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The influence of bioorganic nanofertilizer on spring barley and oilseed rape productivity and economical effectiveness

Vidmantas Spruogis,

Elena Jakienė,

Anželika Dautartė,

Romualdas Zemeckis

Aleksandras Stulginskis University, Studentų St. 11, 53361 Academy, Kaunas Region, Lithuania
Email: Vidmantas.Spruogis@gmail.com; Elena.Jakiene@gmail.com; Anzelika.Dautarte@asu.lt; Romualdas.Zemeckis@asu.lt

Fertilizing field experiment was carried out at the Experimental Station of Aleksandras Stulginskis University in 2014–2015. Spring rape and spring barley with under-crop, perennial grass in the 1st year of use, and winter wheat were grown in four-field crop rotation. The experiment aim was to evaluate the influence of fertilizer on spring barley and on oilseed rape applying bioorganic nanofertilizers (BNF) and $N_{60}P_{60}K_{70}$. The spring barley breed '*Luokė*' and the oilseed rape '*Sponsor*' were grown for the experiment. The research showed that $N_{60}P_{60}K_{70}$ and BNF had a positive effect on the yield of spring barley '*Luokė*' and of oilseed rape '*Sponsor*'. The spring barley grain yield increased from 6.8 to 16.3% and the oilseed rape seed yield increased from 8.1 to 23.3% compared to the control. The best yields were obtained fertilizing with $N_{60}P_{60}K_{70}$ and BNF rate 1.0 l ha^{-1} and spraying twice. Fertilization with $N_{60}P_{60}K_{70}$ and BNF 1.0 l ha^{-1} sprayed twice increased the crude protein content in grains by 0.51%. Fertilization with $N_{60}P_{60}K_{70}$ and BNF solutions significantly increased the yield of spring barley grain and straw and improved the grain quality, positively influenced 1 000 grain weight, sprouting energy and germination. Application of $N_{60}P_{60}K_{70}$ and BNF for barley is economically beneficial because it gave the highest profit compared to other options, 158.10 € ha^{-1}. The premium yield of spring rape, sprayed with BNF 1.0 l ha^{-1} solution twice, was higher by 89.92 € ha^{-1} than that of the oilseed rape sprayed once. Application of $N_{60}P_{60}K_{70}$ and BNF on oilseed rape is economically beneficial because it gave the highest profit compared with other options, 172.90 € ha^{-1}.

Keywords: spring barley, spring rape, bioorganic nanofertilizers, yield, chemical composition, economical effectiveness

INTRODUCTION

Spring barley is one of the oldest oilseed crops in the world. It is one of the most important spring crops according to Lithuanian conditions. Spring barley is grown for food, feed and industry. The largest barley grains (approximately 70–75%) are consumed as a feed. It is a good concentrated feed, suitable for all types of livestock. Barley straw and chaff are also used for feed and bedding. Grains are widely used in beer, alcohol, textile, confectionery, pharmaceuticals, varnishes, leather and beer industry (Čaikauskas, 1995; Jovaišienė, 1994; Lazauskas, 1998; Mineev, Voronina, 2008; Svirskis, 2008).

It is difficult to imagine modern agriculture without mineral fertilizers. Fertilizers improving soil physical, chemical and biological properties increase the yield and improve its quality. Plant nutrients in the soil are constantly changing (Janusauskaite, Ciuberkis, 2010). Some of them are used by plants, others are washed out by water, a significant proportion is consumed by soil microorganisms. Plants should receive a sufficient amount of all essential nutrients; fertilizing is one of the most important stages (Kučinskas et al., 1999).

The crop growing season is short and plants are demanding a high nutrition. Fertilization is more effective when the fertilizer rate and the ratio of nutrient items are optimal when applied locally, and when they are added additionally. Additional fertilization is an effective tool for improving the quality of the harvest, especially in light soils where nutrients are easily leached to deeper soil layers. An additional fertilization method is usually determined by the cultivation method and fertilizer type (Kučinskas et al., 1999; Kutra, Aksomaitiene, 2003).

