

Andrii Doronin¹, Olena Polishchuk², Vitalii Rybchak²

¹ National Academy of Agrarian Sciences of Ukraine

² Uman National University of Horticulture

Ecological-economical aspects of the use of nutritious residues of agricultural crops in various business entities

Summary. The paper covers the analysis of the development of the crop output market in Ukraine which ensures both food security of the country and the production of alternative fuel. The preconditions of negative changes in agriculture of Ukraine were studied. High profitability of corn and sunflower production encourages producers to increase their sown areas. The analysis of the production of some agricultural crops was made in the years of 2000–2019. The challenge of the use of nutritious residues of agricultural crops is discussed in the paper. The estimation of the production efficiency of some kinds of agricultural products at farm enterprises of Ukraine for the period of 2009–2019 was made. Some ecological-economical aspects of the use of nutritious residues of agricultural crops to balance mineral crop nutrition and to manufacture bio-fuel were suggested.

Key words: food economy, elements of nutrition, renewable sources of energy, bio-fuel, straw, granules, ecology, efficiency, competitive ability

Introduction

In Ukraine a decrease in the development rates of livestock production resulted in the expansion of sown areas under grain and industrial crops which in turn changed the approaches to the use of nutritious residues of agricultural crops in the agro-industrial complex. At the beginning of the 90's, almost all the residues were used to satisfy the needs of livestock production; at present they are left in the fields as fertilizer or used to manufacture energy materials – granules and briquettes. So, the use of by-products of crop production becomes of great significance for the balance of mineral plant nutrition and the manufacture of alternative kinds of fuel. In Ukraine the urgent issue of the production of alternative bio-fuel is studied by such scientists as H. Kaletnik, M. Kodenska, M. Roik, V. Sinchenko, P. Sabluk, O. Shpychak, O. Zakharchuk, V. Bondar, A. Fursa and others. However, the issue of the efficient use of nutritious residues of agricultural crops for the balance of mineral plant nutrition and the manufacture of bio-fuel requires additional research.

✉ vryb4ak@gmail.com

Materials and Methods

The purpose of the research is to ground practical recommendations concerning the enhanced efficiency of the use of nutritious residues of agricultural crops to balance mineral plant nutrition and to produce solid kinds of fuel.

In the process of the research the following methods were used: a method of a system analysis and a logical generalization to study the preconditions of the use of nutritious residues for the balance of mineral plant nutrition and the production of bio-fuel; a comparative analysis – to analyze statistical information; a calculation-construction method – to determine the efficiency of the use of nutritious residues of agricultural crops; methods of induction and deduction – to generalize the research results; an abstract-logic method – to formulate conclusions and suggestions.

Research results

In Ukraine the introduction of approximate prices for agriculture which increased at much lower rates than those of consumer goods and service, consumed in agriculture, led to a structure change of the sown areas of agricultural crops. In the period of 2000–2019 we had the increase of industrial crops in the structure of sown areas, as more profitable ones – to 32.6% in 2019 (15.4% – in 2000), grain crops – to 54.7% in 2019 (50.2% – in 2000). There was a serious decrease of fodder crops – 6.2% in 2019 (26.0% – in 2000) which had a negative effect in the development of livestock production in Ukraine. In the structure of sown areas potato and vegetable-melon crops remained almost unchanged – 6.5% in 2019 (8.4% – in 2000) (Tab. 1).

In this period an accurate implementation of the cultivation technology of agricultural crops, the main elements of which are the introduction of new high-yielding cultivars and hybrids, plant nutrition and plant protection from pests, diseases and weeds along with soil-climatic conditions of Ukraine, ensured the yield capacity increase of these crops, namely: corn for silage by 2.4 times – to 7.19 t/ha in 2019 (2000 – 3.01 t/ha), wheat by 2.1 times – to 4.16 t/ha in 2019 (2000 – 1.98 t/ha), sunflower by 2.1 times – to 2.56 t/ha in 2019 (2000 – 1.22 t/ha), rye by 1.9 times – to 2.89 t/ha in 2019 (2000 – 1.52 t/ha), barley by 1.8 time – to 3.42 t/ha in 2019 (2000 – 1.86 t/ha), oats by 1.3 time – to

Table 1. Structure of sown areas under main agricultural crops in Ukraine in 2000–2019

Agricultural crops	Sown area structure by years [%]	
	2000	2019
Grain and leguminous crops	50.2	54.7
Industrial crops	15.4	32.6
Fodder crops	26.0	6.2
Potato and vegetable-melon crops	8.4	6.5

Source: O.M. Prokopenko: Crop production of Ukrain, Statistical Bulletin 2019, State Statistics Committee of Ukraine, Kyiv 2020, p. 183.

2.32 t/ha (2000 – 1.83 t/ha). However, in Ukraine the productivity potential of these crops has not been exhausted yet.

In the years of 2000–2019 we record the production increase of these agricultural crops due to both the increase of their share in the total sown area and to the increase of their yield capacity (Tab. 2).

