# Bioenergetical appraisal of the technology of jerusalem artichokes growing at different systems of fertilization in western forest and steppe regions of Ukraine

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*Received July 17.2014: accepted July 19.2014*

Abstract. The article suggests a bioenergetical analysis of energy content in humus of grey forest soil depending on its fractionally grouped structure. It presents culculations of energetic efficiency of applying mineral, organic and organically – mineral systems of fertilizing jerusalem artichokes, in particular with including multifunctional preparation of phylazonit. The research determines efficiency of applying agrocenosis of the gross energetic resource .

Key words: system of fertiliazation, humus, bioenergetical analysis, coefficients of energetical efficiency.

## INTRODUCTION

A high potencial of productivity and wide consumption of jeraselem artichokes facilitate public interest in growing this crop as a source of biomass. In spite of a high energetic capacity of jerusalem artichokes, the technology of this crop growing needs additional developments of the potential methods of increasing its yielding capacity under conditions of different soils and different climatic zones of Ukraine.

Therefore, the problem of appraising efficiency of various agrotechnical instruments including the systems of fertilization as well as their energetic effects is of an acute importance now.

## RECENT RESEARCH AND PUBLICATIONS ANALYSIS

One of the priority ways of solving the problem of enlarging the share of renewable energy in energetical balance of agriculture is growing bioenergetical crops accumulating the dry substance with concentrated energy received in the result of photosysthesis[1, 3, 22 ].

The problem of delievering renewable sources of energy in agriculture is connected with growing a biomass. The plant biomass, including jerusalem artichokes is able to produce energy by means of the immediate combustion of solid, biofuels and conversions into liquid fuels (biofuels) or the gasform fuels (methane) [7]. Some analysts forcast that the biomass of the plant resources will manage to become one of the major sources of biofuels manufacture [8, 15, 19].

The jerusalem artichoke is a universal crop .It is widely used as a foodstaff as well as an industrial crop, forage and a medical herb. In addition, it is a raw material for phitoenergetics [6]. The jerusalem artichoke is a crop with a potential ability of attaching solar energy [6, 18] and is able to perform a function of a reliable source of renewable types of energy [4, 20]. It may be used for combustion of a dry biomass including the case of its utilization in combination with the coal formed in brickets or pellets for producing biogases [6, 17, 18,20]. The jerusalem artichoke got serious perspectives of becoming a source of bioethanol receiving [14], in particular in Ukraine with colossal facility for its manufacture [12].

## OBJECTIVES

The research is focused on the analysis of bioenergetics efficiency of jerusalemartochokes growing in Western Forest and Steppe regions of Ukraine on grey forest soils at various rates of mineral nutrition.

## MAIN PRESENTATION

The research was carried out under industrial condotions of the branch of the department of soil science , crop – growing and agrochemistry of Lviv national agrarian university. All laboratory experiments were carried out by the standard methods in the research laboratory of agrochemistry of the department (A certificate No RL 1354/09, 24 Apr. 2007).

Field experiments were carried out on grey forest soils of the Western Forest and Steppe regions of Ukraine on the plot of the jerusaleum artichoke at the mineral organic and organically – mineral systems of application with the use of phylazonit which is a multifunctional preparation of bacterial origin.

The versions of the experiment are as follows: 1. Without fertilizers (control); 2. $N_{100}P_{90}K_{160}$; 3. $N_{140}P_{90}K_{160}$ ; 4. A manure 20 l/ha; 5. A manure 20 t/ha + phylazonit 10 l/ha; 6. A manure 10 t/ha + $N_{50}P_{25}K_{60}$; 7. A manure 15 t/ha + $N_{65}P_{53}K_{70}$ ; 8. Amanure 20 t/ha + $N_{40}P_{40}K_{40}$; 9. $N_{100}P_{50}K_{160}$ + Phylazonit 10 l/ha ; 10. $N_{140}P_{90}K_{160}$ + phylazonit 10 l/ha. 11. A manure 15 t/ha + $N_{65}P_{53}K_{70}$ + phylazonit 10 l/ha 12. A manure 20 l/ha + $N_{40}P_{40}K_{40}$ + phylazonit 10 l/ha.

