

## EFFECT OF ORGANIC NITROGEN FERTILIZERS PROVITA AND FERMENTATOR PENERGETIC–K WINTER WHEAT AND ON SOIL QUALITY

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**Abstract.** Not only in Lithuania, but also in the European Union, one of applicable means for environment protection is organic farming. The direction of organic production in agriculture ensures safe nutrition because it reduces the use of fertilizers and consequently the pollution of environment: food quality is improving, soil remains biologically active and natural balance is maintained. Investigation of the effect of organic nitrogen fertilizer Provita and fermentator of organic matter Penergetic–k on organically grown winter wheat and soil was carried out in 2006–2008 on the farm of organic production of The Center of Agroecology at Lithuanian University of Agriculture. As the outcome of research it was determined, that spraying soil with Penergetic–k and Provita resulted in an essential increase of winter wheat productivity compared to either spraying with Penergetic–k or application of Provita alone; essential increase in the amount of proteins compared with application of Provita alone; essential increase in the amount of green fiber, compared with spraying with Penergetic–k alone; essential increase in the amount of phosphorus compared to untreated wheat. Penergetic–k and Provita did not have essential effect on the amount of gluten, index of sedimentation, amounts of potassium, magnesium and calcium in organically grown winter wheat. Spraying soil with Penergetic–k and application of Provita resulted in the essential decrease in grain and soil pH value, compared to spraying soil with Penergetic–k alone; essential decrease in redox potential compared with untreated wheat. Application of Provita fertilizers to winter wheat essentially increased the value of grain and soil specific electric conductivity, compared with spraying soil with Penergetic–k or application of combination of Penergetic–k and Provita fertilizers. The effect of usage of Penergetic–k and organic nitrogen fertilizers Provita on changes in soil qualities under the circumstances of organic farming, except for traditional measurements of soil, electrochemical tests of soil were carried out that provide us with additional information about their qualities and vitality.

**Keywords:** organic farming, productivity, composition, electrochemical characteristics.

### 1. Introduction

Quality of organic production, the protection of soil and the environment is fundamental to organic farming (Pfißner *et al.* 2001). The most important factors, influencing winter wheat productivity and grain qualities, are supplying plants with nitrogen. If more proteinous grains are to be matured, winter wheat should be treated with nitrogen fertilizers several times during the period of fertilization (Peltonen 1995; Janušauskaitė 1997; Šiuliuskas *et al.* 2000; Ehdaie and Waines 2001).

Appropriation of nitrogen fertilizers depends on the richness of soil in other nutrition elements, especially potassium and phosphorus; on soil's physical characteristics, which settle the routine of humidity and appropriation of nutrition matters. It also depends on fertilizer rates and time of fertilization. It has been found that winter wheat uses up

41 % of total nitrogen used before the period of coming to node, 18 % of total nitrogen used is appropriated in the period between coming to node and heading, 12 % of it is used up in the period between heading and flowering and finally 28 % of total nitrogen used is appropriated between flowering and harvesting. This is why to form proteinous grains of supreme quality; nitrogen should be supplied to plants not only at the early but also at late stages of their development (Тищенко and Благовещенская 1987; Petraitienė 1996; Woolfolk *et al.* 2002; Janušauskaitė and Šidlauskas 2004; Birkas *et al.* 2006). Under the conditions of organic farming, nitrogen could be supplied to plants, soil's productivity and biological activity maintained by growing leguminous plants or by application of organic fertilizers. If organic matter is slow to mineralize in soil, nitrogen shortage might become evident in decreasing yield, deterioration of its quality (Stopes *et al.* 2002).

