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GROWTH AND PRODUCTIVITY OF PORUMBEN CORN HYBRIDS WITH THE APPLICATION OF BIOECOGUM IN SOUTHEAST KAZAKHSTAN

K.B. KARABAYEV[1*], B.U. SULEIMENOV[2*], A.ZH. SMANOV[1], A.N. ZHAKATAYEVA[3], A.M. USTEMIROVA[3], G.D. ZHASSYBAYEVA[3], and A.O. DUTBAYEV[3]

[1]Kazakh National Agrarian Research University, Almaty, Kazakhstan
[2]U. Uspanov Kazakh Research Institute of Soil Sciences and Agrochemistry, Almaty, Kazakhstan
[3]LLP - Kazakh Research Institute of Agriculture and Plant Growing, Almaty Region, Kazakhstan
*Corresponding authors' email addresses: kuanish_kz_92@mail.ru, beibuts@mail.ru
Email addresses of co-authors: sso-kz@mail.ru, a.jan.1990@mail.ru, zhanel-aigul@mail.ru, 87756199344@mail.ru, a.dutbayev@gmail.com

SUMMARY

The domestic liquid bioorganic fertilizer, 'BioEcoGum,' which led to improved germination, also positively affected the growth and yield of cereals. The study sought to determine the influence of the domestic bioorganic fertilizer 'BioEcoGum' on the growth, development, and yield of the 'Porumben' corn (*Zea mays* L.) in southeast Kazakhstan. Processing of corn seeds with the bioorganic fertilizer 'BioEcoGum' activated and increased seed germination by accelerating biochemical functions, enhancing immunity and stress resistance (10%–20%), and improving foliar feeding for growth, development, and increase of grain yield by 50%–70%. In the Porumben 456 and 461 corn hybrids, the accumulation of root biomass during seed processing and double leaf emergence increased to 5.93 t/ha compared with the control production, recorded at 3.96 t/ha (without 'BioEcoGum'), with a difference of 19.7 kg/ha (50%). Based on the presented results, the bioorganic fertilizer 'BioEcoGum' requires promotion for widespread use in corn cultivation in the southern regions of Kazakhstan.

Keywords: Corn (*Zea mays* L.), biohumus application, agriculture, soils, productivity, light chestnut soil

Key findings: 'BioEcoGum' fertilizer positively affected the growth, development, and productivity of the corn crop. Corn seed treatment also enhanced stress resistance and seed germination, improving the growth, development, and intensification of the grain yield (25% to 62%) with foliar application.

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INTRODUCTION

Liquid humic acid is a naturally occurring organic compound in soil, peat, water, and sediments. It has multiple organic components that form when decomposed plant materials encounter bacteria and fungi. This powerful acid has many beneficial assets for plants, including the ability to increase nutrient availability, improve soil fertility, and protect plant roots from stressors like extreme weather conditions. Liquid humic acid also helps deter pests, deactivate harmful chemicals in the soil, and combat salinity levels. Furthermore, liquid humic acid promotes healthy root growth and boosts overall plant health (Suleimenov and Seitmenbetova, 2022).

According to FAO statistics, out of 4.85 billion hectares of the world's agro-land, soil exhaustion and soil toxicosis (including contamination by persistent herbicide residues) cover 1.25 billion hectares and are the prime causes of ~25% global losses in agro-product yield (Kurdyukova, 2012). Scientists draw attention to the fact that excessive chemicalization of soils is a consequence of the marketing pressure of large chemical industries. Excessive use of mineral fertilizers and chemical means of protection can negatively impact soil fertility, the ecological state of the environment, and the quality of cultivated crop products.

Increasing soil fertility and improving the quality of crop production belong to fertilizers and preparations of a biogenic nature, which are vital in the development and implementation engaged worldwide (Nestorenko and Bakirova, 2016). However, bio-preparations are valuable with a wide range of actions, which have the functions of a growth regulator, biofungicide, immunomodulator, and fertilizer (Nestorenko *et al.*, 2017). Reducing the use of mineral fertilizers and the chemicals used for different plant protection measures, combined with employing the latest biotechnological developments, makes it possible to obtain high-quality and ecologically healthy agricultural products and reduce environmental pollution (Panfilov *et al.*, 2007).