The total area of each of the experimental plot is 85 $m^2$. The accounting area is 50 $m^2$. The repeatedness is thrice repeated. The soils of the experimental plot are grey – forest light – loamy and coarse dusty. Before the experiments the upper layer ( 0-20 cm ) of humus – eluvial ( HE ) horizon got the following agrochemical indices : PH of salt – 5.6; hydrolite acidity – 1.52; sum of absorbed bases – 9.6 mmol/100 gr of a soil; degree of bases saturation – 86.4 %.

Let us consider the jerusaleum artichokes of Lvivskyi variety characterized by its intensive growth of a vegetative mass and a high degree of receiving nutriets from the soil [2].

The value of humus content was determined by the method of Tiurin [5]. Fractionally – grouped content of humus was estimated by the method of Ponomariova – Plotnikova [13]. Calculations of the costs of energetic resources and energetic efficiency of the system of jerusalem artichokes fertilization were carried out according to current methods [5, 9, 23].

The statistical procession of data was carried out by means of the programmes STATISTIKA 6.0 and EXCEL. To appreciate the energetic state of the grey forest soils by means of its energy contentwe employed the equation [16] which considers the quantalive content of humus and heat capacity of its main fractions. The mentioned above equation got the following form (1):

$$Q = (19{,}96HA + 9{,}16FA + 17{,}86HR)\, H\, d\, 10, \quad (1)$$

where: Q − is the reserve of energy accumulated by the soil humus, Hj/ha; 19,96 − heat of combustion of humidified residue, Kj/g; 9,16 − heat of combustion of fulvoacids, Kj/g; 17,86 − heat of combustion of humificated residue, kj/g; HA − content of humificated acids, %; FA − content of fulvoacids, %; HR content % HR – content of humificated residue, % H – soil layer, m; d – density of soil structure, g/$cm^3$, 10 – coefficient of converting into Hj/ha.

The gross energy accumulated by the yields of Jerusalem artichokers was determined by means of calculation of the content of the total energy of the yield**s** of above - and underground parts by the average indices of 3 years of experiments. The gross energy costs for the period of growing were determined by means of evaluation of energetic costs on the basic of technological charts. Energy of photosynthetically active radiation received for crop rotation in the zone of Western Forest Steppe constituted 18,01 Hj/ha for the period of vegetation.

Coefficient of energetic efficiency $C_{ee}$(2) was introduced as a share of energetic costs for growing from the total energy accumulated by the yields:

$$C_{ee} = E_y/E_a, \quad (2)$$

where: $E_y$ – total energy accumulated by yields; $E_a$ – total costs of anthropogenic energy for growing Jerusalem arthichokes.

For comprehensive appraisal of efficiency of agrocenosis as an open thermodynamic system closely connected with the currents of solar energy we employed the equation of calculating the coefficient of the use of energetic resources in agrocenosis $C_{na}$ (3) which takes into consideration energy reserves in the humus of soils and photosynthetically active radiation [2]:

$$C_{na} = E_y/E_r + Q + E_a, \quad (3)$$

where: $E_r$ – reserve of humus of soils (0-40 cm), Hj/ha; $Q$ – gross photosynthetically active radiation for the vegetation period, Hj/ha.

Calculations of the biological coefficient of the use of anthropogenic energy and energy of photosynthetically active radiation by the yields of agrocenosis of Jerusalem artichokes were carried out according to (4):

$$C_b = E_b/Q + E_a. \quad (4)$$

Our calculations resulted in the position that growing of Jerusalem artichokes is energetically reasonable in all experimental versions except on the version of control. Coefficients of energetic efficiency, nevertheless, were fluctuating rather sufficiently depending on the system of fertilization (See Table)

Depending on the applied fertilizers the average content of the humus compound in the upper layer (0-20 cm) of grey forest soil was ranging in a rather wide diapason (from 1,29 on the control plots to 1,76% on the version of organically-mineral fertilizers application combined with the use of phylazonit).

