

Economic and energy efficiency of potato growing under drop irrigation in the Southern Steppe

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Goal. To determine the features of economic and energy efficiency and productivity of potato plants of variety Kobza depending on the elements of the technological process of growing under drip irrigation in the South of Ukraine.

Methods. The research was performed during 2013 – 2015 in the area of the Inhulets irrigation system by generally accepted methods. Field, laboratory, mathematical-statistical, computational, and comparative methods were used, abstract and system analysis was performed. **Results.** The maximum yield was obtained when using local application of mineral fertilizers at a dose of N₆₀P₆₀K₆₀ on the background of soil moisture 0.6 m by 35.81 t/ha with the number of tubers under the bush 6.3 pcs. The average cost of the material obtained in the experiment — 1,522 thousand UAH/t. Increasing the depth of the calculation layer and applying fertilizers in various ways helped to reduce costs. The exception was the use of N₆₀P₆₀K₆₀ with irrigation water, which led to a slight increase in cost. On average, according to the experiment, the energy yield was 103.9 GJ/ha, in the control, it was accumulated from 79.2 to 82.9 GJ/ha. **Conclusions.** The lowest cost (1,345 thousand UAH/t of product), the maximum net profit (77,160 thousand UAH/ha), and the increase in energy (66.30 GJ/ha) were obtained under conditions of moistening of 0.6 m of the soil layer and local application of N₆₀P₆₀K₆₀. The level of profitability was 160%, the energy efficiency ratio was 2.24.

Key words: *economic evaluation, yield, moisture conditions, fertilizer application method, calculated soil layer, mineral fertilizers.*

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Potato are one of the most productive crops in the medium climate zone. But the cultivation of potato in the Southern Steppe of Ukraine is a rather difficult task: due to climate change and high air temperatures, potato plants stop growing [1-2].

Agricultural innovators point to the significant benefits of implementing a drip irrigation in potato production [3-4]. Increased yields and quality, ease of access to fields and reduced water consumption, use of fuel, labor, and fungicides are all reflected on the final product and are the reason for the drip irrigation use in potato growing [5-6].

In a market economy, a necessary condition for efficiency is the competitiveness of products. Ukraine is among the leading countries in Europe in gross production volumes, but the efficiency of the industry is significantly lower. At the same time. Some agricultural enterprises even have losses from the sale of potatoes [7].

The efficiency of production, which determines the level of management and the branch development, depends on many components. Among them are the placement of crops and their concentration in climatic zones and the organization of production [8].

Due to the rapid growth of material resources cost, an increase depreciation expense, despite a certain crop capacity increase, the cost of growing potatoes has been increasing over the past years [9]. The cost of potato can be reduced due to the rational and economical use of planting material, organic and mineral fertilizers, chemicals, fuel and oil [10-11].

The purpose of research — to determine the productivity, features of economic and energy efficiency of Kobza potato variety, depending on the elements of cultivation technique with drip irrigation in the South of Ukraine.

Materials and research methods. The study was carried out during 2013-2015. at the Institute of Irrigated Agriculture of Ukraine NAAS (IZZ NAAS), located on the right bank of the Dnieper in the zone of the Ingulets irrigation system.

The soil of experimental plot is dark chestnut, slightly saline, medium loam. The humus horizon is 47-52 cm soil, is characterized by high fluff, connectivity and a tendency to float, which is associated with its natural high salt content and a narrow ratio of Ca²⁺ and Mg²⁺ (2.5-2.8). The water-physical and physical-chemical properties of experimental plot soil are generally typical. In addition, when dry, such soil acquires high density, low water permeability and a tendency to swell. In the arable layer, the humus content is 2.2%, the lowest moisture capacity is 21.3% in the meter layer of soil, the wilting moisture is 9.5% of the dry soil mass, the structure density is 1.41 t/m³, the pH of the water extract of the arable layer soil - 6.8-7.2.

Subsoil waters occur at a depth of 18-20 m and have almost no effect on the water-air regime of the zone of active moisture exchange. For irrigation we used water from a borehole. This water level of mineralization was within 1.4-

1.6 g/dm³ during the research period. According to the anionic composition, the water is chloride-sulfate, according to DSTU 2730-94 it belongs to the II class (limited use for irrigation).

The experiment was based on the split plot method. The plots of the first order had a plant area of 98 m², the accounting area - 49 m², the second order - 14 and 7 m². The plots had four lines and four repetitions. The feeding area is 70x25 cm (Table 1).

