TECHNICAL AND ECONOMIC EFFICIENCY OF ANCIENT WHEAT SPECIES, GROWN UNDER DIFFERENT TECHNOLOGIES OF ORGANIC FERTILIZATION

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Abstract

The consumer awareness and interest in food quality is growing which leads to greater demand for organic products. Organic farming is helping to maintain biodiversity in the agro-ecosystems, as well as to preserve traditional species and varieties of crops and rare breeds of animals in certain regions or countries. The main objective of the paper is to observe the technical and economic efficiency of the three species of ancient wheat, grown under different technologies of organic fertilization and sowing rates. The study is conducted at the experimental centre for organic production at the Agricultural University – Plovdiv during the period 2014 – 2017. The analysis of results showed different levels of technical efficiency of the three wheat species, grown under different technologies of bio fertilizer treatment. On the other hand, the high prices of the approved fertilizers for organic production do not guarantee the economic efficiency of their application. In fact better economic results were observed without use of fertilizers. It was also concluded that higher sowing rates of the wheat species impacts positively on yields.

Key words: *Triticum monococcum L., Triticum dicoccum Sch. and Triticum spelta L.,average yields; organic fertilizers*

INTRODUCTION

The intensification and chemicalization of agriculture in the past decades had a negative impact on the environment, soil, landscape and biodiversity of ecosystems. These agronomic practices have led also to air pollution, soil and groundwater pollution [3, 5]. Nowadays there are serious challenges related to the growing population and consumption on the one hand and reduced natural resources, climate change and worsening living environment on the other. It is necessary to transform agricultural production patterns to more sustainable ones. This is combined with the growing consumer awareness in the field of food quality and safety.

Organic agriculture is an alternative to the conventional production. In the last years demand for organically produced food is growing [4]. In many countries worldwide farmers are getting more and more interested in the environmentally friendly organic production technologies. One of the reasons is associated with the governmental support, but the wider application of these practices is related also to the possibilities for greater economic efficiency.

According to Eurostat the total area under organic farming in the EU continues to increase, and in 2018 covered 13.4 million hectares of agricultural land [9].

In the European Union, the largest markets for organic products are Germany, with 10 billion EUR and France, with 7.9 billion EUR. Organic farming is priority area in the European common agricultural policy beyond 2020 [8]. In Bulgaria, organic farming is becoming more important, as the demand for organic products is gradually increasing.

Organic farming is helping to maintain biodiversity in the agro-ecosystems, as well as to preserve traditional species and varieties of crops and rare breeds of animals in certain regions or countries. The role of agriculture for the economy and the sustainability of rural regions are really important [14, 20].

In the technologies of organic production, chemical fertilizers are almost prohibited, but some soil additives and leaf fertilizers are approved for application, which is an effective option for farmers to improve quantity and quality of production.

Therefore it is important to study the effect of organic fertilization on crop productivity and efficiency.

Advantages of organic farming are related to the opportunity to grow such varieties of crops or keep animal breeds that are more resistant (durable) to diseases and are more adapted to regional and local conditions.

Triticum monococcum L., *Triticum dicoccum* Sch. and *Triticum spelta* L. are ancient species of wheat, grown in Bulgaria since centuries ago.

Triticum monococcum L. is old cereal crop that has been grown 9,000 years ago in the Balkans and the Central Europe. It has valuable characteristics as resistance to many diseases and the grain contains 17.0 – 22.5% protein [1, 13].

Triticum dicoccum Sch. has been traditionally grown and used as a part of the human diet [17]. *Triticum spelta* L. is considered old European cultural wheat. It contains more proteins, mineral elements, lipids, fibre and vitamins [1].

These wheat species along with the growing interest for organic food, are gaining popularity in the last decades.

Their importance has increased due to the significant change in consumers` perceptions related to healthy diet and food quality.

Some authors analyse the effect of ancient wheat types as a new source of healthy food [2, 6, 15].

Food safety and food quality become matter of global concern [10, 11]. Innovations and adoption of new technologies are considered as an option to solve the emerging challenges. However, the answer of the global issues could be found also by looking back to the past.