Quality of winter wheat grains depends on many factors, rates of nitrogen fertilizers and application time being among the most important ones (Klupczyński *et al.* 2000; Janušauskaitė and Šidlauskas, 2004; Krištaponytė and Maikštėnienė 2004; Sileikiene *et al.* 2006). The greatest variations are characteristic to indexes of yield and amount of proteins in grains. Accumulation of proteins in bread wheat depends on the time of application of nitrogen fertilizers and meteorological conditions. Value of fall number is more dependant on breed qualities and intensity of fertilization than on the time of harvesting (Fowler 2003; Topal *et al.* 2003; Farrer *et al.*, 2006; Cesevičienė and Mašauskienė 2007).

While assessing technological qualities of grains, the greatest attention is paid to their proteinous qualities. Amount of proteins and gluten in flour are the most important quality indexes of nutritional grain, because other qualities depend on these ones to a greater or smaller extent. Amount of proteins in both grains and flour is a criterion of bread quality. Amount of proteins in grain may vary from 6 to 20 %. It is believed that good quality bread is impossible to produce from flour containing a small amount of proteins. This is why only grains with 11.5 % or superior amount of proteins are used for bread production. However, a sufficient amount of proteins alone is not enough to produce good quality bread. Baking qualities of some grain breeds is practically independent from the amount of proteins. In certain cases, increase in the amount of proteins in grains of such breeds, might result in decreased bread quality (Finney *et al.* 1987; Pomeranz 1993; Hosney 1993).

Factors that had essential influence on the good baking qualities with qualities of amount of proteins in winter wheat breeds and values of sedimentation index in grains, position themselves in such order of decreasing effect: meteorological conditions, application of nitrogen fertilizers, breed characteristics (Cesevičienė and Mašauskienė, 2008).

In the Center of Agroecology at Lithuanian University of Agriculture research was carried out which found that productivity of organically grown winter wheat breeds and values of yield quality indexes depended on breeds cultivated, application of organic nitrogen fertilizer Provita and spraying with liquid organic fertilizer Biojodis as well as growth activator Penergetic-p. When suitable breeds are chosen, dry organic nitrogen fertilizers are applied and liquid organic fertilizers and growth activators are sprayed on plants during the period of vegetation, productivity of wheat grains increased and their quality improved (Sliešaravičius *et al.* 2006; Pekarskas 2008a; Pekarskas and Mickus 2008; Rutkovienė *et al.* 2008).

As it results from the data of investigations carried out in Lithuania, Finland and Canada, amount of proteins and gluten in grains cultivated under the circumstances of organic farming is lower than that in grains grown under the circumstances of intensive farming (Beke *et al.* 2006; Poutala *et al.* 1994; Nieberg *et al.* 1996; Baltramaitytė and Rutkovienė 2000). As the data of Lithuanian investigation demonstrates, correlation coefficients between proteins and gluten, proteins and sedimentation index, amount of gluten and sedimentation index ( $r = 0.98; 0.75$

and 0.75) show direct and firm interdependency of these indexes (Rutkovienė *et al.* 2003).

Traditionally the quality of agricultural and nutritional products is assessed according to the amounts of product's composite parts. If this method is used, amounts of nutritional matters both beneficial and harmful to humans in organically grown products are calculated (Lundegardh and Martinsson 2003). Historically formed method of quality assessment of chemical analysis is one-sided, because it only reflects composition of different components, but does not give information about physiological and metabolic processes taking place (Hunt *et al.* 1999). One of the more recent quality assessment methods is bioelectric testing. They include method called electrochemical analysis. Roujun (1975) introduced the Theory of Bioelectronics, which is based on pH values, redox potential and electric conductivity (resistivity) in different (organic and nonorganic) water media. pH value in plants shows activity of protons and reflects energy changes. Products are regarded the healthier, the closer their pH value is to pH of human blood. Concentration of hydrogen ions changes cell's surroundings and redox potential, depending on it, changes cell's electric energy. When electric conductivity is measured, it shows ion concentrations in the cell as well as characteristics of osmotic pressure. It is rather difficult to explain separately how each of these three electrochemical characteristics are connected to product's quality. Because all three parameters are expressed by electricity rates it is possible to use NERST equation to find a derivative rate P (Rutkovienė and Nominaitis 2004).