1. Experience scheme

| Calculation layer, m (factor A) * | Fertilization method (factor B) |
|--|--|
| 0,6 0,4 0,2 | No fertilizers |
| | N ₆₀ P ₆₀ K ₆₀ locally at planting |
| | N ₆₀ P ₆₀ K ₆₀ with irrigation water |
| | Calculated dose for obtaining a crop of tubers 35 t/ha locally at planting |
| | Calculated dose for obtaining a crop of tubers 35 t/ha with irrigation water |
| Note: * The accepted mode of pre-irrigation soil moisture – 80-80-70% lowest soil moisture capacity, differentiated by periods: shoots-budding; budding-flowering; flowering-wilting. | |

One of the best varieties of potatoes adapted to the weather conditions of the South of Ukraine for cultivation on irrigation is the variety Kobza used in the experiment. It has the following characteristics: an early ripening variety of table potatoes; tubers are short-oval, white, with a smooth skin, few and shallow eyes; the pulp is creamy; taste is good; flowers are white. The originator is the Institute of Potato of NAAS. Technological yield is 21 t/ha on 40-45 days after shoots emergence, 52 t/ha at the end of the growing season, after summer planting with freshly harvested tubers – 22 t / ha, with last year's tubers - 35 t/ha.

Starch content - 17.1-18.7%, taste - 4.2 points. The variety is resistant to cancer, stem nematodes, fusarium and common scab, relatively resistant to ring rot, is affected by the M virus and late blight. The variety is included in the State register of plant varieties suitable for distribution in Ukraine in 1995.

The study was carried out in accordance with the current methods for field experiments and related research [12-14]; calculations of irrigation rates - according to the recommendations from the operational control and management of crop irrigation regimes using the tensiometric method [15]; the structure of the crop was determined taking into account the requirements of the State standard of Ukraine [16]; the statistical processing of the experiments was carried out according to the method of Ushkarenko and others [17]; economic assessment - on the basis of standards, norms and prices adopted at the Institute of Irrigated Agriculture of the NAAS for the production of crops [18]. The energy efficiency was calculated according to the methods for the cultivation of agricultural crops [19].

The result and discussion. The type of fertilizer applied had the biggest influence on the cost. Since the most expensive of them is Master®, the costs of cultivation were the highest when N₆₀P₆₀K₆₀ was applied with irrigation water - more than the unfertilized control by 12.620 thousand UAH (31%) on average for the factor (Table 2). The smallest costs compared to other types of fertilizers were when applying ammonium nitrate (calculated dose of fertilizers locally) - only 5.439 thousand UAH (13% in addition compared with unfertilized control). The costs in the variant without fertilizers differed insignificantly - on average, they were 40.784 thousand UAH / ha. Additional costs for water in the layer of moisturing of 0.4 and 0.6 m were 548 and 731 UAH compared with a layer of 0.2 m.

The average cost of the material obtained in the experiment is 1.522 thousand UAH / t. Both increasing the depth of the calculated layer and applying fertilizers in different ways helped to reduce the cost. An exception was the use of N₆₀P₆₀K₆₀ with irrigation water, which led to an insignificant cost increase. Thus, an increase in the calculated layer from 0.2 to 0.4 m reduced the cost of potato by 85 UAH (5.4%), to 0.6 m - by 114 UAH (7.2%); applying the calculated dose of fertilizers locally - by 270 UAH (16.1% compared to unfertilized control); with irrigation water – by 241 UAH (14.4%); application of N₆₀P₆₀K₆₀ locally - by 16%.

2. Economic efficiency of using different methods of fertilization and moistening conditions with drip irrigation of potato (average for 2013-2015)