The aim of the paper is to observe the technical and economic efficiency of the three species of ancient wheat treated with different organic fertilizers and sown at different sowing rate.

MATERIALS AND METHODS

The study can be divided into two stages– theoretical analysis and practical experiments. During the first one, an extensive review of the scientific literature, related to *Triticum monococcum* L., *Triticum dicoccum* Sch. and *Triticum spelta* L. is done. Various theories and methodologies are examined and adapted for the specifics of this research.

The practical part of the study was conducted at the Agro-ecological Field (Demonstration Centre for Organic Farming) at the Agricultural University – Plovdiv during the period 2014 – 2017. The agro-ecological centre has been a member of the International Federation of Organic Agriculture (IFOAM) since 1993 and it was the first certified organic farm in Bulgaria.

The sowing was conducted in mid-October using a block method in three repetitions with a size of the reported parcel of 10.5 m^2, with sowing rate of 500 g.s./m^2 and 700 g.s./m^2 (germinating seeds per sq.m.) after a pepper as a predecessor. The seeds are from biological origins and are provided by the Institute of Plant Genetic Resources "K. Malkov" – Sadovo, accompanied by the required documents for organic farming.

Three factors analyse was made:

Factor A – growing season:

A1 – 2014/15; A2 – 2015/16; A3 – 2016/17.

Factor B – species if ancient wheat:

B1 – *Triticum dicoccum* Sch.;

B2 – *Triticum spelta* L.;

B3 – *Triticum monococcum* L.

Factor C – types of fertilizers:

C1 – Control (0) – without fertilizers;

C2 – Control (C) – adding to the soil of Agriorgan pellet – 100 kg/da;

C3 – Amalgerol;

C4 – Litovit;

C5 – Baikal M – 1U;

C6 - Tryven;

C7 – (CH-700) – higher sowing rate (700 g.s./m^2) and including Agriorgan pellet – 100 kg/da.

Amalgerol® is a liquid concentrated fertilizer with a large amount of hydrocarbons and natural plant growth hormones. It increases the resistance of plants to drought and improves their condition after frost, drought, hail, etc. Amalgerol accelerates the decomposition of plant residues in the soil and improves microbial activity, in particular mycorrhiza, as well as the structural condition of the soil.

Litovit® is a high-quality nanotechnology product created by tribodynamic activation and micronization. Spryed on the surface of the leaves, it is absorbed directly and is converted into CO_2, which significantly increases photosynthesis. This leads to higher yields and reduced water needs. The additional micronutrients, such as manganese, lead, zinc, etc. also improve the physiology of plants. Not suitable for plants that prefer acidic soil.

Baikal EM-1U is probiotic product containing a large number of beneficial microorganisms. This bacterial fertilizer stimulates microbiological processes in the soil and leads to higher yields of the crops.

Tryven is organic fertilizer. It is a complex mixture of NPK, intended for use through foliar feeding. It is suitable for all types of crops - vegetable, fruit, vineyards, cereals, fodder, technical, citrus, etc., especially efficient for crops with large leafs.

Agriorgan pellet is an organic fertilizer made from sheep manure, enriched with microorganisms and a supplement of trace elements. Improves the structure and quality of the soil, increases fertility and stimulates the humification of organic matter. Agriorgan pellet is a product with an exceptional impact on the physical, chemical and biological characteristics of the soil. It supports the reproduction of microorganisms, increases the biological activity in the soil and thus "rejuvenates" the tired soil.

For each growing season of the analysed period, three repetition of each of the three wheats with the abovementioned foliar fertilizers are made. In order to differentiate the influence of fertilizers as a factor for efficiency and profitability, two more variants were included – Control (C), which represents production method without fertilization and Control (0) which is without foliar fertilization and without Agriorgan pellet. In order to isolate the influence of sowing rate on the technical and economic efficiency of the three crops one more variant, called (CH 700) was tested. It represents repetitions of the three wheats, sown at 700 g.s./m^2.