Such fertilization secured not only increased indices of humus content in soils but also facilitated modification in its fractionally-grouped srtructure. This phenomenon has been already discussed in our previous publications [11].

The results of the content of different fractions of humus compounds showed that the increase of the standards of organic fertilizers caused the increase of the content of humidified acids and decrease of the fulvoacids. This fact effected the correlation $C_{ha}$ :$C_{fa}$ and reflected improvements of indices of humus quality.

The best indices of the correlation $C_{ha}$:$C_{fa}$ were in the versions of organically-mineral systems of fertilization with application of phylazonit. Huminal acids have two times more heat-producing capacity comparing with fulvoacids and 10% more in comparison with an unhumidified residue. Therefore, modifications in fractionally-groupped content of humus provided different indices of the reserve of energy accumulated by humus.

**Table.** Bioenergetics analysis of the fertilizer systems under Jerusalem artichoke in Western Forest Steppe of Ukraine

| No | Version | H % | $E_r$ | $E_y$ | $E_a$ | $C_{ee}$ | $C_{na}$ | $C_b$ |
|---|---|---|---|---|---|---|---|---|
| | | | Hj/ha | | | | | |
| 1 | Without any fertilizer(control) | 1,29 | 26,6 | 354,9 | 169,5 | 2,09 | 1,66 | 1,89 |
| 2 | $N_{100}P_{50}K_{120}$ | 1,42 | 29,5 | 559,7 | 194,5 | 2,88 | 2,31 | 2,63 |
| 3 | $N_{140}P_{90}K_{160}$ | 1,44 | 30,1 | 579,1 | 198,5 | 2,92 | 2,35 | 2,67 |
| 4 | Manure 20 t/ha | 1,55 | 33,3 | 566,0 | 189,5 | 2,99 | 2,35 | 2,73 |
| 5 | Manure 20 t/ha + phylazonit 10l/ha | 1,58 | 34,1 | 594,3 | 190,0 | 3,13 | 2,45 | 2,86 |
| 6 | manure 10 t/ha + $N_{50}P_{25}K_{60}$ | 1,63 | 35,3 | 560,7 | 191,5 | 2,93 | 2,29 | 2,68 |
| 7 | Manure 15 t/ha + $N_{65}P_{53}K_{70}$ | 1,68 | 36,2 | 590,4 | 200,5 | 2,94 | 2,32 | 2,70 |
| 8 | Manure 20 t/ha + $N_{40}P_{40}K_{40}$ | 1,70 | 37,2 | 596,4 | 205,5 | 2,90 | 2,29 | 2,67 |
| 9 | $N_{100}P_{50}K_{120}$+ phylazonit10 l/ha | 1,45 | 30,4 | 593,2 | 195,0 | 3,04 | 2,44 | 2,78 |
| 10 | $N1_{40}P_{90}K_{160}$+ phylazonit10 l/ha | 1,48 | 31,2 | 615,5 | 197,0 | 3,12 | 2,50 | 2,86 |
| 11 | Manure 15 t/ha + $N_{65}P_{53}K_{70}$ + phylazonit10 l/ha | 1,72 | 38,0 | 654,6 | 203,0 | 3,22 | 2,53 | 2,96 |
| 12 | Manure 20 t/ha + $N_{40}P_{40}K_{40}$ + phylazonit10 l/ha | 1,76 | 38,9 | 709,8 | 206,0 | 3,44 | 2,70 | 3,17 |

The best indices of the total energy accomulated by humus in the upper layer (0-20 cm) of the grey forest soil was provided by organically-mineral system of fertilization with application of phylazonit which facilitated accumulation of humus content on the level of 1,72 – 1,76%. The indices of the total energy, then were on the level of 38,0 – 38,9 Hj/ha. These indices prevailed the analogical data of the control version in 11,4 – 12,3 Hj/ha.