| Calculated soil layer, m (factor A) | Fertilization method (factor B) | | Productivity, t / ha | Expenses, thousand UAH / ha | Cost, thousand UAH / t | Conditional net income thousand UAH / ha | Profitability, % |
|-------------------------------------|--|-----------------------|----------------------|-----------------------------|------------------------|--|------------------|
| 0,6 | No fertilizers | | 24,9 | 40,958 | 1,645 | 46,192 | 113 |
| | N ₆₀ P ₆₀ K ₆₀ | locally at planting | 35,8 | 48,140 | 1,345 | 77,160 | 160 |
| | | with irrigation water | 32,5 | 53,641 | 1,651 | 60,109 | 112 |
| | Calculated dose for obtaining a crop of tubers 35 t/ha | locally at planting | 34,5 | 46,586 | 1,350 | 74,164 | 159 |
| | | with irrigation water | 34,0 | 46,897 | 1,379 | 72,103 | 154 |
| 0,4 | No fertilizers | | 24,5 | 40,843 | 1,667 | 44,907 | 110 |
| | N ₆₀ P ₆₀ K ₆₀ | locally at planting | 33,9 | 47,742 | 1,408 | 70,908 | 149 |
| | | with irrigation water | 31,7 | 53,451 | 1,686 | 57,499 | 108 |
| | Calculated dose for obtaining a crop of tubers 35 t/ha | locally at planting | 33,3 | 46,320 | 1,391 | 70,230 | 152 |
| | | with irrigation water | 34,5 | 46,952 | 1,361 | 73,798 | 157 |
| 0,2 | No fertilizers | | 23,7 | 40,552 | 1,711 | 42,398 | 105 |
| | N ₆₀ P ₆₀ K ₆₀ | locally at planting | 32,2 | 47,281 | 1,468 | 65,419 | 138 |
| | | with irrigation water | 30,7 | 53,122 | 1,730 | 54,328 | 102 |
| | Calculated dose for obtaining a crop of tubers 35 t/ha | locally at planting | 31,1 | 45,764 | 1,472 | 63,085 | 138 |
| | | with irrigation water | 29,4 | 45,849 | 1,559 | 57,051 | 124 |

The main factor that affects the net profit per area unit is yield. And since the yield without the use of fertilizer and with different methods of its application differed significantly, the profit was also different (Fig. 1).

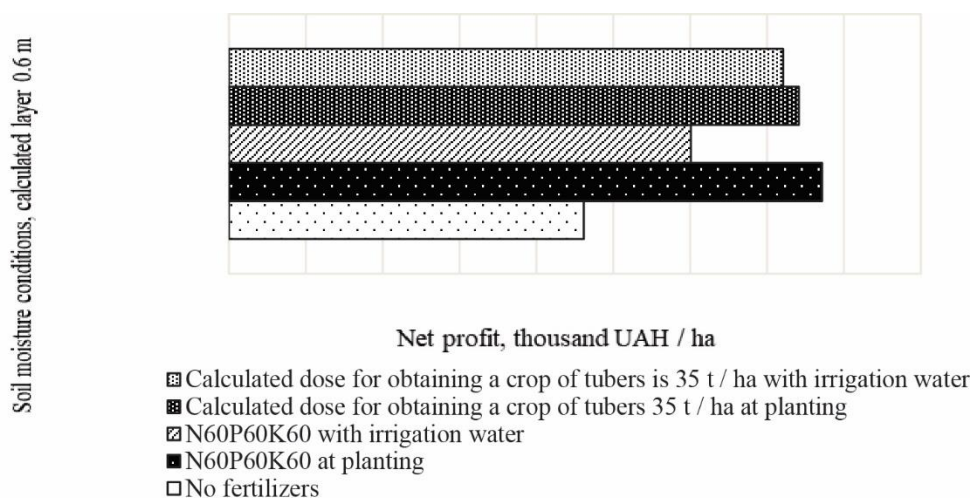


Fig. 1. Conditionally net profit depending on the method of fertilizing the calculated layer of 0.6 m (average for 2013-2015):

Soil moisture conditions, calculated layer 0.6 m

Net profit, thousand UAH/ha 0 10 20 30 40 50 60 70 80 90

Calculated dose for obtaining a crop of tubers is 35 t/ha with irrigation water;

Calculated dose for obtaining a crop of tubers 35 t/ha at planting;

N₆₀P₆₀K₆₀ with irrigation water; N₆₀P₆₀K₆₀ at planting

Conditional net profit an average of 44.5 thnds UAH/ha was received without application of mineral fertilizers. Application of N₆₀P₆₀K₆₀ with irrigation water gave 57.3 thnds UAH / ha (+ 29%); application of the calculated dose with irrigation water - 67.7 thnds UAH (+ 52%), locally at planting - 69.2 thnds UAH (55.4%); Application N₆₀P₆₀K₆₀ locally - 71.2 thnds UAH (60%). The average profit in moisture conditions varied as follows: against the background of humidification of a 0.2 m layer - 56.5 thnds UAH; 0.4 m - 63.5 (+ 12.4%); 0.6 m - 66 thnds UAH (+ 16.8%).

The energy assessment made it possible to compare the effectiveness of using different methods of fertilizing and increasing the depth of the calculated moisture layer. An important indicator of energy efficiency is energy input with the harvest, which depends on the level of yield.

On average in the experience, the energy input was 103.9 GJ/ha, without the use of fertilizers - from 79.2 to 82.9 GJ/ha (Table 3). When the 0.2 m layer was moistened, on average, the energy input was at the level of 98.3 GJ/ha. The moistening of the 0.4 layer made it possible to increase the indicator by 7.3% - up to 105.5 GJ/ha. The most efficient in terms of energy input was the 0.6 m layer – the average was 108; when applying N₆₀P₆₀K₆₀ with irrigation water - 105.7 GJ/ha, which is the smallest for fertilized options and on 30% more in comparison with unfertilized control.