Implementation of these methods to assess quality of organic products enables scientists to evaluate vitality of these systems. Measurements performed supply information about product's energetic value and its suitability for human organism, as well as its health status, age, level of maturity, depending on meteorological conditions and physiological characteristics. Although this method is very informative, it is rather difficult to interpret the data obtained. Value of pH index, even when statistically reliable differences are present, is rather small, because differences in pH manifest themselves only with hundredth parts of an integer. rH value is proportional to P value; electrical conductivity usually is inversely proportional to rH and P values. Products with low P and rH values and high rh value are considered to be more valuable. (Alföldi *et al.* 1996; Granstedt *et al.* 1997; Beaton 2001; Busscher *et al.* 2004; Rutkovienė and Nominaitis 2004; Goldin *et al.* 2007; Kahl *et al.* 2008).

## 2. Materials and methods

Investigation of the effect of organic nitrogen fertilizer Provita and fermentator of organic matter Penergetic-k on organically grown winter wheat was carried out in 2006–2008 on the farm of organic production of The Center of Agroecology at Lithuanian University of Agriculture. The soil on the farm was loamy of moderate heaviness *Endohypogleyi – Eutric Planosol – PLe-gln – W*, which was close to neutral and neutral (pH 6.7–7.0),

of high humusity (3.26–3.56 %), potassium rich (154–173 mg kg<sup>-1</sup>) and phosphorus rich (234–293 mg kg<sup>-1</sup>), extremely base saturated (99.8 %), with 0.166–0.1882% of total nitrogen determined in soil.

Index values of agrochemical characteristics were determined in the laboratory of the Center of Agrochemical Research at Lithuanian University of Agriculture. Soil's pH<sub>KCl</sub> was measured by potentiometer (ISO 10390), amount of mobile phosphorus and potassium by A–L, humus was determined by the method of dry burning (ISO 10694), total nitrogen values were found by Kjeldahl method.

Total test site for winter wheat investigations had the area of 30 m<sup>2</sup> (3×10), accountable area was 17.6 m<sup>2</sup> (2.2×8). Investigation was performed in four repetitions. Preceding crop of winter wheat was summer barley. Investigation was carried out on a Lithuanian winter wheat breed 'Širvinta 1'. No means for plant protection were applied.

Organic winter wheat had organic nitrogen fertilizer Provita applied to it before the last cultivation before sowing and then inserted into soil. Stubble-field of summer barley was sprayed with fermentator of organic matter PENERGETIC–k. 0 test - unsprayed and unfertilized, I test - Provita N<sub>14</sub> applied before sowing, II test - Before sowing soil was sprayed with PENERGETIC–k 300 g ha<sup>-1</sup> and fertilized with Provita N<sub>14</sub> and III test - before sowing sprayed with PENERGETIC–k 300 g ha<sup>-1</sup>.

Amount of proteins and gluten in grains of winter wheat was determined by LST 1522, sedimentation (by Zeleny method) according to LST 1498 the spectroscopic method of passing infrared radiation (AACC method 39–25:1998) with computer analyzer „Infratec“. Fall number was determined by LST ISO 3093. Green fats, fiber, ashes and Ca, P, K and Mg were determined by infrared computer analyzer.

Index values of electrochemical characteristics of winter wheat were determined by chopping grain with a chopping mill until homogeneous flour mass was achieved. Flour obtained was put into plastic container and poured over with distilled water (20 g of flour was covered with 40mg of distilled water). The mixture obtained was beaten in a shaker GFL 3017 (200 slew/min); after 45 minutes the mixture was centrifuged with a centrifuge EPENDORF 5702 (duration 4 minutes, 4000 slew/min). Centrifuged liquid was then poured out and pH, redox and conductivity measurements were performed.

