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The influence of biofertilizers and organic fertilizers on productivity, quality and storing of cabbage (*Brassica oleracea var. capitata* L.) in the South-East of Kazakhstan

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Abstract

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According to official statistics, cabbage is annually cultivated in the area of 120-150 thousand ha in Kazakhstan, and there is still a demand for cabbage in local market. Therefore, there are high requirements to productivity and quality of cabbage. Due to a high demand for healthy food, including vegetables, the research on cultivation of cabbage by using biofertilizers and organic fertilizers promotes to increase a number of local farmers that grow ecologically safe products. The present study was conducted to investigate the effect of biofertilizers and organic fertilizers on yield, quality and ecological purity of cabbage crop. Data were collected for 3 consecutive years. Among different biofertilizer variants, variant with manure 60 t/ha + Straw 3 t/ha + N_{30} produced the highest yield in cabbage followed by variant with manure 60 t/ha. Both of these variants produced significantly higher cabbage yield as compared to control variant. MERC 1 l/ha variant produced cabbage with maximum vitamin C while sugar content of cabbage was highest in variant with Biosok 5 l/ha. Overall, yield and quality of cabbage was higher in biofertilizers and organic fertilizers variants as compared to control. There was observed no negative effect of biofertilizers and organic fertilizers on cabbage storability.

Keywords: cabbage; *Brássica olerácea*; biofertilizer; organic fertilizer; manure; yield; storing quality
Abbreviations: KazRIPaVG – Kazakh Research Institute of Potato and Vegetable Growing; N – nitrogen; P – phosphorus; K – potassium; t – ton; ha – hectare; t/ha – ton per hectare; kg – kilogram; g – gram; mg – milligram; m^2 – square meter; mg% – milligram/percentage; % – percentage; MPC – maximum permissible concentration

Introduction

Vegetables are source of essential vitamins such as vitamin C, vitamin A, vitamin B1, vitamin B6, vitamin B9, vitamin E, and minerals, dietary fiber and phytochemicals to humans (Autko, 2008; Rai et al., 2013; Bahadur et al., 2006). Vegetable consumption also helps to reduce dangerous diseases and other medical conditions (Herencia et al., 2011; Autko, 2008).

Almost three-fourths of the world's production of vegetables occurs in Asia, mostly in China, which produces over half of the world's vegetables (Official Statistical Data RK). The area of world land devoted to vegetables has been increasing due to the potential income value from vegetables (Aitbayev et al., 2018). Production of vegetables is more profitable than traditional crops farming (Autko, 2008; Aitbayev et al., 2018). However, vegetable production is a high-input and labor-intensive activity that requires a large labor force from cultivation to processing (Boyhan et al., 2009). Furthermore, many vegetable crops require careful monitoring of plant health, and careful attention to weed control, irrigation, fertilization, harvest timing, and handling (Organic Farming in Germany, 2017).

Cabbage (*Brassica oleracea L. var. capitata*), is one of the most important vegetable of the Brassicaceae family (Znidarcic et al., 2007). Cabbage contains 18-24% of dry substances, 12-17% of sugar, and 13-15 mg of vitamin C (Rai et al., 2013; Bahadur et al., 2006; Kedino et al., 2009; Mitova & Dinev, 2018). Cabbage is unique in its content of biologically and physiologically active substances. The caloric content is also very high. It contains proteins, fats, fiber, pectins, sugars (sucrose, fructose, and glucose), organic acids (malic, citric, oxalic and folic), vitamins C, B1, B2, P, PP, and minerals (sodium, potassium salts, calcium, iron, phosphorus, iodine, magnesium, cobalt and manganese) (Westerveld et al., 2003; Znidarcic et al., 2007). In Kazakhstan, according to statistics in 2016, vegetables were cultivated in the area of 146.2 thousand ha, and 3.564 million t were harvested. The country supply by vegetables was 210% (Official Statistical Data of RK). Cabbage was cultivated nearly on an area of 7 thousand ha (5%) (Official Statistical Data of RK). Nowadays, newly released cabbage varieties in market have yield potential up to 50-70 t/ha. However, the actual yield of these varieties is low (28-32 t/ha) (Official Statistical Data of RK). Deterioration in soil fertility, less availability of soil moisture, and change in climatic conditions are among few factors that adversely affect cabbage yield irrespective to its good genetic potential. Breeding programs are directed to development of hybrid varieties that are more resistant and suitable for biological production (Antonova, 2012; Antonova et al., 2012).