Fertilization of plants through the leaves has a number of advantages: it is possible to regulate plant growth and development, taking into account the weather conditions and the condition of plants themselves, it can quickly remove the plant physiological disorders, with nutrient deficiency, or when the soil is chemically or biologically binding or blocking nutrients (Delin et al., 2005; Doltra et al., 2011). The majority of applications in these areas have focused on the significance of nanomaterials for improved efficiency and productivity. These materials are also used in agriculture production and crop protection (Khot et al., 2012). Many studies have shown that fertilization of plants through the leaves increases yield by 5–10% (the data obtained from a number of field crops).

Lack of phosphorus and potassium slows plant growth and affects plant development. Potassium stimulates photosynthesis, carbohydrates and vitamins macromolecular synthesis, improves the metabolism of water in the cell. Potassium does not contain enzymes, but it is necessary as a catalyst in enzyme activity. Crops, rich in potassium, are more resistant to drought and low temperatures. When it is missing, the leave edges start to dry (Čaikauskas, 1995).

The deficiency of microelements in the soil causes a variety of physiological plant diseases. Boron plays an important catalytic role. Manganese deficiency in plants decreases the amount of chlorophyll, the leaves turn white, their yield goes down and plants may even die. Magnesium is an integral part of chlorophyll and an essential element of photosynthesis. If there is lack of manganese, it decreases the intensity of photosynthesis and leaf growth, and leaf spots occur, which slows plant growth and reduces its yield (Kučinskas et al., 1999; Čaikauskas, 1995).

Science and technology demonstrated a great potential providing novel and improved solutions to many grand challenges facing agriculture and society (Chen, Yada, 2011). BNF was used for additional spray fertilization through leaves. This is an environment safe product, made from an organic substrate with micro-, macro-, mezo-elements and bioactive materials, designed for all types of agricultural, ornamental crops, forest, parks green areas in various types of soils. Application of fertilizers increases yields, enhances plant immunity, protects against stress (drought, frost, impact of pesticides) and diseases, shortens the ripening period, improves the quality of products and the fruit storage period. There are different opportunities for the application: as a water solution for seed treatment before sowing, leaf processing, root irrigation. The fertilizer composition is as follows: humus extract, at least 0.2% of humic and fulvic acids, total nitrogen (N) not less than 0.015%, total potassium (K_{20}) not less than 0.02, total phosphorus not less than 0.002%. It is a dark brown liquid with a characteristic odour, pH from 7.0 to 9.9.

The research object is spring barley and oilseed rape fertilized with ammonium nitrate N_{60}, granular superphosphate P_{60}, potassium salt K_{70} and newly investigated BNF for an additional treatment.

The research aim is to investigate the impact of $N_{60}P_{60}K_{70}$ fertilizers and their combinations with BNF on spring barley and oilseed rape.

The research objectives:

1) to determine the influence of $N_{60}P_{60}K_{70}$ fertilizers and their combinations with BNF on spring barley and on oilseed rape yield;

2) to identify and evaluate the influence of $N_{60}P_{60}K_{70}$ fertilizers and their combinations with BNF on spring barley and on oilseed rape grain qualitative characteristics;

3) to implement an economic evaluation of $N_{60}P_{60}K_{70}$ fertilizers and their combinations with BNF application on spring barley and on spring rape.

MATERIALS AND METHODS

Experiment location and soil characteristics. The experiment was carried out at the ASU Experimental Station in 2014–2015. The soil was *Epihypogleyic Luvisol (Calc (ar) i-Epihypogleyic Luvisol) – IDg8-k (LVg-pw-cc)*, the soil texture was loam on moderate to heavy loam. The plowing layer of the soil was close to neutral (pH 6.8 to 7.2), basic, with medium humus content, medium or even large amounts of phosphorus and medium potassium, boron, magnesium and cuprum, low zinc and molybdenum, enough manganese.

Soil samples were taken according to sampling methodology, the analysis of soil agrochemical properties was carried out at the Agrochemical Research Centre of the Lithuanian Institute of Agriculture.