Grains' PENERGETIC value is determined according to the formula:  $[\mu W] = [29,07 \text{ mV} \cdot (\text{rH} - 2\text{pH})]^2 \cdot \text{rh}_0^{-1}$ .

Organic nitrogen fertilizer Provita is produced according to a special technology from specially processed swine bristles, by eliminating humidity, chopping them and pressing into granules of 4mm. Chemical composition of Provita fertilizers is as follows: 14 % of nitrogen, 0.2 % K<sub>2</sub>O, 1.4 % P<sub>2</sub>O<sub>5</sub>, 0.3 % MgO, 1.7 % CaO, microelements such as zinc, boron, copper and others. PENERGETIC–k is a fermentator of organic matter, used in preparation of composts and treating manure (Pekarskas, 2008b).

Treatments were done every year three times reiteration, the data was statistically evaluated by the

method of disperse analysis using software ANOVA (Tarakanovas and Raudonius 2003).

### 3. Results and discussion

Spraying PENERGETIC–k and application of Provita to organic winter wheat before sowing resulted in the yield increase of 0.21–0.51 t ha<sup>-1</sup> or 5.01–12.17 per cent. Comparing productivity of organic winter wheat with untreated winter wheat it was found that increase was obtained by both spraying with PENERGETIC–k alone, application of Provita only and the combination of spraying with PENERGETIC–k and application of Provita fertilizers. Spraying soil with fermentator of organic matter PENERGETIC–k before sowing winter wheat and then applying Provita essentially increased winter wheat productivity compared to spraying with PENERGETIC–k only or application of Provita fertilizers only. No essential differences in organic winter wheat productivity were obtained between winter wheat sprayed with PENERGETIC–k and treated with Provita fertilizers (Table 1).

Application of organic nitrogen fertilizer Provita and spraying with fermentator of organic matter PENERGETIC–k resulted in increased intensity of mineralization processes of both Provita fertilizers and soil's organic matters and in this way organically grown winter wheat was better supplied with nitrogen and spraying soil with PENERGETIC–k (Table 1).

Application of organic nitrogen fertilizer Provita to winter wheat before sowing resulted in smaller amount of proteins in grains of winter wheat compared to untreated winter wheat. However, when soil was sprayed with fermentator of organic matter PENERGETIC–k and grains were treated with PENERGETIC–k as well as fertilized with Provita, amount of proteins was found to have increased, compared to unfertilized and unsprayed winter wheat. Spraying with PENERGETIC–k and application of Provita fertilizers resulted in greater amounts of proteins in grains compared to untreated wheat or treatment with Provita fertilizers only.

Fermentator of organic matters PENERGETIC–k and organic nitrogen fertilizer Provita increased the amount of gluten in grains of organic wheat. The greatest amount of gluten (19.91 %) was found when seeds were sprayed with PENERGETIC–k before sowing and fertilized with Provita fertilizer. PENERGETIC–k and Provita did not have an essential effect on the amount of gluten in grains of organic wheat, but the trend of increase of index value of gluten was observed under the effect of such treatments (Table 1).

When soil was sprayed with PENERGETIC–k, fermentator of organic matter, and organic nitrogen fertilizers were applied, winter wheat grown according to index values of sedimentation and amount of proteins in grains corresponded to quality class 2, although according to the amount of gluten in grains they corresponded to quality class 3 only. Either spraying soil with PENERGETIC–k or applying Provita fertilizers alone resulted in even poorer quality of wheat grain than when wheat was treated with a combination of PENERGETIC–k and Provita. The main

reason of such performance was the shortage of nitrogen in the course of wheat growth. This is a proof for results of investigations, carried out both in Lithuania and abroad (Janušauskaitė 1997; Stopes *et al.* 2002; Janušauskaitė and Šidlauskas 2004; Krištaponytė and Maikštėnienė 2004). Due to the lack of nitrogen organic wheat are of poorer quality than those intensively grown (Poutala *et al.* 1994; Nieberg *et al.* 1996; Baltramaitytė and Rutkoviėnė 2000).