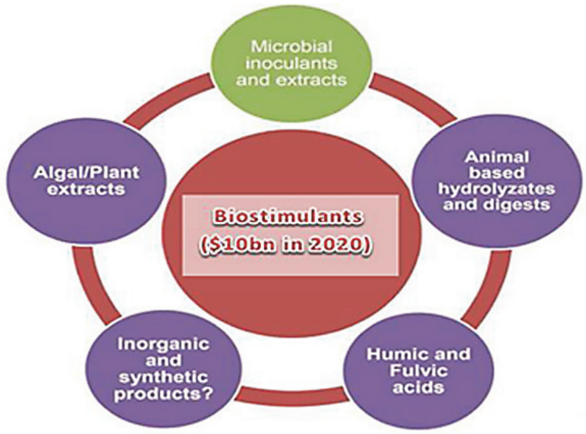

Fig. 1. Biostimulant market share in 2020

The first biostimulants was rhizobium "atmospheric nitrogen fixing microbes in legume plants" introduced by Martinus Beijerinck in 1888 (Kumari et al., 2015; Westerveld et al., 2003). Since then, various types of biostimulants have been either discovered or invented (Kumari et al., 2015). In literature, there are many types based on origin, extraction, mode of action. However broadly speaking, these biostimulants can be divided into two categories: microbial and biochemical. Microbials include biopesticides, bio-fertilizers, inoculants, plant growth-promoting rhizo-bacteria. Biochemicals include antioxidants, bio-molecule, enzymatic extracts, plant extract, phyto-hormones, bio-pesticides (Figure 1) (Turan et al., 2014; Kumari et al., 2015).

Biofertilizers foster plant growth and development throughout the crop life cycle from seed germination to plant maturity in different ways which depend on their nature, composition, mode of action, application timing and growing conditions. Organic production and consumption are growing steadily and constantly across the world (Figure 2)

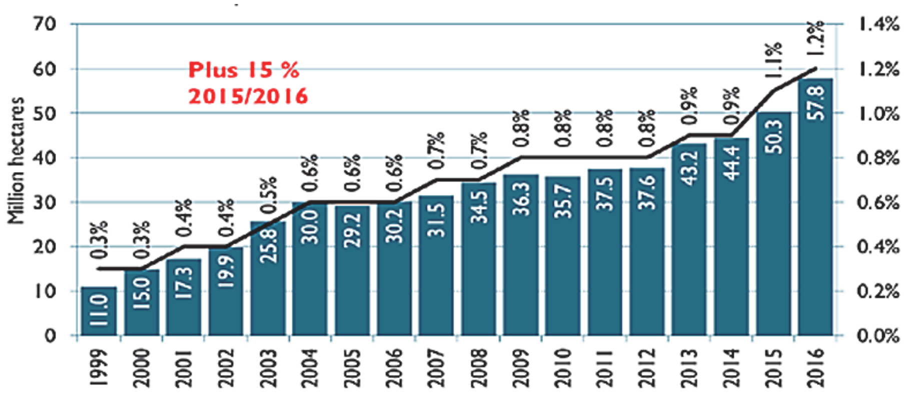

Fig. 2. Growth of the organic agriculture land and share

(Willer & Lernoud, 2016; Bulluck et al., 2002; Birkhofer et al., 2008).

Cabbage belongs to a group of vegetables with a high nitrate-accumulating ability. The main factor affecting the level of nitrates in products is the use of fertilizers (Znidarcic et al., 2007). Fertilizers act as the main agrochemical method for increasing the productivity of vegetables and determine the quality of the crop (Birkhofer et al., 2008; Nenova & Mitova, 2018). Therefore, it is necessary to use environmentally safe fertilizer systems. Taking into the consideration the above mentioned, the Kazakh Research Institute of Potato and Vegetable Growing conducted field experiments to study the effect of various types of bioorganic preparations and organic fertilizers on the yield, quality, and storing quality of cabbage.