Each type of wheat was tested in 7 variants and 3 repetitions. Consequently, 21 pitches with *Triticum monococcum* L., 21 pitches with *Triticum dicoccum* Sch. and 21 pitches with *Triticum spelta* L. are evaluated. The study is based on average data for each of the three wheats, based on the three repetitions, in the three year periods.

The analysis of efficiency focuses on the optimization of the production function [19].

Farrell [12] is one of the first authors that define that economic efficiency and link the term to the combination of production factors and optimal output. According to [12] two types of efficiency can be distinguished – allocative and technical efficiency. The allocative efficiency is related to choice of input combination [7, 18]. Technical efficiency refers to the proper choice of production function among all those actively in use by farmers [16].

The study focuses on the analysis of technical and economic efficiency. Economic efficiency in this case measures the difference between revenue and costs for the production of the crops, grown under different technologies of organic fertilization. For the purpose of the analysis, the gross economic result was calculated. That is the value of grain produced (yield multiplied by market price) plus income from selling the straw minus production cost (seeds, fertilizers, chemicals, cultivation, peeling).

The other elements of the revenues and costs are not included in the analysis. Farm subsidies, wages, etc., differ among enterprises. However, all of these potential revenues or costs are not related to the species of wheat or the applied fertilizer. This methodology provides sufficient information on the efficiency of each variant of leaf fertilization.

Technical and economic efficiency of the production of *Triticum monococcum* L., *Triticum dicoccum* Sch. and *Triticum spelta* L. grown under different technologies of organic fertilization is estimated and analysed for three consecutive vegetation years 2014/15; 2015/16 and 2016/17. The results are also averaged for the three year period.

Experimental data is processed with MS Excel and SPSS V.13.0, using the Duncan, Anova method.

RESULTS AND DISCUSSIONS

During the period 2014/2015, five variants of technology are tested for each of the three wheats – a control (C) without any fertilizers and four variants leaf fertilizers- Amalgerol, Litovit, Baikal EM and Tryven. In all five variants for all of the three wheats is applied organic fertilizer Agriorgan pellet.

The results indicated that *Triticum monococcum* L. has the highest yield even in control (C), without fertilization (247 kg/da unpeeled grain), followed by *Triticum dicoccum* Sch. (193 kg/da unpeeled grain). *Triticum spelta* L. registered the lowest yield (183 kg/da unpeeled grain).

The application of different fertilizers showed different level of technical efficiency. The highest yield (205 kg/da) of *Triticum dicoccum* Sch. is registered from the technology based on application of Amalgerol. The yields of the other variants of fertilization were around 199 kg/da. The comparison of the different variants of foliar fertilization and the control (C) shows relatively small differences. Therefore from economic point of view the application of foliar fertilizers depends on their prices.

For *Triticum spelta* L., the only efficient technology of fertilization was the one with Amalgerol. The yield is 185 kg/da, which is higher than the Control (C), where the result was 183 kg/da. The application of Litovit did not improve the results, achieved in Control (C). Triven and Baikal EM contributed to lower yields than the Control (C) – 178 kg/da and 170 kg/da respectively.

Data from the research showed that *Triticum monococcum* L. had potential during 2014/15 to react greatly on leaf fertilization. All studied fertilizers increased the yield compared to the Control (C). The most effective was the application of Tryven, with average yield 312 kg/da., followed by Amalgerol (275 kg/da), Litovit (264 kg/da) and Baikal EM (264 kg/da).

Economic efficiency differed among wheats and technologies used during the 2014/15 growing season.

Economic results from *Triticum dicoccum* Sch., under all variants of fertilization were positive, but only the application of Amargerol and Baikal EM contributed to gross revenue (216 BGN/da) and (222 BGN/da) respectively, higher than the one of Control (C) – 194 BGN/da.

Based on the technological and market conditions in 2014/15 it can be concluded that *Triticum spelta* L. in all five variants of fertilization was economically inefficient. The main reasons are associated with the lower yields and the lower market price of the wheat species (2 BGN/kg).