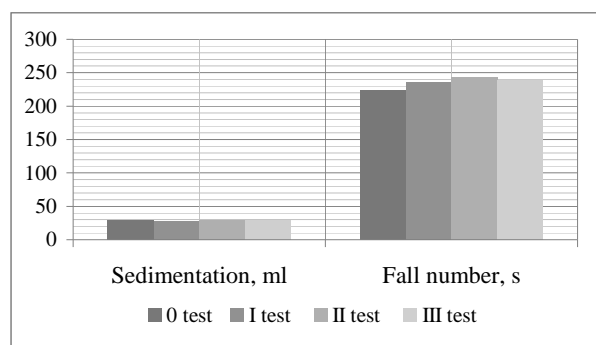
**Table 1.** Effect of organic nitrogen fertilizer Provita and fermentator of organic matter Pengergetic-k on productivity of organically grown winter wheat and amount of proteins and gluten in their grains. LUA, Agroecology Centre, 2006–2008

Treatment	Productivity t ha <sup>-1</sup>	Protein %	Gluten %
0 test	4.19	10.92	18.38
I test	4.49	10.88	18.70
II test	4.70	11.62	19.91
III test	4.40	11.18	18.92
LSD <sub>05</sub>	0.14	0.60	2.56

Application of organic nitrogen fertilizer Provita to winter wheat before sowing resulted in a low index value of sedimentation compared to untreated winter wheat. However, when the soil was sprayed with fermentator of organic matter Pengergetic-k, grains were treated with Pengergetic-k and fertilized with Provita, index value of sedimentation increased compared to untreated wheat. The greatest index value of sedimentation in grains was observed when grains were sprayed with Pengergetic-k before sowing and fertilized with Provita fertilizer. Pengergetic-k and Provita fertilizers did not have essential effect of the value of sedimentation index, but the tendency under the effect of fermentator of organic matter and under the effect of combination of fermentator and nitrogen fertilizers value of sedimentation index in grains increases (Fig 1).

Application of fermentator of organic matter Pengergetic-k and organic nitrogen fertilizers Provita resulted in increased fall number of winter wheat four. The increase obtained was 223–243 s. Spraying fermentator of organic matters Pengergetic-k on soil before sowing, application of both Pengergetic-k and Provita fertilizers increased values of fall number essentially compared to unfertilized organically grown winter wheat, but no essential differences were obtained compared to whiter wheat fertilized with Provita only (Fig 1).

Spraying Pengergetic-k on soil before sowing and application of Provita fertilizers increased the amount of green fats in organically grown winter wheat grains. When soil was sprayed with fermentator of organic matter Pengergetic-k, amount of green fats in grains increased essentially compared to untreated organically grown winter wheat grains, however, no essential differences in the amount of green fats was obtained when compared with application of either nitrogen fertilizers Provita or combination of Pengergetic-k and Provita (Table 2).



**Fig 1.** Effect of organic nitrogen fertilizer Provita and fermentator of organic matter Pengergetic-k on index value of sedimentation and fall number in grains of winter wheat grains. LUA, Agroecology Centre, 2006–2008

**Table 2.** Or Effect of organic nitrogen fertilizer Provita and fermentator of organic matter Pengergetic-k on the amount of green fats, fiber and ashes in grains of organically grown winter wheat. LUA, Agroecology Centre, 2006–2008