The experiment scheme and research methods. The field experiment was carried out in accordance to the scheme:

1. Control (unfertilised).
2. $N_{60}P_{60}K_{70}$.
3. $N_{60}P_{60}K_{70}$ + BNF 0.5 l ha^{-1}, treated 1 time.
4. $N_{60}P_{60}K_{70}$ + BNF 1.0 l ha^{-1}, treated 1 time.
5. $N_{60}P_{60}K_{70}$ + BNF 0.5 l ha^{-1}, treated 2 times.
6. $N_{60}P_{60}K_{70}$ + BNF 1.0 l ha^{-1}, treated 2 times.

Experiments were carried out in three replications, the total field area of 56 m^2 (14 m × 4 m), and the estimated area 26.4 m^2 (12 m × 2.2 m).

The total nitrogen content in spring barley and in oilseed rape grain was determined by the Kjeldahl method, green protein was calculated by multiplying the total nitrogen content by a coefficient of 6.25. Humus was estimated by the Tyurin method, mobile phosphorus and potassium by the A-L method, pH in 1 N KCl extract, mineral nitrogen in 1 N KCl extract, the load (10 g) and solution ratio was 1:2.5 (Tarakanovas et al., 2003).

Field test results of the variance analysis. LSD_{05} is a significant difference in the threshold 95% probability level. Barley grain and straw samples for product quality analyses were collected from each field separately. The market and harvest purchase prices and production costs used for economic calculations reflect the actual production costs of the ASU Experimental Station.

Meteorological data of the Kaunas Meteorological Observatory were used for the description of meteorological conditions.

Agrotechnical measures and timing. Spring barley was sown in April 2014–2015, seed rate 170 kg ha^{-1}, variety '*Luokė*'. Oilseed rape was sown in April 2014–2015, seed rate 6 kg ha^{-1}, variety '*Sponsor*'. Standard bulk fertilizer ammonium nitrate N_{60}, granular superphosphate P_{60}, potassium salt K_{70} and the newly investigated universal BNF for additional treatment were used for the main fertilization in field experiments. Main fertilization $N_{60}P_{60}K_{70}$, superphosphate ($Ca(H_2PO_4)_2 \cdot CaSO_4$), ammonium nitrate ($NH_4NO_3$), potassium fertilizers were applied before sowing. Later an additional fertilization with BNF was carried out through the leaves twice. The composition of the bioorganic nanofertilizer (according to the data of the Russian Accredited Laboratory ANO "NIES") was the following: pH 9.12, dry matter 27.09 g l^{-1}, nitrogen 1.12 g l^{-1}, phosphorus 0.08 g l^{-1}, potassium 0.54 g l^{-1}, organic matter 9.96 g l^{-1}, carbon (total) 4.98 g l^{-1}, carbon (humic a.) 3.54 g l^{-1}, carbon (fulvoic a.) 1.44 g l^{-1}, humic acid 6.66 g l^{-1}, fulvoic acid 3.24 g l^{-1}, trace elements (Fe, Zn, Mg, Mn, Mo, B, Ca, Cu, Co, Se) and other biologically active substances. The water rate for the solution was 400 l ha^{-1}. Plant protection measures were not used. Grain was dried to 14%, cleaned, and the yield was estimated in t ha^{-1}. Its chemical composition was investigated at the ASU Experimental Station with an infrared analyzer.

Data were statistically evaluated using the analysis of the variance ANOVA program (Tarakanovas et al., 2003; Raudonius, 2008, 2017).

Meteorological conditions. Spring was early and warm in 2014–2015. In April, the weather conditions for sowing and seed germination were not very favourable. In April, the average precipitation was 16.4 mm less than the multi-annual average. The highest average daily temperature of the month was in the third decade (14.0°C), by 7.8°C higher than the multi-annual average, but there was lack of moisture for seed germination. In May, there was an average of warm weather. The average daily temperature varied only by 0.1°C from the perennial average. The largest amount of precipitation fell in the second decade – 22 mm. However, the monthly rainfall had a little difference from the multi-annual average – 47.0 mm. Development conditions were optimal. June was warm, the highest air temperature was fixed at the beginning of the month when the average daily temperature was 21.2°C. The monthly average temperature was by 2.6°C higher than the multi-average. During the month 54.0 mm of rainfall fell, it is 15.1 mm less than the multi-annual average. The soil was dry, it was hard for the plants to take nutrients from the soil and it was worth spraying BNF solution through the leaves. July was the hottest month of the summer months. The soil was wet, during the month 146 mm of rainfall fell. Most rainfall (67.0 mm) fell on the first decade; the average monthly precipitation was 62.6 mm higher than the average multi-annual precipitation. Rainy weather started in August, although still warm and sunny. During the month even 152.0 mm rainfall fell, 82.2 mm more than the multi-annual average. The average monthly temperature was by 0.8°C higher than the multi-annual average.