The introduction of biological preparations also aimed to optimize natural parameters that determine the mechanisms of self-regulation of soil ecosystems, often used as diagnostics for soil fertility levels (Tereshchenko, 2000; Tiunov, 2004). In contrast to chemical preparations, biological preparations have a more pronounced selectivity of action, are also recognized as harmless to humans and animals, and rapidly decompose in the soil (Unzhakov and Ruchin, 2009; Tolstopyatova, 2010).

Applying such agricultural technologies to obtain high yields makes it possible to attain ecological safety for agronomic production without harming the environment (Atiyeh *et al*., 1999; Ansari and Ismail, 2012). Using biological components and plant growth stimulants can lead to greater profitability, as they cost much less than traditional fertilizers. Biostimulants, such as humic substances (HS), protein hydrolysates (PHs), seaweed extracts (SWE), and microorganisms, have proven effective in improving plant growth, enhancing crop productivity and quality, and lessening the stress effects. In addition, other reasons are to keep developing, investing, and implementing them, eventually banning the use of pesticides in Europe by 2030. Thanks to these biological compounds, they could someday fully replace chemical fertilizers and pesticides (Bano *et al*., 1993).

Corn grains benefit for food (20%), technical (15%–20%), and fodder (60%–65%) purposes. In terms of grain yield, it exceeds all other grain crops. Corn grain dominated the oats, barley, and rye for feed units. A kilogram of it contains 1.34 feed units and 78 g of digestible protein (Durasov and Tazabekov, 1981; Edwards, 1998). In Kazakhstan, maize (*Z. mays* L.) is a valuable forage and grain crop. It is also an essential and promising crop for the Republic of Kazakhstan, cultivated primarily in the Southern zone. New maize hybrids' introduction has also emerged, which have favored high yields with less fertilizer inputs. The chief regions for the production of corn are Almaty, Zhambyl, and Turkestan regions. The total area of corn cultivation is 135,170 ha. The gross corn harvest was 762,360.32 tons, with an average grain yield of 5.64 t/ha in 2018. The maize production of Kazakhstan increased from 435,210 t in 2002 to 1.13 million t in 2021, growing at an average annual rate of 5.33%. The chief goal of the presented research was to study the effects of the liquid humic preparation 'BioEcoGum' on the growth, development, and productivity of grain corn on light chestnut soils under environmental conditions of Southeast Kazakhstan.

MATERIALS AND METHODS

The effects of bioorganic fertilizers and vermicompost on corn productivity gained scrutiny through a field experiment. The core research methods utilized an experimental field, laboratory, and statistical experiments. Field plots 3a and 3b became parcels for sowing the corn crop (Figure 1).

Analytical methods detailed in the 'Manual for General Analysis of Soils 13' helped study the soil composition. Laboratory studies ensued according to generally accepted procedures. Soil samples from a 0–40 cm layer aided in determining the organic matter (GOST 26213-91), mobile compounds of phosphorus and potassium (Machigin method as modified by CINAO GOST 26205-91), and the content of humus, basic nutrients, and the pH.

Further, to assess soil contents with the essential nutrients using spatially coordinated analytical data, calculating their statistically reliable average 'background' contents proceeded in the soils of the surveyed area. In the field (3a), where the cultivation of the corn hybrid 'Porumben 461' exists, the total humus content ranged from 1.29% to 1.51%, the full nitrogen content was 0.091%, gross phosphorus was 0.148%, potassium was 2.47%, and there was an alkaline pH (Table 1). The hydrolyzed nitrogen concentrations and mobile phosphorus were low, while the potassium exchange was high. The soil of field 3b, where the maize hybrid 'Porumben 456' grows, also has similar contents of total humus, hydrolyzed nitrogen, and potassium exchange. These soils only have average levels of mobile phosphorus, but in the previous field, it was low, and in this field, it was higher (Table 2).

Figure 1. Satellite image of the location of research objects ('Agropark Kaskelen').

Table 1. Statistical indicators of Field No. 3a.