During the 2014/15 season it was most economically efficient to grow *Triticum monococcum* L. and especially by using Tryven as organic fertilizer. Despite its relatively high price, the yield ensured the best gross revenue (BGN 359/da). The technology variants with Amalgerol, Baikal EM and Litovit were also more efficient than Control (C). Their gross economic benefits were BGN 264/da, 242 BGN/da and 182 BGN/da respectively.

In the second year 2015/2016, two more controls are introduced in order to survey the impact of organic fertilization, as a factor of productivity and economic efficiency- Control (0) with no fertilizer and no Agriorgan Pellet, and variant (CH 700) – with higher sowing rate -700 g.s./m^2.

Triticum monococcum L. had the highest results (152 kg/da) in Control (0), followed by *Triticum dicoccum* Sch. (130 kg/da.) and *Triticum spelta* L. (113 kg/da).

When soil fertilizer Agriorgan pellet is introduced – Control (C), yields were significantly higher. The yield of *Triticum spelta* L. increased by 53%, while the *Triticum monococcum* L. and *Triticum dicoccum* Sch.- by 35% and 30% respectively.

The Agriorgan pellet has positive impact on the yields for the three wheats, but its technical efficiency was higher when higher sowing rate is applied. The variant (CH 700) increased the yield of *Triticum monococcum* L. by 52%, *Triticum dicoccum* Sch. by 83% and *Triticum spelta* L.by 111%.

The application of organic fertilizers showed different level of technical efficiency. The use of Amalgerol, Litovit and Tryven provided similar results for *Triticum dicoccum* Sch. (178-179 kg/da). The application of Baikal EM, did not contribute to higher yields, compared to the Control (C).

Triticum spelta L. achieved the highest results by the application of Litovit (204 kg/da), Amalgerol (193 kg/da) and Tryven (187 kg/da). The application of Baikal EM, did not improve the yields compared to the Control (C).

The survey of *Triticum monococcum* L. registered positive effects of all four bio fertilizers. The highest results are achieved by the application of Litovit (253 kg/da), followed by Amalgerol (238 kg/da), Tryven (231 kg/da) and Baikal EM (223 kg/da).

Economic efficiency of *Triticum dicoccum* Sch. was highest in the variant with higher sowing rate (CH 700) with gross revenue 288 BGN/da. Organic fertilization with Amalgerol provided economic result of 108 BGN/da, followed by Litovit and Tryven – about 95 BGN/da. The economic result of Baikal EM (53 BGN/da) was lower than the Control (C) with 93 BGN/da. Control (0) recorded the lowest efficiency - 55 BGN/da.

Triticum spelta L. grown under all variants of leaf and soil fertilization is not economically efficient because of the higher production costs.

Triticum monococcum L. in all variants had positive economic results. The highest economic efficiency is registered by the application of Litovit (201 BGN/da), followed by Amalgerol (169 BGN/da), Baikal EM (133 BGN/da) and Triven (120 BGN/da). Control (0) and Control (C) returned gross benefits respectively 54 BGN/da and 102 BGN/da. Variant (CH 700) is not economically justified, because gross revenue was relatively low (68 BGN/da).

In the last year of the analysis 2016/17 the data shows that *Triticum spelta* L. had the highest yield without foliar fertilizers and Agriorgan pellet – 309 kg/da.