Material and Methods

Field data

The research was carried out during the period 2015-2017 at the experimental fields of the Kazakh Research Institute of Potato and Vegetable Growing (KazRIPaVG) located in the foothill zone of the South-East of Kazakhstan and on the northern slope of the Zailiysky Alatau Mountains (1000-1050 m above sea level). The South-East Kazakhstan (Almaty region) is a large region of the country farming potatoes and vegetables.

The climate of the foothill zone of the South-East of Kazakhstan is sharply continental, characterized by large daily and annual variations in air temperature, cold winters and prolonged hot summers. The air temperature reaches the minimum values in January by -32-35°C, the average by 6-14°C, the maximum values are in July by +37-43°C, the average by +22-25°C. The warm period is 240-275 days, and the frost-free period is 140-170 days. The sum of positive temperatures (above 0°C) is 3450-3750°C, and the sum of active temperatures (above 10°C) is 3100-3400°C. The relative air humidity reaches its maximum in winter by 85-90% and minimum in summer by 35-40%. In average, it is within 50-60% in the warm period.

The hydrothermal coefficient is 0.7-1.0. The annual amount of precipitation is 350-600 mm, during the warm period is 120-200 mm. The soil cover of the foothill zone of the South-East of Kazakhstan is represented by the most diverse types of soils (chernozem, chestnut and serozem).

The soil of the experimental fields of KazRIPaVG is dark chestnut and medium loamy. The soil layer contains 2.9-3.0% humus, 0.18-0.20% of total nitrogen, and 0.19-0.20% of total phosphorus. The content of hydrolized in alcaline solution N is 47.6 mg/kg, P_2O_5 is 130 mg/kg and K_2O is 200 mg/kg in soil. The cation exchange capacity is 20-21 meq. per 100 g. The reaction of the soil solution is slightly alkaline (pH 7.3-7.4). The volumetric mass of the soil is 1.1-1.2 kg/cm^3, and the lowest moisture capacity is 26.6%. As a result of long-term use (more than 60 years) of soil in irrigated vegetable farming, dark chestnut soils underwent a significant change in fertility parameters.

Sample preparation and analytical methods

In the field experiments and laboratory studies, classical methods were used such as agrochemical methods for studying soils, method of agrochemical research (Yudin, 1980); method of field experiment (Dospekhov, 1985); experimental methodology in vegetables and melon growing (Belik, 1992).

There are several methods for identification of the qualitative indicators of cabbage was used in the research. Dry matter analyzed by weight method (drying); total sugar analyzed according to Bertrand; vitamin C analyzed according to Murray; nitrates analyzed by potentiometry using ion-selective electrodes.

Objects of research are cabbage, organic fertilizers, biofertilizers (Biohumus, MERC and Biosok). There is a brief description of biofertilizers used in the research.

Biohumus (Kazakhstan) is an organic fertilizer obtained in the process of processing organic waste by earthworms. Biohumus is a 100% natural product with a rich and diverse composition. The main components of biohumus are humus (40%), nitrogen (3%), potassium (1.2%), phosphorus (5%), calcium (5%), and magnesium (5%). In addition, biohumus contains microelements, such as boron, manganese, copper and zinc. Also, there are many humic substances, growth stimulants and enzymes (Aitbayev et al., 2018).

MERC (Kazakhstan) is a new generation of microbiopreparations based on compounds of chlorophyll-vitamin-phytoncide composition of plants and microelements (Fe, Mo, Cu, Zn, Mn, Co, B). It has high effect on increasing crop yields and creates favorable conditions for reproduction of soil microorganisms that translate into the form (salt) assimilated for plants more than 19 macro and micro elements, providing plants with a balanced diet of 100% (Aitbayev et al., 2018).