Variants	N, cm	Humus (%)	pH	CO_2	Total gross compounds			Movable connections		
					N	P_2O_5	K_2O	N	P_2O_5	K_2O
P – 1	0-40	1.49	8.41	4.12	0.091	0.148	2.60	35.0	14.5	420
P – 2	0-40	1.41	8.73	3.53	0.091	0.162	2.63	32.2	13.0	435
P – 3	0-40	1.29	8.36	2.96	0.091	0.160	2.47	37.8	12.5	205
P – 4	0-40	1.44	8.45	2.99	0.098	0.160	2.54	37.8	18.0	320
P – 5	0-40	1.51	8.54	3.21	0.105	0.178	2.57	49.0	14.0	300

Table 2. Statistical indicators of Field No. 3b.

Variants	N, cm	Humus (%)	pH	CO_2	Total gross compounds			Movable connections		
					N	P_2O_5	K_2O	N	P_2O_5	K_2O
P – 1	0-40	1.22	8.46	3.79	0.098	0.170	2.63	32.2	39.5	345
P – 2	0-40	1.46	8.59	2.91	0.133	0.152	2.69	26.6	28.5	410
P – 3	0-40	1.57	8.30	3.33	0.105	0.148	2.69	44.8	47.5	415
P – 4	0-40	1.19	8.54	3.95	0.084	0.168	2.57	42.0	44.0	285
P – 5	0-40	1.35	8.61	4.09	0.091	0.192	2.57	50.4	67.5	300

Table 3. Scheme of field experiments laid on light chestnut soils with the use of biofertilizer 'BioEcoGum'.

Fields	Predecessor	Area (ha)	Agricultural practices
Field №3 a	Corn	1	$N_{100}P_{70}$ - background + untreated corn seeds of the Porumben 461 hybrid without plant spraying – control
		5	Background + treatment of seeds of corn hybrid Porumben 461 and double spraying with BioEcoGum
Field №3 b	Corn	1	$N_{100}P_{70}$ - background + untreated corn seeds of the Porumben 456 hybrid without plant spraying – control
		5	Background + treatment of seeds of corn hybrid Porumben 456 and double spraying with BioEcoGum

Employing the methods of complex soil study helped solve the set tasks. Arranging the production field experiments pursued scientific and practical research to develop and implement agro-meliorative methods in increasing corn productivity based on the use of bioorganic fertilizer 'BioEcoGum' (Table 3). With a nitrogen-phosphorus background (N100P70), assessing the effects of seed treatment and spraying of corn plants showed a comparison with the control (without treatments). As presented in Table 1, the experiments ran on four sites on the fields labeled No. 3a and 3b at the Agropark Kaskelen, Almaty Region, Kazakhstan.

RESULTS AND DISCUSSION

One of the significant factors that determine the productive state of the soil cover, its features, and prospects for use in crop production is the spatial belonging of the research objects to soil and climatic conditions, with a brief description given as follows (Bekenova *et al*., 2017). It is also well known that climate, as a factor of soil formation, directly impacts biological, chemical, and physical properties, as well as the water-thermal regime of the soil cover (Boonlertnirun *et al*., 2012; Fernandez *et al*., 2023).

The climate in Kaskelen, Almaty region, Kazakhstan, is cold and temperate with significant rainfall, including the driest month. The average temperature and annual precipitation in Kaskelen were 7.80 °C and 494 mm, respectively. September emerged as the driest month, with an average rainfall of 22 mm. However, most precipitation falls in May at an average of 81 mm. The warmest month was July (22.10 °C), while the coldest was January (-7.90 °C).

Field studies transpired on light chestnut soils, taking soil samples from 0–40 cm depth in five repetitions, characterizing the soil fertility. The organic matter content of humus in the upper soil layer (40 cm) was 1.35%, with an alkaline soil-pH reaction. The carbonate (CO_2) content was average, while the common forms of nitrogen, phosphorus, and potassium were 0.102%, 0.166%, and 2.57%, respectively. The plants used the active forms of macronutrients for nutrition. The topsoil contains hydrolyzable nitrogen, mobile phosphorus, and exchangeable potassium, i.e., 39.2 mg/kg, 45.4 mg/kg, and 415 mg/kg, respectively. Thus, the experimental soil sufficiently contained active forms of macronutrients for the maize crop growth and development.