RESEARCH RESULTS AND ANALYSIS

According to Table 1, we see that the minimum grain yield of spring barley in 2014–2015 was received from the control plots. All experiment plots, where $N_{60}P_{60}K_{70}$ and BNF were applied, received a significant yield increase. The spring barley yield increased by 6.8–16.3% or from 0.39 to 0.93 t ha^{-1} compared to the control.

The minimum premium grain yield in 2014–2015 was when applying only $N_{60}P_{60}K_{70}$. The premium grain yield in comparison to the control was 0.39 t ha^{-1} (6.8%). The combination, having the most affecting impact on the barley yield, was $N_{60}P_{60}K_{70}$ + BNF 1.0 l ha^{-1} treated 2 times (variant 6). There the yield of spring barley was 6.61 t ha^{-1}. Investigations were carried out with sufficient precision, as the test accuracy (S_x%) was 1.23%. The influence on the grain yield increased due to the BNF spray rate and the number of treatment times. Higher yield was obtained by spraying the BNF rate 1.0 l ha^{-1} twice.

The research carried out in 2014–2015 showed (Table 2) that in all experiment plots, where $N_{60}P_{60}K_{70}$ and BNF were used, a significant spring barley straw premium yield was received. The spring barley straw yield increased by 9.5–17.6%, or from 0.38 to 0.70 t ha^{-1} compared to the control.

The minimum premium straw yield was when fertilizing only with $N_{60}P_{60}K_{70}$, comparing all experiment plots. The premium straw yield in these variants, as compared to the control, was 0.38 t ha^{-1} (9.5%). The combination, having the most affecting impact on the barley yield, was $N_{60}P_{60}K_{70}$ + BNF 1.0 l ha^{-1} 2 times (variant 6). The straw yield of spring barley was 4.68 t ha^{-1}, or 0.70 t ha^{-1} (17.6%) of the premium yield.

One of the yield quality indicators is 1 000 seed weight. 1 000 seed mass increased significantly under the application of $N_{60}P_{60}K_{70}$ and BNF. Table 3 shows that the lowest 1 000 seed weight of spring barley (55.7 g) was in the control plot. The maximum weight of 1 000 seeds was received from variants 5 and 6, where both $N_{60}P_{60}K_{70}$ and BNF were applied, with different concentrations of BNF (57.3 g).

Cereal grain quality is determined by proteins and starch. Various organic compounds in plants depend on the plant species and the characteristics of the variety, growing conditions.

Table 1. **Influence of $N_{60}P_{60}K_{70}$ and BNF on the spring barley grain yield**

Treatment	Grain yield, t ha^{-1}	Increase of yield, t ha^{-1}	Increase of yield, %
1. Control	5.69	–	–
2. $N_{60}P_{60}K_{70}$	6.07	0.39	6.8
3. $N_{60}P_{60}K_{70}$ + BNF 0.5 l ha^{-1} 1 time	6.27	0.59	10.3
4. $N_{60}P_{60}K_{70}$ + BNF 1.0 l ha^{-1} 1 time	6.40	0.71	12.5
5. $N_{60}P_{60}K_{70}$ + BNF 0.5 l ha^{-1} 2 times	6.47	0.78	13.7
6. $N_{60}P_{60}K_{70}$ + BNF 1.0 l ha^{-1} 2 times	6.61	0.93	16.3
LSD_{05}	0.224		

Table 2. **Influence of $N_{60}P_{60}K_{70}$ and BNF on the spring barley straw yield**