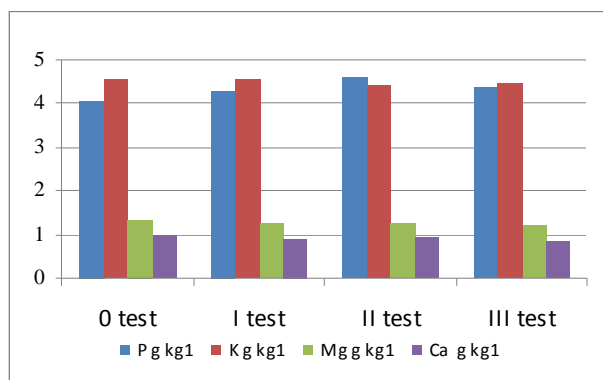
Treatment	Green fats %	Green fiber %	Green ashes %
0 test	0.96	3.24	1.60
I test	1.03	3.33	1.67
II test	1.10	3.73	1.68
III test	1.19	3.00	1.67
LSD <sub>05</sub>	0.20	0.35	0.24

When Pengergetic-k was sprayed on soil before sowing, smaller amounts of green fiber accumulated in grains of winter wheat compared to untreated winter wheat. When Pengergetic-k was sprayed on soil and nitrogen fertilizer Provita was applied, grains accumulated larger amounts of green fiber and this difference was essential compared to unfertilized and unsprayed wheat as well as with the ones sprayed with fermentator of organic matter Pengergetic-k. Pengergetic-k and Provita nitrogen fertilizers resulted in the increase of the amount of green ashes in wheat grains, but the increase was not essentially affected by these substances (Table 3).

**Table 3.** Effect of organic nitrogen fertilizer Provita and fermentator of organic matter Pengergetic-k on electrochemical values of winter wheat grains. LUA, Agroecology Centre, 2006–2008

Treatment	pH	Redox potential mV	Specific Electric conductivity $\mu\text{S cm}^{-1}$	P value $\mu\text{W}$
0 test	6.44	154.0	2.77	12.59
I test	6.38	145.7	3.45	13.31
II test	6.36	148.4	2.88	11.81
III test	6.43	148.8	3.16	12.35
LSD <sub>05</sub>	0.06	3.72	0.24	1.03

Spraying of Pengergetic-k on soil before sowing and application of Provita fertilizers increased the amount of phosphorus in grains of organic winter wheat. When soil was sprayed with fermentator of organic matter Pengergetic-k and organic nitrogen fertilizer Provita was applied, the amount of phosphorus increased essentially compared to unsprayed and unfertilized organically grown winter wheat, however, no essential differences were obtained compared with either application of organic nitrogen fertilizer Provita or spraying with fermentator of organic matter Pengergetic-k only (Fig 2).



**Fig 2.** Effect of organic nitrogen fertilizer Provita and fermentator of organic matter Pengergetic-k on amounts of calcium, phosphorus, potassium and magnum in grains of organically grown wheat grains. LUA, Agroecology Centre, 2006–2008

Spraying soil with Pengergetic-k before sowing and application of Provita nitrogen fertilizers resulted in reduction in the amount of potassium in winter wheat grains, however this decrease was unessential. The tendency for reduction of potassium in winter wheat grains under the effect of Pengergetic-k and Provita was established, though. The least amount of potassium was observed in winter wheat grains which had been sprayed with Pengergetic-k before sowing and fertilizer (Table 4).

Fermentator of organic matter Pengergetic-k and organic nitrogen fertilizers Provita decreased the amount of calcium and magnum in grains of organic winter wheat. The smallest amount of magnum and calcium was observed in grains of winter wheat that had been grown in soil sprayed with Pengergetic-k before sowing, Spraying soil with Pengergetic-k and application of Provita fertilizers did not have any essential effect on accumulation of calcium and magnum in grains of organically grown winter wheat .

Application of fermentator of organic matter Pengergetic-k and organic nitrogen fertilizer Provita lessened the pH values of organic winter wheat grains. pH value was the least, when the soil had been sprayed with Pengergetic-k before sowing and organic nitrogen fertilizer Provita had been applied. Having sprayed soil with Pengergetic-k before sowing and applying Provita fertilizers caused an essential decrease in grains' pH values, compared to unfertilized and unsprayed winter wheat as well as with spraying Pengergetic-k alone (Table 4).