Other methods (applying the calculated dose of fertilizers locally at planting and with irrigation water) made it possible to increase the energy input to 34.1 and 35.3% of the unfertilized control on average over the layers of moisture. The largest energy input was observed with the local application of N₆₀P₆₀K₆₀ at 113.5 GJ/ha, which is 39.5% more than the control. The absolute leader in the experience is the application of N₆₀P₆₀K₆₀ locally against the background of 0.6 m layer moistening - 119.6 GJ/ha (+ 44.3% of control).

On average, 51.4 units of energy per ha were spent on crop cultivation. The non-fertilized variants required less energy - all at 38 GJ/ha. The use of fertilizers in any form increased energy consumption by 35 to 49%. The most energy-intensive was the application of the calculated dose of fertilizers with irrigation water - on average 56.9 GJ/ha, which is 47.4% more than the control. The energy consumption for the cultivation of potato with the application of N₆₀P₆₀K₆₀ with irrigation water and the calculated dose of fertilizers locally were on average at the same level and amounted to 54 GJ / ha. The least energy-consuming method of fertilizing was the application of N₆₀P₆₀K₆₀ locally - 52.7 GJ/ha, which is only 36.4% more than the unfertilized control. The energy requirements for growing potato in plots with different calculated moisture layers differed by no more than 2%.

3. Energy efficiency of using different methods of fertilization and moisture conditions for drip irrigation of potato (average for 2013-2015)

| Estimated soil layer, m (factor A) | Fertilization mode (factor B) | | Energy input with harvest, GJ / ha | Energy consumption for crop cultivation, GJ / ha | Energy gain, GJ/ha | Energy efficiency ratio | Energy intensity, GJ/c |
|------------------------------------|--|-----------------------|------------------------------------|--|--------------------|-------------------------|------------------------|
| 0,6 | No fertilizers | | 82,9 | 38,7 | 44,2 | 2,14 | 0,16 |
| | N ₆₀ P ₆₀ K ₆₀ | locally at planting | 119,6 | 53,4 | 66,3 | 2,24 | 0,16 |
| | | with irrigation water | 108,6 | 54,3 | 54,3 | 2,00 | 0,17 |
| | Calculated dose for obtaining a crop of tubers 35 t/ha | locally at planting | 115,3 | 55,1 | 60,2 | 2,09 | 0,16 |
| | | with irrigation water | 113,6 | 57,4 | 56,2 | 1,98 | 0,17 |
| 0,4 | No fertilizers | | 81,9 | 38,7 | 43,2 | 2,11 | 0,16 |
| | N ₆₀ P ₆₀ K ₆₀ | locally at planting | 113,3 | 52,7 | 60,6 | 2,15 | 0,16 |
| | | with irrigation water | 105,9 | 54,1 | 51,8 | 1,96 | 0,17 |
| | Calculated dose for obtaining a crop of tubers 35 t/ha | locally at planting | 111,0 | 54,6 | 56,3 | 2,03 | 0,16 |
| | | with irrigation water | 115,3 | 57,8 | 57,5 | 1,99 | 0,17 |
| 0,2 | No fertilizers | | 79,2 | 38,5 | 40,7 | 2,06 | 0,16 |
| | N ₆₀ P ₆₀ K ₆₀ | locally at planting | 107,6 | 52,0 | 55,6 | 2,07 | 0,16 |
| | | with irrigation water | 102,6 | 53,9 | 48,7 | 1,90 | 0,18 |
| | Calculated dose for obtaining a crop of tubers 35 t/ha | locally at planting | 103,9 | 53,8 | 50,1 | 1,93 | 0,17 |
| | | with irrigation water | 98,3 | 55,6 | 42,7 | 1,77 | 0,19 |

Energy increment is the difference between the energy obtained with the harvest and the energy expended on its cultivation, and in the control variants it was in the range of 40.7-44.2 GJ/ha (Fig. 2).

The smallest energy increment was observed when fertilizers were applied with irrigation water: N₆₀P₆₀K₆₀ - 51.6 GJ/ha (20.8% more than control) and the calculated fertilizer dose - 52.1 GJ/ha (22.1% more). The same dose applied during planting made it possible to increase the energy increment in these variants up to 55.5 GJ/ha. The largest energy increment was noted with local application of N₆₀P₆₀K₆₀ - 60.8 GJ/ha (more by 42.5% than unfertilized control). The influence of the calculated layer depth on the energy increment is more significant in comparison with the previous indicator: layer 0.2 m - 47.6 GJ / ha; 0.4 m - 53.9 (13.3% more); 0.6 m - 56.2 GJ / ha (18.3% more than 0.2 m layer).