Table 2. Production indicators of some agricultural crops in Ukraine for the years of 2000–2019

Indicators	Year					2019 in % to	
	2000	2010	2017	2018	2019	2000	2018
Wheat							
Harvested area [thous. ha]	5161.6	6284.1	6361.2	6603.9	6812.4	132.0	103.2
Production [thous. t]	10197.0	16851.3	26158.0	24695.8	28327.9	277.8	114.7
Yield capacity [t/ha]	1.98	2.68	4.11	3.73	4.16	210.1	111.5
Barley							
Harvested area [thous. ha]	3689.1	4316.9	2501.5	2484.3	2609.2	70.7	105.0
Production [thous. t]	6871.9	8484.9	8284.9	7349.1	8916.8	129.8	121.3
Yield capacity [t/ha]	1.86	1.97	3.31	2.96	3.42	183.9	115.5
Rye							
Harvested area [thous. ha]	638.1	279.1	171.0	148.4	115.4	18.1	77.8
Production [thous. t]	968.3	464.9	507.9	393.8	334.7	34.6	85.0
Yield capacity [t/ha]	1.52	1.67	2.96	2.66	2.89	190.1	108.6
Oats							
Harvested area [thous. ha]	481	310.8	197.8	195.8	181.9	37.8	92.9
Production [thous. t]	881.4	458.5	471.4	418.5	422.0	47.9	100.8
Yield capacity [t/ha]	1.83	1.48	2.39	2.14	2.32	126.8	108.4
Corn for grain							
Harvested area [thous. ha]	1278.8	2647.6	4480.7	4564.2	4986.9	390.0	109.3
Production [thous. t]	3848.1	11953.0	24668.8	35801.1	35880.1	932.4	100.2
Yield capacity [t/ha]	3.01	4.51	5.51	7.84	7.19	238.9	91.7
Sunflower seeds							
Harvested area [thous. ha]	2841.6	4525.8	6060.7	6166.5	5958.9	209.7	96.6
Production [thous. t]	3457.4	6771.5	12235.5	14165.2	15254.1	441.2	107.7
Yield capacity [t/ha]	1.22	1.5	2.02	2.3	2.56	209.8	111.3

Source: O.M. Prokopenko: Crop production of..., op. cit., p.15, 20, 27, 34, 36, 38; Basic economic indicators of agricultural production in agricultural enterprises, Statistical Bulletin 2013, State Statistics Committee of Ukraine, Kyiv 2014, p. 84.

In recent years the profitability level of sunflower seed production increased by 28.5% in 2013 to 32.5% in 2019; corn for grain – from 1.5% (2013) to 27.2% (2019), barley – from 0.6% (2013) to 25.6% (2019), wheat – from 2.4% (2013) to 24.6% (2019), oats from unprofitability –2.6% (2013) to profitability 10.3% (2019), the efficiency level of rye production increased but yet the production remained to be unprofitable – 15.3% (2013) to –2.2 % (2019), respectively (Tab. 3).

Table 3. Production efficiency of some kinds of the output at farm enterprises for the years of 2013–2018

Kind of output	Rate of profitability (loss) by years [%]					
	2013	2014	2015	2016	2017	2018
Wheat	2.4	28.0	36.4	31.7	26.8	24.6
Barley	0.6	18.3	28.3	25.4	24.0	25.6
Rye	–15.3	–5.6	21.9	24.6	20.2	–2.2
Oats	–2.6	10.7	21.5	34.4	21.2	10.3
Corn for grain	1.5	26.2	50.3	45.7	23.7	27.2
Sunflower seeds	28.5	36.5	80.5	63.0	41.3	32.5

Source: Basic economic indicators of agricultural production in agricultural enterprises, Statistical Bulletin 2013, State Statistics Committee of Ukraine, Kyiv 2014, p. 14; Basic economic indicators of agricultural production in agricultural enterprises, Statistical Bulletin 2014, State Statistics Committee of Ukraine, Kyiv 2015, p. 14; Basic economic indicators of agricultural production in agricultural enterprises, Statistical Bulletin 2015, State Statistics Committee of Ukraine, Kyiv 2016, p. 9; Basic economic indicators of agricultural production in agricultural enterprises, Statistical Bulletin 2016, State Statistics Committee of Ukraine, Kyiv 2017, p. 8; Costs of agricultural production in agricultural enterprises in 2017, State Statistics Service of Ukraine, <http://www.ukrstat.gov.ua/> (access: 03.04.2020); Costs of agricultural production in agricultural enterprises in 2018, State Statistics Service of Ukraine, <http://www.ukrstat.gov.ua/> (access: 03.04.2020).

Renewable crop production resources are the main component of a modern system of arable farming built on a maximal use of carbon and other macro- and micro-elements into a biological circulation which, to a great extent, are to balance nutrient substances deficit, caused by the application of mineral and organic fertilizers the rates of which do not exceed 10–17% of the required amount¹.