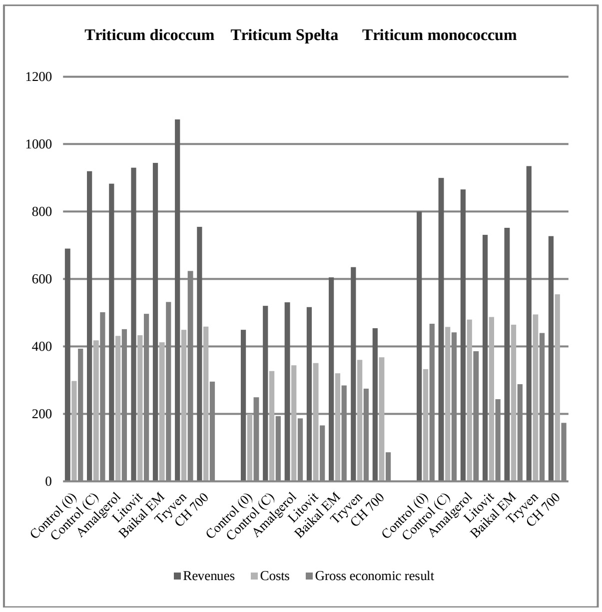

Fig. 1.Economic results, growing season 2016/2017 (BGN/da)
Source: Own Survey.

It is followed by Triticum monococcum – 273 kg/da and Triticum dicoccum – 212 kg/da. The application of Agriorgan pellet increased the yield of all three wheats substantially, with major effect on the Triticum dicoccum (+36%). Triticum monococcum yield is 20% higher and that of Triticum spelta – 16% higher.

On the other hand, the results from the application of CH 700 were lower than of Control (C). In this case, the yields from Triticum dicoccum decreased by 22%, from Triticum monococcum by 11.6% and from Triticum spelta by 2.5%.

The survey of Triticum dicoccum indicated that the application of Tryven led to the highest results (336 kg/da), followed by Baikal EM (303 kg/da). By contrast, Litovit and Amalgerol showed lower results compared to Control (C).

The analysis of *Triticum spelta* showed that Tryven led to the highest yield (445 kg/da), followed by Baikal EM (384 kg/da), Litovit (384kg/da) and Almagerol (366 kg/da).

The study of *Triticum monococcum* in all variants registered lower technical efficiency than Control (C).

Economic efficiency differed among wheats and technologies. The greatest gross revenue was achieved from *Triticum dicoccum* Sch, grown under the technology with application of Tryven (624 BGN/da), followed by Baikal EM (523 BGN/da). The use of Litovit (497 BGN/da) and Amalgerol (451 BGN/da) had lower economic efficiency than Control (C) with 502 BGN/da.

The lowest economic result was registered in the variant (CH 700) – 295 BGN/da, which is 25% lower than the variant without fertilization.

Averaged results for the period 2014-2017

Results for the yields, averaged for the period 2014-2017 are presented in Figure 2.

The highest levels of technical efficiency for the 3-year period was observed for *Triticum monococcum* L., followed by *Triticum spelta* L. and *Triticum dicoccum*.

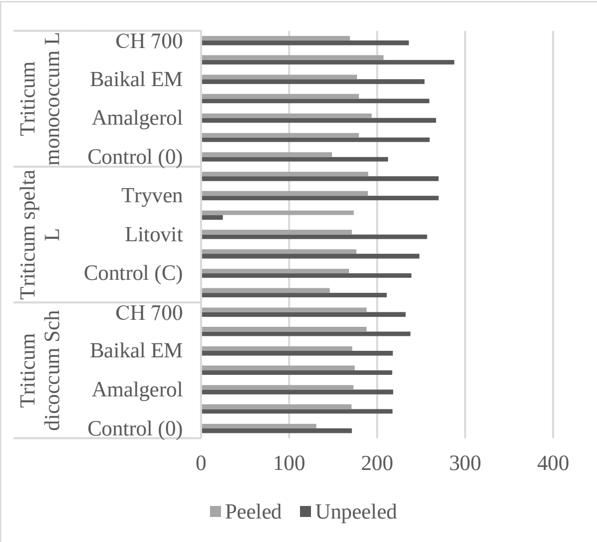

Fig. 2. Technical efficiency (kg/da)
Source: Own survey.