The corn cultivation technology is traditional for the foothill zone. Corn also has the highest demands for moisture, heat, light, nutrients, and other environmental factors. Corn uses soil moisture sparingly, absorbing approximately 250–400 kg of water to create one kg of dry matter. The long vegetative period of maize ripening allows the formation of a powerful leafy mass, while the water consumption can reach 3–6 t/ha during the growing season. A significant reserve for enhancing the corn yield is the optimization of the introduction of nutrients because the corn responds well to fertilization. At the same time, in conditions of intensified agricultural production, a crucial task is to prevent massive losses of humus, especially the labile part of organic matter.

Almost all genetic and agronomic properties and soil regimes have close linkages to the content and composition of organic matter. Bioorganic fertilizer has an accumulative, regulatory, and protective function in the life of plants, helping increase crop yields by 20%–30% and improving product quality. Plants absorbed it by almost 100%, while the nitrate content in the product is at the natural level (Igonin, 2012). Corn is a heat-loving plant with seeds germinating at 8 °C–10 °C. The average daily temperature of 20 °C–23 °C is most favorable for the growth and development of maize crops during the brushing season.

Porumben maize hybrids 456 and 461, having medium-late maturity traits, attained cultivation on light chestnut soils. Their seeds incurred 'BioEcoGum' liquid treatments at 2.5 liters of biofertilizer per ton of seeds, with a working solution of 20 liters of water. At the initial stages of development of three to five and seven to eight leaves, foliar treatment with the 'BioEcoGum' liquid ensued at 5 l/ha, and the working solution was 300 liters of water. The sowing of corn occurred on April 16, 2018, with a seeding depth of 5–6 cm. The three- to five-leaf phase started on May 8, the seven- to eight-leaf phase was on June 1, and the maturity phase was on July 26.

The number of plants per 1 m^2 in the control variant (without treatments) in the three- to five-leaf phase was 8.2. The variant with seed treatment and double spraying of corn plants gave a slightly higher number of plants (11.4 pcs). The height of the stems of the Porumben corn hybrids 456 and 461 was approximately the same in both variants (11.9 and 12.3 cm, respectively).

At the maturity stage, the number of plants was slightly lower than the three- to five-leaf stage, while maintaining the difference in variants. However, in the corn hybrids Porumben 456 and 461, the plant height increased to 192.3 cm in the control treatment. In the variant with the corn seed treatment before sowing and double-foliar feeding of 'BioEcoGum' plants, the plant height was 30.7 cm higher than the control variant. The number of ears on the variant with 'BioEcoGum' was also higher than the control variant by 2.3 pieces. Corn requires increased mineral nutrition, probably due to the long growing season and the ability of plants to absorb nutrients before physiological maturity (Kravchenko *et al*., 2002, 2004).

For producing a ton of maize grain yield, depending on hybrids and other conditions, corn takes out, on average, 34 kg of nitrogen, 20 kg of phosphorus, and about 37 kg of potassium. Corn consumes nitrogen from the soil throughout the growing season; however, the critical period for nitrogen consumption falls on the flowering-grain formation phase. Lack of nitrogen negatively affects grain yield and its quality traits. Phosphorus is also essential throughout the growing season, and its acute need was evident from the first stage of plant growth and development, utilized for root progress. Lack of phosphorus at the beginning of the growing season receives no compensation when applied later (Kravchenko *et al*., 2004). Potassium enters the maize plants at the moment of germination, and more than 90% accumulates in the brush phase (Kravchenko *et al*., 2002). Potassium affects the metabolism and movement of carbohydrates, participates in protein metabolism, and increases the plant body's resistance to fungal diseases. The presented results also showed that pre-sowing treatment of corn seeds and double foliar feeding of plants, regardless of the presence of soil with mineral nutrition, provides a reliable increase in the corn grain yield.

Comparatively high efficiency of BioGumEco biofertilizer application was visible in Porumben maize hybrid 456, where the number of plants at spraying per m^2 was 6.6 pieces compared with the control variant. The highest indicator of grain weight per cob (133 g) appeared in the variant Porumben corn hybrid 461, which was 26% higher, on average, than the control variant. Maize grain yield in field 3b with Porumben hybrid 456 in the control was 6.4 t/ha. However, in the variant with the application of BioEcoGum, the yield enhanced and reached 10.4 t/ha, with a significant grain increment of 4.0 t/ha (62%) (Table 4).