Treatment	Straw yield, t ha^{-1}	Increase of yield, t ha^{-1}	Increase of yield, %
1. Control	3.98	–	–
2. $N_{60}P_{60}K_{70}$	4.36	0.38	9.5
3. $N_{60}P_{60}K_{70}$ + BNF 0.5 l ha^{-1} 1 time	4.46	0.48	12.0
4. $N_{60}P_{60}K_{70}$ + BNF 1.0 l ha^{-1} 1 time	4.60	0.62	15.5
5. $N_{60}P_{60}K_{70}$ + BNF 0.5 l ha^{-1} 2 times	4.61	0.63	15.9
6. $N_{60}P_{60}K_{70}$ + BNF 1.0 l ha^{-1} 2 times	4.68	0.70	17.6
LSD_{05}	0.268		

Table 3. **Influence of $N_{60}P_{60}K_{70}$ and BNF on the spring barley 1 000 seed weight, sprouting energy and germination**

Treatment	1 000 seed weight, g	Sprouting energy, %	Germination, %
1. Control	55.7	80.0	92.5
2. $N_{60}P_{60}K_{70}$	56.8	89.5	92.5
3. $N_{60}P_{60}K_{70}$ + BNF 0.5 l ha^{-1} 1 time	57.0	90.3	93.1
4. $N_{60}P_{60}K_{70}$ + BNF 1.0 l ha^{-1} 1 time	57.2	90.8	93.4
5. $N_{60}P_{60}K_{70}$ + BNF 0.5 l ha^{-1} 2 times	57.3	91.9	95.0
6. $N_{60}P_{60}K_{70}$ + BNF 1.0 l ha^{-1} 2 times	57.3	92.8	95.8
LSD_{05}	0.49	10.3	0.85

The literature indicates that the barley grain has on average 11% protein, 75% nitrogen-free extractives (NEM), 5% fiber, 2% fat and 2.5% ash (Kučinskas et al., 1999). Plant nutrition conditions are important for yield and yield quality. For example, plants rich fertilized with nitrogen accumulate more protein; plants receiving a large dose of potassium synthesize more carbohydrates (Kučinskas et al., 1999). The research data shows that fertilization with $N_{60}P_{60}$K70 and BNF influenced the chemical composition of spring barley grain (Table 4).

The average data (Table 4) shows that the fertilizer $N_{60}P_{60}K_{70}$ and BNF increased the green protein content in spring barley grain. Most of all – 10.37% of green protein accumulation in spring barley grain was observed treating with fertilizers $N_{60}P_{60}K_{70}$ and BNF 1.0 l ha^{-1} 2 times. The green protein content considerably increased in comparison with the control (0.31 to 0.56%). The protein content in spring barley grain was higher in almost all cases, compared to the control. NEM increased by 77.86–78.47%, fat by 1.99–2.12%, fiber from 5.52 to 5.66%.

In primary agricultural production, economic impact key indicators are agricultural gross output and net income. If the total output or yield depends on agrotechnical practices, production is

Table 4. **Influence of $N_{60}P_{60}K_{70}$ and BNF on the spring barley grain chemical composition**

Treatment	Proteins, %	NEM, %	Fat, %	Fiber, %
1. Control	9.81	77.86	1.99	5.52
2. $N_{60}P_{60}K_{70}$	9.90	78.02	2.04	5.59
3. $N_{60}P_{60}K_{70}$ + BNF 0.5 l ha^{-1} 1 time	10.11	78.14	2.06	5.62
4. $N_{60}P_{60}K_{70}$ + BNF 1.0 l ha^{-1} 1 time	10.12	78.19	2.09	5.64
5. $N_{60}P_{60}K_{70}$ + BNF 0.5 l ha^{-1} 2 times	10.32	78.22	2.10	5.66
6. $N_{60}P_{60}K_{70}$ + BNF 1.0 l ha^{-1} 2 times	10.37	78.47	2.12	5.66
LSD_{05}	0.296	0.023	0.062	0.167

affected by profits and sales, the purchase price, etc. (Treinys, 1982).

Examining the economic indicators for fertilization, additional costs were used: fertilizer value, including its transport to the farm and the storage conditions, fertilization costs, the costs of premium yield harvesting, additional indirect costs. Control is taken as a base rate (reference point).

Economic impact indicators shall be calculated after calculating of the production effect. They are expressed in terms of agricultural value, or part of it. The most commonly used indicators of economic effect are gross output value and net income. The gross output value is calculated by multiplying the quantity of harvested yield from the unit purchase price. The net income is calculated from the gross production value minus the cost of production.

