Pb14 + liquid cultures of *A. pullulans* YA05 and *Rh. mucilaginosa* YR07 in dilution 1:5). The barley yield at the ripening stage was determined.

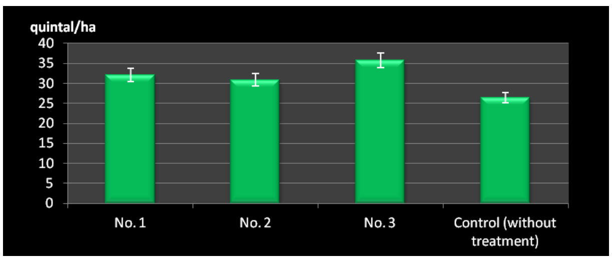

Figure 2. Influence of micromycetes on soybean (*Glycine max* cv Almaty) yield ($p<0.05$).

DISCUSSION

The *plant growth*-promoting microorganisms promote plant growth and development, increase yield, enhance phosphorus, nitrogen, potassium and other elements' up-

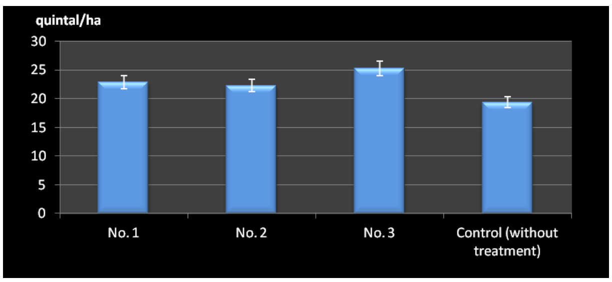

Figure 3. Influence of micromycetes on barley (*Hordeum vulgare* cv Arna) yield ($p<0.05$).

Table 4. The structure of the barley (*Hordeum vulgare* cv Arna) yield.
Three various compositions of bio-preparations were applied: No. 1 — based on the strain of filamentous fungi *P. bilaiae* Pb14 (culture filtrate in dilution 1:5); No. 2 — based on the *A. pullulans* YA05 and *Rh. mucilaginosa* YR07 strains (liquid cultures in dilution 1:5); No. 3 — based on the mix of micromycetes (culture filtrate of *P. bilaiae* Pb14 + liquid cultures of *A. pullulans* YA05 and *Rh. mucilaginosa* YR07 in dilution 1:5). The yield components of barley were studied.

Variant	Plant height (cm)	Ear length (cm)	Number of grains per ear	Grain weight per ear (g)	Weight of 1000 grains (g)
No. 1	89.5±2.5	6.7±0.2	17.9±0.5	1.03±0.03	43.4±1.6
No. 2	88.2±2.1	6.9±0.2	18.8±0.7	1.05±0.02	44.9±1.5
No. 3	90.4±1.5	7.7±0.3	19.3±0.7	1.1±0.02	45.5±0.5
Control (without treatment)	78.1±1.5	6.1±0.1	15.4±0.5	0.9±0.04	37.9±1.3

take, protect against phytopathogens. These beneficial effects on plants allow the use of microorganisms as biofertilizers (Singh *et al.*, 2011; Glick, 1995; Agamy *et al.*, 2013; Hu & Qi, 2013; Ji *et al.*, 2014; Verma & Yadav, 2014).

It is known that intensive metabolism and biochemical transformations start at the earliest stages of seed germination. Therefore the impact of nutrients on the plant, its growth processes, is directly related to the penetration of these biogenic substances into the seeds during germination. One of the important conditions for normal plant development is the optimal concentration of physiologically active substances in the environment (Miransari & Smith, 2014; Kucera *et al.*, 2005). It has been observed that in all experimental variants, plants have more developed leaf blades compared to the control. The most positive effect was obtained in the variant with 1:5 dilution of liquid culture, culture supernatant and fungal filtrate. Probably, in such ratio the optimal concentration of physiologically active substances is achieved.

In studying the influence of cell-associated and extracellular biologically active compounds of micromycetes, the plant growth-promoting activity of liquid culture was higher than the activity of supernatant. Furthermore, it would exclude a centrifugation step which could reduce the cost of the preparation. Localization of these biologically active compounds with plant growth-promoting activity indicates the physiology of interaction between microorganisms and plants, and helps to choose the direction of the biotechnological production of strain-producers and technology of plant treatment.

Microfield experiments on soybean (*Glycine max* cv Almaty) and barley (*Hordeum vulgare* cv Arna) were carried out to evaluate the properties of test samples of bio-preparations. The yield and yield components of these crops were investigated.

The yield is the main integrating criterion of cultivation of any crop. The yield depends on soil fertility, specific weather conditions, the technology used and properties of a cultivar. High yield of investigated crops was obtained after application of tested bio-preparations. Yield of soybean and barley increased by 17–35% and 15–30%, respectively, when compared to the untreated variant.

Weight of 1000 seeds (grains) is an important quality parameter, which reflects the amount of nutrients contained in the seeds and its size. Large seeds contain more nutrients that provide faster plant development in the first phases of growth, higher yields, and more powerful and productive plants. Compositions of bio-preparations had a positive influence on the value of 1000-seeds (grains) weight. There was a significant increase in the weight of 1000 seeds by 7–14% in experiments with soybean and by 15–20% in variants with barley.

Analysis of the data revealed a positive effect of test samples of preparations on the growth characteristics of soybean, which is reflected in increasing of plant height by 21–29%, increase in the number of pods and seeds per plant by 19–26% and 21–29%, respectively, in the experimental variants compared to the control. These results are in agreement with the studies of other authors (Morel *et al.,* 2012; Cassán *et al.,* 2009; Silva *et al.,* 2013).

In the study of the structure of barley yield in the experimental variants, the increases in the plant height by 13–16%, ear length by 10–26%, number of grains per ear by 16–25%, grain weight per ear by 14–22%, were achieved. Similar studies on the influence of microorganisms on the barley yield and yield components were conducted by other researchers (Nabti *et al.,* 2014; Mehrvarz *et al.,* 2006).

The study of yield components of forage crops such as soybean (*Glycine max* cv Almaty) and barley (*Hordeum vulgare* cv Arna) determining its size and quality, has allowed to more fully estimate the efficiency and potential of the various compositions of bio-preparations. It is noted that preparations had a positive influence on all main yield components. The most effective bio-preparation was based on the mix of fungal strains (culture filtrate of *P. bilaiae* Pb14 + liquid cultures of *A. pullulans* YA05 and *Rh. mucilaginosa* YR07, in dilution 1:5). It was found that application of mix of micromycetes was the most effective compared to their separate use. The results obtained are in agreement with literature data (Cassán *et al.,* 2009; Kawai & Yamamoto, 2006).

The increased yield and improving of various yield parameters due to *use* of a mix of micromycetes (composition of bio-preparation No. 3) compared to their separate use (samples No. 1 and No. 2) allows to make an assumption about the possibility of synergistic relationship between the components of micromycetes composition.

Acknowledgments

The laboratory experiments were carried out in Laboratory of general microbiology, Research Institute of Biology and Biotechnology Problems.

This research was implemented in the frames of the project 2198/GF4 “Development of the technology of application of microorganisms with growth-stimulating and fungicidal activity in order to increase agricultural yields” financed by the Ministry of Education and Science of the Republic of Kazakhstan in the frames of the program 055 “Research and / or scientific and technical activities”.

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