On field 3a, with a low content of mobile phosphorus, the grain yield of Porumben maize hybrid 461 with the control variant was 6.0 t/ha. However, in the variant with seed treatment and double foliar application to the plants, the yield increased to 10.8 t/ha, with a grain increment of 4.8 t/ha (80%) (Table 4). Thus, seed treatment with bioorganic fertilizer BioEcoGum activates the process of seed germination by accelerating biochemical functions, increases seed germination by 10%–20%, enhances immunity and stress resistance, improving foliar feeding for growth and development, and eventually raising the grain yield by 50%–70%.

Table 4. Productivity of Porumben two corn hybrids 456 and 461.

Variants	Plants m^2 (#)	Cobs plant^{-1} (#)	Grain weight cob^{-1} (g)	Grain yield (t/ha)	Increment	
					t/ha	%
Porumben corn hybrid 456 (t/ha, average for 2019–2020)						
No treatment	6.4	1.1	102	6.4	-	-
Seed treatment, 2-fold spraying of plants	6.6	1.3	126	10.4	4.0	62
SSD				0,88		
Porumben corn hybrid 461 (t/ha, average for 2018–2020)						
No treatment	6.3	1.1	105	6.0		
Seed treatment, 2-fold spraying of plants	6.5	1.2	133	10.8	4.8	80
SSD				0.72		

SDD (smallest significant difference)

The use of 'BioEcoGum' liquid not only improves the growth, development, and productivity of corn, but also enhances the progress and maturity of the root system. The root system of corn is fibrous and consists of several layers. The grain germinates with one embryonic root, from which the lateral embryonic roots extend, making up the first layer of the root system. Primary roots' formation (second layer of the root system) emerged from the first node of the underground part of the stem. From other underground nodes of the stem, nodal roots (the third layer of the root system) develop. Supporting (aerial) roots occur from above-ground nodes located on the soil surface, which, going deeper into the soil, ensure the stability of plants. When hilling plants, aerial roots form an additional fibrous system, which is involved in nutrition.

The bulk of the roots extends to a depth of 30–60 cm, and some of the roots penetrate to a depth of 150–200 cm. With a lack of moisture in the upper layer at the beginning of the growing season, the roots spread deeply; however, with a moisture excess in the upper layer, the roots branch out at the soil surface. Plants with a root system close to the soil surface tolerate a lack of moisture during flowering and are inferior to plants with a root system that penetrates deeply. In the field experiment, the accretion of the biomass of the corn roots' measurement depended on experimental variants. Maize seed treatment and double spraying of the plants positively affected the root biomass accumulation.

Thus, the accumulation of root biomass of corn hybrids Porumben 456 and 461 in the control variant was 3.96 t/ha and, in the case of seed treatment and two-fold foliar application, an increase in root biomass resulted in 5.93 t/ha, with the difference of 19.7 kg/ha (50%). Mineralization of root crops and plant residues allows organic matter reserves and macro-elements replenishment. Comparative analysis showed that during the growing season, there was a tendency to increase the content of organic matter (humus) from 0.350% to 0.354%. According to the analysis, the corn root system contains 0.560%, 0.120%, and 0.325% nitrogen, phosphorus, and potassium, respectively. A distinct instance of such an advantage was the difference between the root system of maize (in control) compared to the variant with the 'BioEcoGum' option.

CONCLUSIONS

Liquid bioorganic fertilizer BioEcoGum positively affected the growth, development, and productivity of the Porumben corn hybrids 456 and 461. Pre-sowing treatment of corn seeds with BioEcoGum solution increases the germination by 10%–30%. Foliar treatment of maize plants enhances the growth and development of the plants, increasing the grain yield (62% to 80%) and the biomass of roots by 50%. Corn seed treatment and foliar application of the plants, regardless of the availability of the soil with elements of mineral nutrition, provide a reliable increase in grain yield. Therefore, when growing corn in the southern regions of Kazakhstan, the bioorganic fertilizer 'BioEcoGum' attained a high recommendation for wide use.

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