Biosok (Kazakhstan) is a new complex microbiological organo-mineral humic fertilizer, bio-stimulator of growth, plant protection and development. Biosock is produced by red earthworms. Enriched with nitrogen and potassium, extract of bio-humus contains humins, fulvic acids, phytohormones, antibiotic compounds, a complex community of microelements and microorganisms (metabolic products of earthworms) that revive the fertility of without fertilizers (Aitbayev et al., 2018).

In the field studies, mineral fertilizers used as control variant in comparison to biofertilizers. There is as nitric fertilizers used ammonium nitrate (34.5% a.i. N), phosphoric used double superphosphate (46% a.i. P_2O_5) and potassium used potassium chloride (60% a.i. K_2O).

The size of experimental plot was 35 m² (3.5 m × 10 m), 4-fold repetition used in the research.

Also, a local cabbage variety "Nadiusha" selected by KazRIPaVG researchers was used in the experiment. Agricultural methods of growing cabbage are common for the foothill zone of the South-East of Kazakhstan, and it was carried out with the recommendation of KazRIPaVG for farmers.

Results and Discussion

In Kazakhstan, vegetables are cultivated by irrigated methods (Grigoruk & Klimov, 2016; Aitbayev et al., 2018). In the foothill zone of the South-East of the Kazakhstan, each ha of irrigated land has a great value, where high-fertile soils and sufficient water resources are concentrated. Therefore, all new developed scientific methods, such as selection achievements and developed technologies should be aimed at increasing the productivity of vegetables. The yield of vegetables remains as a main indicator of the effectiveness in any agriculture technologies and/or methods.

The present research showed that biofertilizers application in cabbage increased the yield. In the control plot, where cabbage was grown without fertilizers, the yield was on average 27.90 t/ha where the yield decreased during the last three years.

On the control plot with fertilizers ($N_{180}P_{90}K_{90}$), where the norms of mineral fertilizers recommended by KazRIPaVG for cabbage were applied, 39.4 t/ha yield was obtained. On three variants of field studies with organic fertilizers, high yields of cabbage were obtained. For instance, the yield in the variants with 60 t/ha of manure + straw was 43.5 t/ha; in the variants with 60 t/ha of manure was 40.6 t/ha; in the variants with biohumus was 39.2 t/ha. The yield increase of variants compare to control plot in percentage was 55.91%, 45.52% and 40.50%, respectively (Table 1). In other variants, the yield was lower than the fertilized control (NPK) but significantly exceeded the unfertilized control. On variants with biofertilizers, yield was obtained from 33.1 to 38.0 t/ha. Hence, there was additionally 5.2-10.1 t/ha of yield, which is higher by 18.64-36.20% to the control plot.

According to current experimental study, it could be concluded that biofertilizers and organic fertilizers have positive effect on cabbage yield. Cabbage is very responsive to organic fertilizers, especially late varieties with a long growing season (Mitova & Dinev, 2012). All applied organic fertilizers provided a significant increase in the yield of cabbage compare to unfertilized control. This is due to a better supply of plants with nutrients when applying organic fertilizers (manure, bird droppings and straw) and biofertilizers (Biohumus, Biosok and MERC).

In vegetable production, a quality of the fruit is very important, since they have a direct impact on the human health. Vegetables are used mainly for fresh or after shallow processing. Therefore, vegetables should be environmentally safe without toxic residues and with high contents of vitamins. Hence, we tested biochemical analyzes of the yield of cabbage considering the importance of the quality of vegetables for fresh and processing uses.