The core of economical evaluation is necessity to compare technologies and the allocation of resources used to their benefit or detriment. The result can be both positive and negative. Each composite indicator shall be expressed in monetary terms. In this experiment, the premium yield value was calculated by multiplying the yield and the spring barley price (Table 5). The average 2014–2015 spring barley purchase price was 203 € per ton of seeds. Additional production costs are calculated according to the BNF (13 € ha^{-1}) and the spray works (9 € ha^{-1}) prices. Additional gross profit was calculated according to the yield value and the additional production costs.

The evaluation of BNF efficiency shows that the spring barley seed yield varied from 0.39 to 0.93 t ha^{-1}. The maximum premium yield was received after the application of BNF 1.0 l ha^{-1} product solution, spraying twice. Spring barley, sprayed with BNF solution twice, gave the 0.93 t ha^{-1} premium yield compared to that of spring barley, sprayed once. The premium yield value was greater than the additional costs. The premium yield of spring barley, treated with BNF 1.0 l ha^{-1} solution twice, was higher by 68.9 € ha^{-1} than that of spring barely sprayed once.

The largest additional production costs were when spraying spring barley with BNF 1.0 l ha^{-1} solution twice – 30.4 € ha^{-1}. However, the cost of production minus produced the highest total profit of 158.1 € ha^{-1} or 50.47 € ha^{-1} higher than when spraying plants once.

According to Table 6, we see that the minimum seed yield of oilseed rape in 2014–2015 was received from the control plots. All experiment plots, where $N_{60}P_{60}K_{70}$ and BNF were used, achieved a significant yield increase. The oilseed rape yield increased by 8.1–23.3%, or from 0.18 to 0.52 t ha^{-1} compared to the control.

The minimum premium seed yield in 2014–2015 was when fertilizing only with $N_{60}P_{60}K_{70}$. The premium seed yield in comparison with the control was 0.18 t ha^{-1} (8.1%). The combination, having the most affecting impact on the rape yield, was $N_{60}P_{60}K_{70}$ + BNF 1.0 l ha^{-1} sprayed 2 times (variant 6). There the yield of oilseed rape was 2.75 t ha^{-1}. The influence on the seed yield increased due to the BNF spray rate and the number of treatment times. Higher yield was obtained by spraying BNF 1.0 l ha^{-1} twice.

Table 5. **Economic evaluation of the application of $N_{60}P_{60}K_{70}$ and BNF for spring barley according to grain yield**

Treatment	Premium yield, t ha^{-1}	Premium yield value, € ha^{-1}	Additional production costs, € ha^{-1}	Additional gross profit, € ha^{-1}
1. Control	–	–	–	–
2. $N_{60}P_{60}K_{70}$	0.39	79.1	24.6	54.5
3. $N_{60}P_{60}K_{70}$ + BNF 0.5 l ha^{-1} 1 time	0.59	119.6	12.0	107.6
4. $N_{60}P_{60}K_{70}$ + BNF 1.0 l ha^{-1} 1 time	0.71	143.9	15.2	128.7
5. $N_{60}P_{60}K_{70}$ + BNF 0.5 l ha^{-1} 2 times	0.78	158.1	23.9	134.2
6. $N_{60}P_{60}K_{70}$ + BNF 1.0 l ha^{-1} 2 times	0.93	188.5	30.4	158.1
LSD_{05}	0.224	40.1		50.9

Table 6. **Influence of $N_{60}P_{60}K_{70}$ and BNF on the oilseed rape seed yield**

Treatment	Seed yield, t ha^{-1}	Increase of yield, t ha^{-1}	Increase of yield, %
1. Control ($N_{60}P_{60}K_{70}$)	2.23	–	100.0
2. $N_{60}P_{60}K_{70}$ + BNF 0.5 l ha^{-1} 1 time	2.41	0.18	108.1
3. $N_{60}P_{60}K_{70}$ + BNF 1.0 l ha^{-1} 1 time	2.52	0.29	113.0
4. $N_{60}P_{60}K_{70}$ + BNF 0.5 l ha^{-1} 2 times	2.60	0.37	116.6
5. $N_{60}P_{60}K_{70}$ + BNF 1.0 l ha^{-1} 2 times	2.75	0.52	123.3
LSD_{05}	0.062		