Triticum monococcum L. registered the highest average yield (unpeeled grain) with the application of Tryven (287.7 kg/da), followed by Amalgerol (267.1 kg/da). The technologies with Baikal EM and Control (C) had similar level of efficiency with about 250-260 kg/da. CH 700 returned 236 kg/da and the lowest result was achieved from Control (0) – 212.4 kg/da. Triticum spelta L. registered the best technical efficiency, when higher sowing rate (CH 700) and Tryven (270 kg/da unpeeled grain) were applied. The other three fertilizers – Amalgerol, Litovit and Baikal EM indicated similar results (around 250 kg/da). The average yield was lowest in Control (0) – 211 kg/da,

Triticum dicoccum achieved lower yields during the period, compared to the other two wheats. The technologies of Tryven and CH 700 performed better than the others, with average result 230-240 kg/da unpeeled grain.

Amalgerol, Litovit and Baikal EM returned the same yield as the Control (C) – around 218 kg/da. Control (0) had significantly lower yield – 171.2 kg/da.

The data allow some conclusions to be drawn. The study showed serious variations in technical efficiency between wheats species and between fertilization technologies.

The economic results observed by the application of different organic fertilizers are illustrated on Figures 3, 4 and 5.

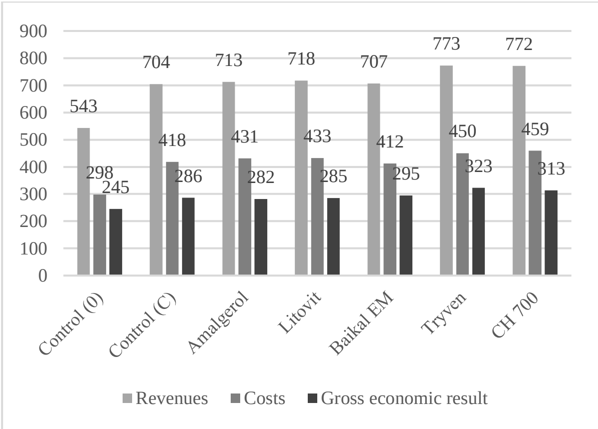

Fig. 3. Economic efficiency of *Triticum dicoccum* Sch 2014-2017 (BGN/da)
Source: Own survey.

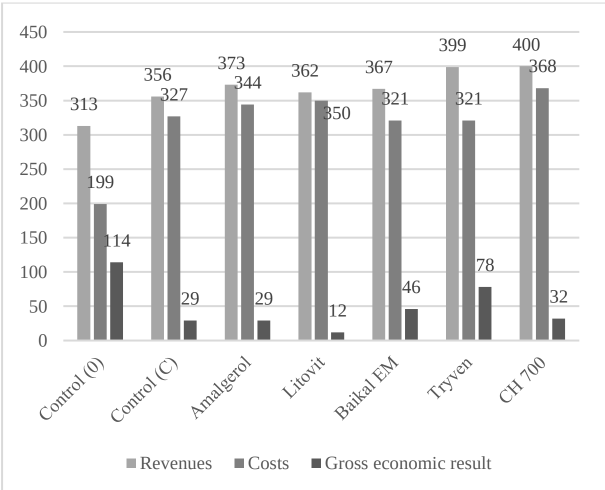

Fig. 4. Economic efficiency *Triticum spelta* L 2014-2017(BGN/da)
Source: Own survey.

The application of Litovit has higher costs, which however do not contribute to higher average yields. The higher sowing rate does not bring a better economic result, but the indicator is higher than Control (C) by 6.8%.

Based on the results it can conclude that is economically unjustified to apply fertilizers, because the efficiency is higher in Control (0).

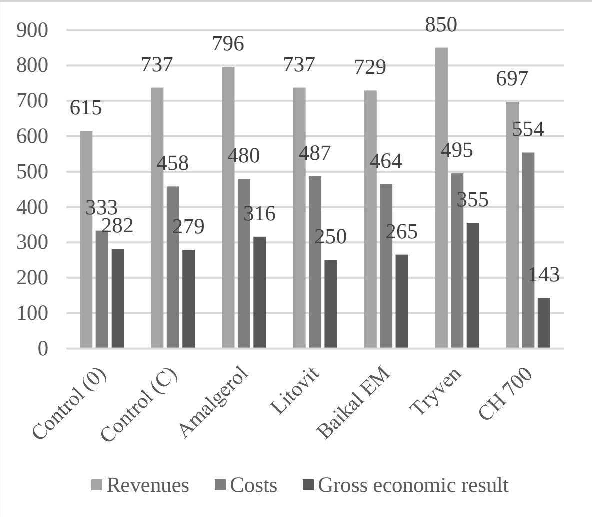

Fig. 5. Economic efficiency *Triticum monococcum* L. 2014-2017 (BGN/dca)
Source: Own survey.