In the study, a dry content of cabbage was from 9.43 to 10.31%. At the same time, a high dry content was observed

Table 1. The effect of biofertilizers and organic fertilizers on the yield of cabbage

Experiment variants	Average yield of cabbage, t/ha				Additional yield	
	2015	2016	2017	Average	t/ha	%
Control (without fertilizers)	29.6	28.5	25.7	27.9	–	–
$N_{180}P_{90}K_{90}$ (control with fertilizers)	38.7	39.2	40.3	39.4	11.5	41.2
Manure 60 t/ha	40.5	39.7	41.6	40.6	12.7	45.5
Bird droppings 5 t/ha	35.4	33.8	32.7	34.0	6.1	21.9
Straw 3 t/ha+N_{30}	36.2	32.4	30.8	33.1	5.2	18.6
Manure 60 t/ha + Straw 3 t/ha + N_{30}	43.8	41.7	45.0	43.5	15.6	55.9
Bird droppings 5 t/ha + Straw 3 t/ha + N_{30}	39.0	38.6	36.5	38.0	10.1	36.2
Biohumus, 4 t/ha	41.4	37.9	38.4	39.2	11.3	40.5
MERC, 1 l/ha	34.9	32.0	33.1	33.3	5.4	19.3
Biosok, 5 l/ha	34.3	32.5	35.2	34.0	6.1	21.9
m, %		2.68	1.98			
md 095, t/ha	2.94	3.51	2.35			

Table 2. The effect of biofertilizers and organic fertilizers on the quality of cabbage

Experiment variants	Dry matter %	Vitamin C mg%	Total sugar %	Nitrates mg/kg
Control (without fertilizers)	10.11	28.64	5.13	106
$N_{180}P_{90}K_{90}$ (control with fertilizers)	10.11	30.19	5.63	183
Manure 60 t/ha	9.71	32.74	5.47	149
Bird droppings 5 t/ha	9.43	29.79	5.41	149
Straw 3 t/ha + N_{30}	10.16	30.24	5.74	127
Manure 60 t/ha + Straw 3 t/ha + N_{30}	10.04	29.24	5.45	151
Bird droppings 5 t/ha + Straw 3 t/ha + N_{30}	9.54	30.77	5.66	179
Biohumus, 4 t/ha	9.67	31.27	5.42	140
MERS, 1 l/ha	10.31	33.62	5.07	126
Biosok, 5 l/ha	9.46	29.79	5.89	129

in the following test options, such as MERC (1 l/ha) with 10.31%, straw 3 t/ha + N_{30} with 10.16%, and manure 60 t/ha + straw 3 t/ha + N_{30} with 10.04%. In the control variant, increased amount of dry content was also noted with 10.11%.

The application of biofertilizers, except MERC, significantly increased total sugar content in cabbage from 5.41 to 5.89%, where control variant showed 5.13%. Vitamins are important indicators that determine the quality of vegetable products. According to the content of Vitamin C, all the biofertilized variants exceeded the control with 29.24-33.62 mg%. The highest content of vitamin C was in the variant with MERC where it showed 33.62 mg%. Moreover, concentration of vitamin C was 32.74 mg% in the variant with manure 60 t/ha. Biohumus used variant showed 31.27 mg% when bird droppings 5 t/ha + straw 3 t/ha + N_{30} variant was 30.77 mg%. In the control variant, this indicator showed lowest vitamin C concentration with 28.64 mg%. Data given above showed that organic fertilizers and biofertilizers improve cabbage quality (Table 2).

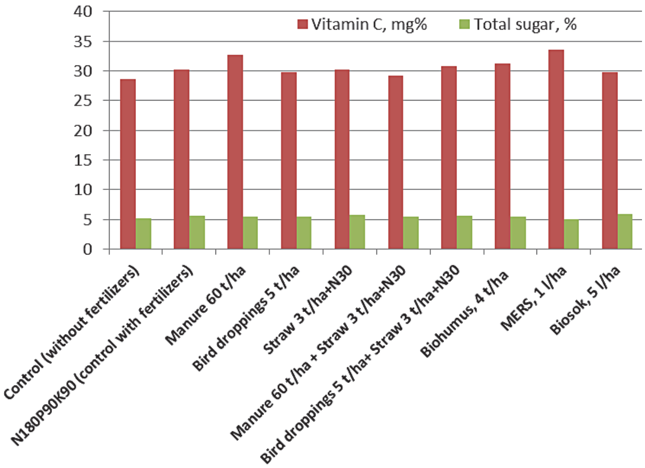

Fig. 3. Effect of biofertilizers and organic fertilizers on cabbage quality

The highest increase in vitamin C was observed in variant MERC 1 l/ha and manure 60 t/ha while highest sugar content in cabbage was observed in variants Biosok, 5 l/ha and Straw 3 t/ha + N_{30} (Figure 3).