The fertilizer $N_{60}P_{60}K_{70}$ and BNF increased the green fats content in oilseed rape seeds (Table 7). Most of all – 26.16% of green fats accumulation in oilseed rape seeds was observed when fertilizing with fertilizers $N_{60}P_{60}K_{70}$ and BNF 1.0 l ha^{-1} 2 times. The green protein content considerably increased in comparison with the control, from 23.43 to 23.93%. Dry matter in oilseed rape seeds was higher in almost all cases, it increased from 97.12 to 97.79% compared to the control.

The average 2014–2015 oilseed rape purchase price was 391 € per ton of seeds. Additional production costs are calculated according to the BNF (13 € ha^{-1}) and the spray works (9 € ha^{-1}) prices. Additional gross profit was calculated according to the yield value and the additional production costs (Table 8).

The evaluation of BNF efficiency shows that the oilseed rape seed yield varied from 0.18 to 0.52 t ha^{-1}. The maximum premium yield was received after the application of BNF 1.0 l ha^{-1} product solution, spraying twice. Spring rape, sprayed with the BNF solution twice, gave the 0.52 t ha^{-1} premium yield compared to that of oilseed rape sprayed once. The premium yield value was greater than the additional costs. The premium yield of spring rape, sprayed with BNF 1.0 l ha^{-1} solution twice, was higher by 89.92 € ha^{-1} than that of the one sprayed once.

Table 7. **Influence of $N_{60}P_{60}K_{70}$ and BNF on the oilseed rape seed chemical composition**

Treatment	Green fats, %	Green protein, %	Dry matter, %
1. Control ($N_{60}P_{60}K_{70}$)	25.80	23.43	97.12
2. $N_{60}P_{60}K_{70}$ + BNF 0.5 l ha^{-1} 1 time	26.03	23.75	97.68
3. $N_{60}P_{60}K_{70}$ + BNF 1.0 l ha^{-1} 1 time	26.07	23.81	97.74
4. $N_{60}P_{60}K_{70}$ + BNF 0.5 l ha^{-1} 2 times	26.13	23.86	97.72
5. $N_{60}P_{60}K_{70}$ + BNF 1.0 l ha^{-1} 2 times	26.16	23.93	97.79
LSD_{05}	0.194	0.315	0.435

Table 8. **Economic evaluation of the application of $N_{60}P_{60}K_{70}$ and BNF on oilseed rape according to the seed yield**

Variants	Premium yield, t ha^{-1}	Premium yield value, € ha^{-1}	Additional production costs, € ha^{-1}	Additional gross profit, € ha^{-1}
1. Control ($N_{60}P_{60}K_{70}$)	–	–	–	–
2. $N_{60}P_{60}K_{70}$ + BNF 0.5 l ha^{-1} 1 time	0.18	70.38	11.95	58.43
3. $N_{60}P_{60}K_{70}$ + BNF 1.0 l ha^{-1} 1 time	0.29	113.39	15.20	98.18
4. $N_{60}P_{60}K_{70}$ + BNF 0.5 l ha^{-1} 2 times	0.37	144.66	23.89	120.77
5. $N_{60}P_{60}K_{70}$ + BNF 1.0 l ha^{-1} 2 times	0.52	203.31	30.41	172.90
LSD_{05}	0.062	42.05		38.60

The largest additional production costs were when spraying spring barley with BNF 1.0 l ha^{-1} solution twice – 30.41 € ha^{-1}. However, when the cost of production is subtracted, the highest total profit is obtained – 172.9 € ha^{-1} or by 74.72 € ha^{-1} higher than when spraying plants once.

CONCLUSIONS

1. A significant premium yield was obtained everywhere where $N_{60}P_{60}K_{70}$ and BNF were used. Compared to the control, the spring barley yield increased by 6.8–16.3% or from 0.39 to 0.93 t ha^{-1}, and the straw yield increased from 0.38 to 0.70 t ha^{-1} or from 9.5 to 17.6%.