Organically-mineral system of fertilization without application of phylazonit provided somewhat lower indices of the reserve of accumulated energy (35,3-37,2 Hj/ha).

The lowest indices (29,5-31,2 Hj/ha) were received from the mineral system of fertilization, including the versions with application of phylazonit.

The value of the net reserves of energy in the yields of Jerusalem artichokes were determined by the indices of productivity of the green mass and tubers [10,21] and their energy capacities which constituted on the average 16,8 Mj/kg of the dry biomass [6].

Determination of the index of the content of accumulated energy in Jerusalem artichokes biomass proved that application of fertilizers sufficiently raise this index even in the versions of mineral systems of fertilization which has much lower positive effect on the increase of indices of energy accumulated by humus. The yield gross reserve of energy on the plots No 2-3 prevailed in 58-65% analogical indices of unfertilized plots. Practically the same values of the reserves of energy accumulated by yields were received on the plots manured with a standard of 20 t/ha.

Organically-mineral system of fertilization provided the highest indices of the total energy accumulated by the yields which prevailed the indices of the control version in 85-100%.

Such a dependence provided the highest indices of energetic efficiency in spite of the increase of costs of anthropogenic energy ($E_a$) with application of organic and mineral fertilizers.

The integral index of the reason for application of energetic resources in agrocenosis is the coefficient of energetic efficiency. The index of this coefficient ranges in a sufficient diapason and is much depended upon the system of fertilization. In the version of control the index $C_{ee}$constituted 2,1. This proves the position that Jerusalem artichokes even without any agrochemical instrumnts are able to accumulate much energy in the yields.

Application of fertilizers provokes the increase of the coefficients of energetic efficiency. This index increased from 2,9 in the versions with mineral system of fertilization to 3,4 on the plots of organically-mineral systems of fertilization. Such a tendency reflects a high payback of the energetic costs put into a technology of the crop growing. As a perennial plant Jerusalem artichokes output high yields without sufficient costs for fertilization. Therefore, the value of energetic efficiency have the tendency to increase only. According to the data [2] in 3-4 years of growing Jerusalem artichokes on the same plantation causes the dramatic decrease of agrocenosis productivity. Therefore, the high payback of energetic resources for these several years facilitates the increase of the indices of energetic efficiency coefficient.

Coefficient of agrocenosis productivity Cpa refleets the efficiency of the use of natural resources by the crop, i.e. the reserves of soils energy and photosynthetically active radiation.

In our research this index was also sufficiently fluctuating and depended much on the system of ferlilization. In our control version it constituted 1,7 and in the versions of organically-mineral system with application of phylazonit it achieved the level of 2,5-2,7.

Mineral system of fertilization provided the sufficient increase of the coefficient of agrocenosis productivity in comparison with the version of control. But its value were much less than in the versions of organically-mineral system. This means, the versions of mineral system of fertilization get their yields due to the reserves of energetic resources of soils. In other words, the increase of productivity of agrocenosis is secured due to dehumification which facilitates the risk of negative anthropogenic loading on the soil.

Biological coefficient of energy utilization by agrocenosis $C_b$ reflects the general trend of the increase of energetic efficiency under conditions of the combined application of organical and mineral fertilizers.

One should confess, the calculations of coefficients of energetic efficiencies pointed to the tendency of their increase due to both increase of energetic costs for growing of biomass and the improvement of the state of the soil humus, in particular its content enlarging and the increase of humid acids share. On the other hand, high energetical costs do not secure higher energy liberation under conditions of soils degradation which was reflected in the versions with mineral system of fertilization.

The correlation $C_{ha}$ :$C_{fa}$0,83 and the quantity of energy accumulated by humus (Er) carry out a mutual influence on the coefficient of energetic efficiency (Fig 1).