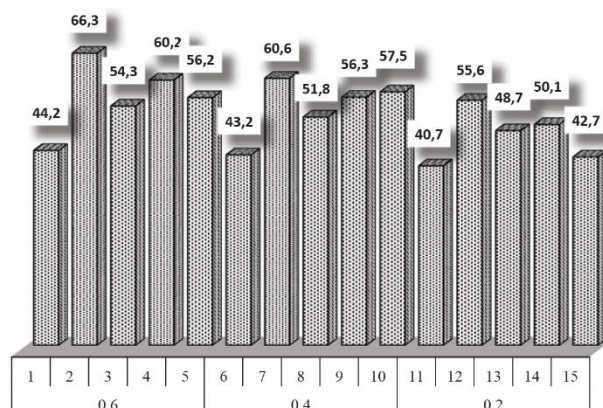


Fig. 2. Energy increment depending on the calculated moisture layer and the method of fertilization, 2013-2015, GJ/ha

Note: 1, 6, 11 - without fertilizers; 2, 7, 12 - $N_{60}P_{60}K_{60}$ locally; 3, 8, 13 - $N_{60}P_{60}K_{60}$ with irrigation water; 4, 9, 14 - the calculated dose for obtaining a crop of tubers 35 t / ha locally; 5, 10, 15 - the calculated dose for obtaining a crop of tubers 35 t / ha with irrigation water.

In our experience, all variants were more or less energy effective, except for $N_{60}P_{60}K_{60}$ locally, other fertilization methods had a coefficient lower than the control without fertilization. The average indicator in the experiment was 2.03, for the calculated moisture layers of 0.4 and 0.6 m, on average, the indicators are more than 2, while for the 0.2 m layer - 1.95, which indicates the lower efficiency of such a moisture layer.

Energy consumption per unit of grown products (quintal) is expressed in terms of energy capacity. The inherent costs of most of the studied options are 0.16-0.17 GJ/q. However, against the background of moistening a 0.2 m layer, when fertilizers are applied with irrigation water, the indicators increase to 0.18 and 0.19 GJ/q. Factor-averaged indicators for various methods of fertilization were as follows: for the calculated dose of fertilizers with irrigation water - 0.18; for $N_{60}P_{60}K_{60}$ with irrigation water - 0.17; for variants without fertilizers, the calculated dose locally and $N_{60}P_{60}K_{60}$ locally - 0.16. So, these two methods do not increase the energy capacity of the resulting product.

Profitability in experience is more than 100%. The average indicator against an unfertilized background is 109.3% (the lowest is against the background of a 0.2 m moisture layer). The average profitability in experience is 132.1%. The application of $N_{60}P_{60}K_{60}$ with irrigation water reduces the profitability from 1 to 3% depending on factors, that is, unprofitable. The highest profitability was obtained against the background of moistening a layer of 0.6 m - 160% when $N_{60}P_{60}K_{60}$ was applied locally with the lowest cost - 1.345 thnds UAH/t. At a calculated dose locally - 159% with a slightly higher cost - 1.350 thnds UAH/t and with irrigation water in a layer of 0.4 m - 157% and a cost price - 1.361 thnds UAH/ha. The largest increase in relation to control was obtained with local application of $N_{60}P_{60}K_{60}$ under conditions of moistening 0.6 m layer and calculated dose with irrigation water in 0.4 m layer - 47%. Slightly lower indicators were obtained with local application of the calculated dose by 46% more relative to the control in the soil layer of 0.6 m.

The lowest cost was obtained under the condition of moistening 0.6 m of the soil layer and local application of $N_{60}P_{60}K_{60}$ - 1.345 thnds UAH/t. The largest conditionally net profit - 77.160 thnds UAH/ha for the years of research was formed with local application of $N_{60}P_{60}K_{60}$ and 0.6 m of a layer of moisture.

Conclusions

The maximum economic and energy efficiency of potato cultivation with drip irrigation was ensured by the local application of mineral fertilizers in a dose of $N_{60}P_{60}K_{60}$, provided moistening calculated 0.6 m soil layer. The level of profitability is 160% at a unit cost of 1.345 thnds UAH/t; conditionally net profit is 77.160 thnds UAH/ha, the energy efficiency ratio was 2.24.

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