The observed positive influence of the combination $N_{60}P_{60}K_{70}$ + BNF 1.0 l ha^{-1} (treated 2 times) on the spring barley yield was 6.61 t ha^{-1}.

2. Application of $N_{60}P_{60}K_{70}$ and BNF positively influenced the 1 000 grain weight, sprouting energy, germination and is economically beneficial because it gave the highest profit compared with other options, 158.10 € ha^{-1}.

3. The combination, having the most affecting impact on the rape yield, was $N_{60}P_{60}K_{70}$ + BNF 1.0 l ha^{-1} sprayed 2 times. There the oilseed rape yield was 2.75 t ha^{-1}. Most of all – 26.16% of green fats accumulation in oilseed rape seeds and the green protein content considerably increased in comparison with the control, 23.43 to 23.93%. Dry matter in oilseed rape seeds was higher in almost all cases, compared to the control.

4. The maximum premium yield was received after the application of BNF 1.0 l ha^{-1} product solution, spraying twice. The premium yield of spring rape, sprayed with BNF 1.0 l ha^{-1} solution twice, was by 89.92 € ha^{-1} higher than that of the one sprayed once. Application of $N_{60}P_{60}K_{70}$ and BNF is economically beneficial because it gave the highest profit compared to other options, 172.90 € ha^{-1}.

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Vidmantas Spruogis, Elena Jakienė, Anželika Dautartė, Romualdas Zemeckis

ORGANINIŲ NANOTRĄŠŲ ĮTAKA VASARINIŲ MIEŽIŲ IR VASARINIŲ RAPSŲ PRODUKTYVUMUI IR EKONOMINIAM EFEKTYVUMUI

Santrauka

Tręšimo bandymas vykdytas Aleksandro Stulginskio universiteto Bandymų stotyje 2014–2015 metais. Vasariniai rapsai ir vasariniai miežiai buvo auginami keturlaukėje sėjomainoje, kur dar augo daugiametės žolės ir žieminiai kviečiai. Bandymų tikslas – įvertinti organinių nanotrąšų (ONT) įtaką vasarinių miežių ir vasarinių rapsų produktyvumui bei ekonominiam efektyvumui tręšiant mineralinėmis trąšomis $N_{60}P_{60}K_{70}$, o gautus rezultatus palyginti su kontrole. Bandymai vyko su vasarinių miežių veisle 'Luokė' ir vasarinių rapsų veisle 'Sponsor'. Nustatyta, kad tręšimas ONT trąšomis ir $N_{60}P_{60}K_{70}$ padidino vasarinių miežių 'Luokė' ir vasarinių rapsų 'Sponsor' derlingumą. Miežių grūdų derlius padidėjo nuo 6,8 iki 16,3 %, o rapsų sėklų derlius – nuo 8,1 iki 23,3 %, palyginti su kontroliniu variantu. Geriausi derliai buvo gauti tręšiant $N_{60}P_{60}K_{70}$ ir ONT norma 1,0 l ha^{-1} purškiant du kartus. Žaliųjų baltymų kiekis grūduose padidėjo 0,51 %. Tręšiant $N_{60}P_{60}K_{70}$ ir ONT ženkliai išaugo vasarinių miežių grūdų ir šiaudų derlius, pagerėjo grūdų kokybė, padidėjo 1 000 grūdų masė, dygimo energija ir daigumas. Tręšimas $N_{60}P_{60}K_{70}$ ir ONT miežiams yra ekonomiškai naudingas, nes davė didžiausią pelną, palyginti su kontroliniu variantu, – 158,10 € ha^{-1}. Tręšiant vasarinius rapsus ONT po 1,0 l ha^{-1} du kartus buvo gauta 89,92 € ha^{-1} daugiau pajamų, nei purškiant vieną kartą. Tręšiant vasarinius rapsus $N_{60}P_{60}K_{70}$ ir ONT po 1,0 l ha^{-1} du kartus, gauta daugiausia grynųjų pajamų – net 172,90 € ha^{-1}, palyginti su kontroliniu variantu.

Raktažodžiai: vasariniai miežiai, vasariniai rapsai, organinės nanotrąšos, derlius, cheminė sudėtis, ekonominis efektyvumas