For Triticum monococcum L all variants register positive economic results. The efficiency was the highest from application of Tryven (BGN 355/da) and Amalgerol (BGN 316/da). The application of Baikal EM and Litovit led to lower results in comparison with the levels of Control (0) and Control (C).

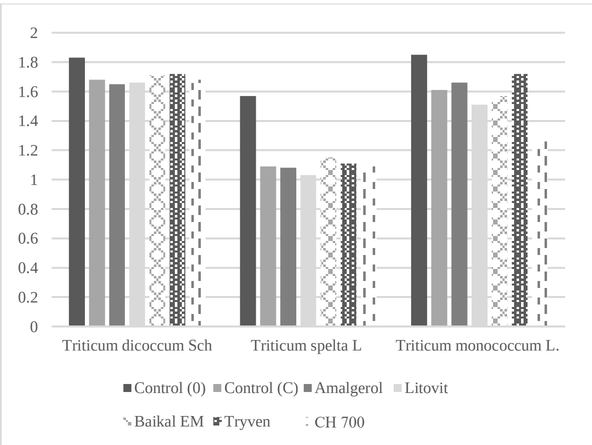

Fig. 6. Economic efficiency coefficient 2014-2017
Source: Own survey.

In addition to the analysis, the efficiency coefficient is observed. It should be emphasized that not all production costs are included, but nevertheless the indicator demonstrates the effect of different types of fertilizers application (Figure 6).

The analysis of the data shows that the highest economic efficiency is registered by the variants without the application of fertilizers. The application of a higher sowing rate (CH 700) can increase yields, but is also associated with higher costs.

In Control (C) the results vary considerably. While for *Triticum monococcum* L the efficiency levels were close to Control (0), for *Triticum Spelta* L the lowest levels of the indicator are observed.

Different variants of application of fertilizers are related to different results for the analysed wheats. Therefore it is not possible to determine a variant of application with the highest efficiency coefficient.

The use of Tryven is associated with the highest results for the *Triticum monococcum* L. and *Triticum dicoccum* Sch. On the other hand, - the application of Baikal EM brings the best economic results for *Triticum spelta* L.

CONCLUSIONS

Triticum monococcum L., *Triticum dicoccum* Sch. and *Triticum spelta* L. are old species of wheat that are gaining popularity in the past decades.

They are related to the healthy lifestyle and changes in consumer's perceptions and demand. Based on the survey some conclusions can be highlighted:

(1)The highest levels of technical efficiency for the three year period are registered by *Triticum monococcum* L., followed by *Triticum spelta* L. and *Triticum dicoccum* Sch

(2)The application of Agriorgan pellet increased the yield of all three wheats species, with major effect on the *Triticum dicoccum* (+36%). *Triticum monococcum* yield is 20% higher and Triticum *spelta* – 16%.

(3)The highest level of efficiency was achieved from *Triticum dicoccum* Sch. The best gross economic result was registered from the technology variant with the application of Tryven (BGN 323/da).

(4)Triticum spelta L. grown under all variants of leaf and soil fertilization is not economically efficient because of the higher production costs. Triticum spelta L. has the highest economic efficiency without fertilizer application (BGN 113/da).

(5)The analysis of *Triticum monococcum* L shows that all variants registered positive economic results. The indicator was the highest with application of Tryven (BGN 355/da) and Amalgerol (BGN 316/da).

(6)The highest economic efficiency is observed by the variants without the application of fertilizers. The application of a higher sowing rate (CH 700) can increase yields, but is also associated with higher costs.

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