Fermentator of organic matter and organic nitrogen fertilizer Provita contributes to the decrease in redox potential of organically grown winter wheat grains. The smallest value of redox potential was found in cases when organic winter wheat had been treated with Provita fertilizer before sowing. Having sprayed Pengergetic-k on organic winter wheat before sowing and treated with Provita fertilizers essential reduction in values of redox potential were observed when compared to unsprayed and unfertilized winter wheat. Comparing effects of Pengergetic-k and Provita fertilizer between themselves, no essential differences were found (Table 4).

The greatest value of winter wheat grain specific electrical conductivity was obtained by application of Provita fertilizers before sowing while the smallest value was in case of unsprayed and unfertilized winter wheat. Application of Provita fertilizers caused an essential increase in the value of specific electrical conductivity compared to spraying soil with Pengergetic-k or treating winter wheat with the combination of Pengergetic-k and Provita.

Spraying soil with Pengergetic-k and application of Provita fertilizers caused essential decrease in P value of organically grown winter wheat grains. Spraying Pengergetic-k on organically grown winter wheat before sowing and treating them with Provita fertilizer resulted in the greatest energetic value of wheat grains (Table 4).

Effect of a certified growth stimulator used Pengergetic - k and application of Provita fertilizers on vicissitude of soil characteristics are presented in Table 4.

**Table 4.** Effect of growth stimulator Pengergetic - k on soil electrochemical parameters and mineral nitrogen, Data of LUA Agroecological centre, 2006-2008

Treatment	pH	Redox potential mV	Specific electric conductivity $\mu\text{S cm}^{-1}$	$\text{N}_{\text{min}}$ mg kg <sup>-1</sup>
0 test	7.05	27.3	173	10,61
I test	7.24	28.0	180	14,12
II test	7.32	28.58	208	16,48
III test	7.33	29.5	188	11,82
LSD <sub>05</sub>	0.04	1.51	23	5.21

It was determined that the use of preparation Pengergetic- k in the technology of winter wheat growth had an effect on vicissitude of electrochemical parameters of soil: increase tendencies of pH, redox and electrical conductivity. Using preparation to felt the seeds and to spray plants during the period of milk maturity results in greater values of electrochemical parameters than solely felting seeds with the preparation.

As oxidation environment grows stronger (redox potential in trial III >28), process of mineralization becomes faster and amount of mineral nitrogen in soil increases after crop harvesting. When in trial III preparation was used to felt seeds and to spray plants during the period of milk maturity.

#### 4. Conclusions

1. Spraying soil with fermentator of organic matter Penergetic-k and application of organic nitrogen fertilizer Provita resulted in essential increase in productivity of winter wheat grains compared fertilizers alone. The amount of proteins increased only compared to application of Provita fertilizers alone, amount of green fiber increased essentially only compared with spraying with Penergetic-k alone, amount of phosphorus only compared to unfertilized and unsprayed wheat. Both spraying soil with Penergetic-k and treating winter wheat with Penergetic-k and Provita fertilizer essentially increased fall number of wheat flour and when soil was sprayed with Penergetic-k, the amount of green fats in grains increased essentially as well.
2. Spraying soil with Penergetic-k and application of Provita fertilizers essentially reduced pH value of wheat grains compared to spraying soil with Penergetic-k; redox potential decreased essentially compared to unsprayed and unfertilized wheat. As winter wheat was treated with Provita fertilizers, value of specific electrical conductivity increased essentially compared to spraying soil with Penergetic-k or treatment with a combination of Penergetic-k and Provita fertilizers. Spraying organically grown winter wheat with Penergetic-k before sowing and application of Provita fertilizer resulted in the greatest energetic value of organically grown winter wheat grains. Grains of organic winter wheat treated this way are the most suitable for human organism.
3. Research shows that stimulator Penergetic-k and Provita fertilizers enhances soils oxidation characteristics, increases its electrical conductivity and has an effect on vicissitude of mineral nitrogen in the soil.

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