At correlation $C_{ha}$:$C_{fa}$ 0,83 and Er 38,9 the maximum value of $C_{ee}$ will constitute 3,4. Nevertheless, the value of $C_{ee}$ is under the greater impact of the quantity of energy accumulated by the yield ($E_y$) (Fig 2). When the value of index of energy accumulated by the yields of Jerusalem artichokes (Ey) is 709 Hj/ha, the maximum value of $C_{ee}$ will constitute 3,6.

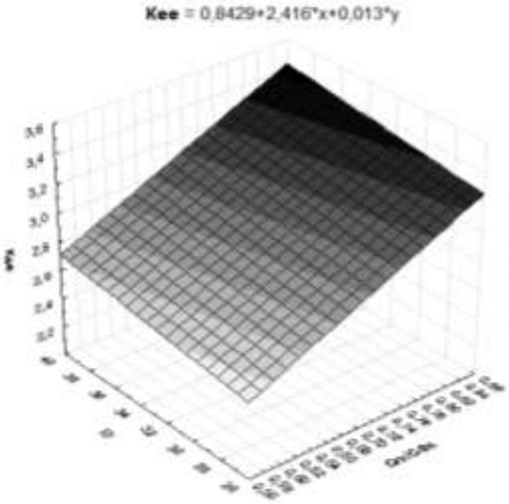


**Fig 1.** Dependence of the coefficient of energetic efficiency on the quality and reserves of energy in humus

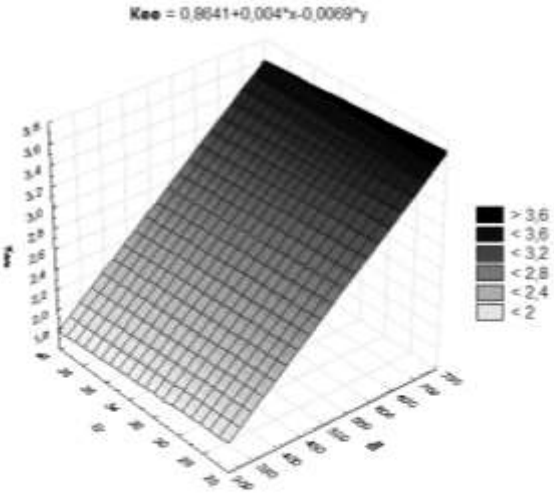


**Fig 2.** Dependence of the coefficient of energetic efficiency on the energy accumulated by the yields and humus

The results of dispersial analysis proved the position that the coefficient of energetic efficiency is under a sufficient impact of the correlation $C_{ha}$ :$C_{fa}$ and the index of energy accumulated by the yields ($E_y$) because the multivariate coefficient of determination $R^2$=0,96 reflects very tight connection according to the scale of Cheddock. The value of F is steady and constitutes 110,17. The regection zone is described by the right-hand interval (4,69; +∞). As $F^A$=110,17 gets into the regection zone, one may state of the absolute reproducibility of the experiment.

## CONCLUSIONS

1. Jerusalem artichoke is a highly productive energetic crop which is able to accumulate a sufficient quantity of a dry substance by its tubers and overground mass. When growing in Western Forest and Steppe of Ukraine the crop's energetic potential achieves 355 Hj/ha . Under conditions of rational standards of fertilization the crop grows two times more intensive.

2. Application of the systems of fertilization both influence the increase of productivity of agrocenosis of Jerusalem artichokes and improves the state of humus of the grey forest soils which effects positively the reserve of energy accumulated by humus. In the upper layer of soil (0-20 cm) the reserves of energy in humus effected by organically-mineral system of fertilization together with the microbiological preparation of Phylazonit achieves 38-39 Hj/ha and 1,4 times prevails the indices of the version of control.

3. The highest indices of energetical efficiency of Jerusalem artichokes growing were received due to organically-mineral system of fertilization with a standard of manure 10 l/ha. Such a system secured the highest indices of the coefficient of energetical efficiency ($C_{ee}$), the coefficient of the use of energetical resources of agrocenosis ($C_{na}$) and biological coefficient of the use of anthropogenic energy ($C_b$) which constituted 3,44; 2,70 and 3,17 correspondingly.

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