In the vegetable production, storing quality is very important. Since, after the completion of the growing season and harvesting of the crops, it becomes necessary to store them in the storage for the long-term to provide consumers during the whole season. Taking into consideration all above mentioned, we have studied the effect of new biofertilizers and organic fertilizers on the storing quality of cabbage during the long-term storage. The research was carried out in the vegetable storage of KazRIPaVG. The results of experiments on storing cabbage for 6 months in two storage seasons (2015-2016 and 2016-2017) are shown in Table 3.

In the experiments, the positive effect of fertilizers on the storing quality of cabbage was noted. In all variants, the storing quality of the product was higher than control variants except with bird dropping 5 t/ha where storability was 80.2%.

In the experiments on the storage of cabbage, it was found that organic fertilizers do not reduce storing quality of cabbage (Table 3). After 6 months of storage period, quality of control was about 80.4% with total storage loss of 19.5%. Natural mass loss accounted for 12.5% with diseased share 7.0%

After 6 months of storage period, quality of fertilized control ($N_{180}P_{90}K_{90}$) was 80.7% with total storage loss of 19.3%. Natural mass loss accounted for 12.3% with diseased share 6.9%.

Fertilized control ($N_{180}P_{90}K_{90}$) has 80.7% storing quality with total losses 19.3%. Also, this variant showed natural mass loss by 12.3%, and affected with disease by 6.9%. On

Table 3. Storing quality of cabbage in the long-term storage depending on the types of biofertilizers and organic fertilizers (2015-2017)

Experiment variants	Storing quality of cabbage during storage, %	Total losses during the storing of cabbage in storage, %	Including	
			natural mass loss	affected by disease
Control (without fertilizers)	80.4	19.5	12.5	7.0
$N_{180}P_{90}K_{90}$ (control with fertilizers)	80.7	19.3	12.3	6.9
Manure 60 t/ha	81.9	18.0	11.9	6.1
Bird droppings 5 t/ha	80.2	19.7	12.3	7.4
Straw 3 t/ha + N_{30}	81.0	18.9	11.9	7.0
Manure 60 t/ha + Straw 3 t/ha + N_{30}	82.1	17.8	11.7	6.1
Bird droppings 5 t/ha + Straw 3 t/ha + N_{30}	80.5	19.4	12.3	7.1
Biohumus, 4 t/ha	81.8	18.2	11.9	6.3
MERC, 1 l/ha	80.9	19.1	11.7	7.3
Biosok, 5 l/ha	81.3	18.6	11.8	6.8

variants with local organic fertilizers, the persistence of cabbage after 6 months of storage fluctuated within 80.2-82.1%, and on variants with new biofertilizers was 80.9-81.8%. It should be noted that, the storing quality of cabbage in all studied variants was close. Also, in terms of total losses during excavation after completion of storage, there are no significant differences. Taking the above into consideration, the studied biofertilizers and organic fertilizers do not impair the keeping quality of cabbage in comparison with the control variants.

Thus, the new biofertilizers and organic fertilizers have positive effects on cabbage during the long-term storage.

Conclusions

All the new biofertilizers have positive effect on cabbage yield. Also, high yields were obtained in the variants 60 t/ha of manure + straw 3 t/ha + N_{30} with 43.5 t/ha, 60 t/ha of manure with 40.6 t/ha, and biohumus with 39.2 t/ha, respectively. Therefore, the additional yield was 55.91%, 45.52% and 40.50%, respectively. The best quality indicators of cabbage production were noted when using Biohumus, Biosok and MERC. The content of dry substances, sugars and vitamin C increased in cabbage by using biofertilizers. The new biofertilizers improved the storing quality of cabbage during the long-term storage. There was found no harmful effects of biofertilizers and organic fertilizers on cabbage.

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