Under the conditions of organic fertilizer deficit in arable farming, the use of nutrient residues of winter and spring crops can substitute the lack of traditional bedding manure of the cattle successfully. The content of dry matter in straw is 85% (for a comparison: in bedding manure – 20–25, in green manure – 10, in liquid manure – up to 3%). An average content of nitrogen in straw is 0.5%, phosphorus – 0.25, potassium

¹ V.P. Sytnyk, M.D. Bezuhlyi, V.V. Adamchuk et al.: Recommendations concerning the use of straw, nutrient residues and cultivation of green manure crops aimed at improving and preserving soil fertility, IMESH 2010, p. 36.

– 0.8% and 35–40% of organic carbon which is energy material for labile forms of humus. When by-products are combined with green manuring, the efficiency of fertilizers and the process of humus formation is equal to the use of bedding manure at rates of 8–10 t/ha². Namely, by-products of crop production are a good source of mineral substances and they play an important role in maintaining the humus balance^{3, 4}.

Besides, Ukraine has a great potential of biomass available for energy production – about 29 million t n.f. The potential mainly includes by-products of agriculture – straw, stems of corn, sunflower and energy crops^{5, 6}. In Ukraine about 2 million t n.f./year of biomass of different kinds, including straw of grain crops, corn, sunflower, are annually used to manufacture energy⁷.

In general, to maintain a balanced plant nutrition taking into consideration the needs of agriculture, the agro-industrial complex can provide up to 30% of straw and other residues of grain agricultural crops, available as fuel, and up to 40% of production wastes of corn for grain and sunflower⁸. After the first crop, straw has to be removed from the field, as it is not appropriate technologically to use it for repeated sowing of this crop. Which is why, it is advisable to bale straw, to make briquettes and move them to the energy market.

In addition, it is not economically relevant to use nutrient residues of agricultural crops for energy purposes since the cost of the balance renewal of nutrition elements in the soil is much higher than the sales proceeds of all nutrient residues of agricultural crops (Tab. 4).

In recent years the average yield capacity of wheat has been 4 t/ha, and we have the output of straw and nutrient residues which is equal to 6.4 t/ha, when it is sold at price 230 hrn/t sales proceeds will be 1472 hrn/ha, and the cost to renew the balance of nutrient elements in the soil will make to 3214 hrn/ha, the losses will be 1742 hrn/ha, respectively. Accordingly, the average yield capacity of barley is 3.2 t/ha, the output of straw and nutrient residues is equal to 4.2 t/ha, sales proceeds will be 957 hrn/ha, and the cost to renew the balance of nutrient elements in the soil will make to 1974 hrn/ha, the losses will be 1017 hrn/ha. The average yield capacity of rye is 2.8 t/ha, the output

² M. V. Zubets, V. P. Sytnyk, M. D. Bezuhlyi et al.: Scientific principles of agro-industrial production in the Forest steppe zone of Ukraine, Agrarian science 2010, p. 978.

³ S.M. Kukharets: The increase of energy independence of agro-ecosyste, Mechanical-technological principles: a monograph, ZhNAEU, Zhytomyr 2016, p. 192.

⁴ H.A. Holub: The problem of the use of straw as fuel, Bulletin of agrarian science 2010, no 8, p. 49–52.

⁵ G.G. Geletukha, T.A Zheliezna: State of the art and prospects for bioenergy development in Ukraine, Industrial heat engineering 2017, vol. 39, no 2, p. 60–64.

⁶ G.G. Geletukha, T.A Zheliezna, P.P. Kucheruk, Ye.M. Oliynyk: The current state and prospects of the development of bioenergetics in Ukraine, Analytical note BEA 2004 no 9, p. 32.

⁷ O.O. Horb, T.O. Chaika, I.O. Yasnolob: The development and improvement of energy systems taking into consideration an available potential of alternative energy sources: a collective monograph, Ukrpromptorgservice Ltd., 2017, p. 326.

⁸ G.G. Geletukha: The current state and prospects of the development of bioenergetics in Ukraine, Bio-energy association of Ukraineи (BEA) 2011, p. 30.

Table 4. Efficiency indicators of the use of nutritious residues of some agricultural crops

Indicator	Wheat	Barley	Rye	Oats	Corn for grain	Sunflower
Yield capacity [t/ha]	4.0	3.2	2.8	2.3	6.8	2.3
Recalculation coefficient in terms of straw	1.6	1.3	2.0	1.5	1.6	2.0
Output of straw and nutritious residues [t/raha]	6.4	4.2	5.6	3.5	10.9	4.6
Content of nutrition elements in residues [a.s.kg/t]						
Nitrogen (N)	5.5	5.0	4.5	6.5	7.5	8.0
Phosphorus oxide (P ₂ O ₅)	2.0	2.0	2.6	3.5	3.0	7.6
Potassium oxide (K ₂ O)	9.1	10	10	16	16.7	52.5
Uptake of nutrition elements with residues [a.s. kg/ha]						
Nitrogen (N)	35.2	20,8	25,2	22,4	81,6	36,8
Phosphorus oxide (P ₂ O ₅)	12.8	8.3	14.6	12.1	32.6	35.0
Potassium oxide (K ₂ O)	58.2	41.6	56.0	55.2	181.7	241.5
Sales proceeds of straw and nutritious residues [hrn/ha]	1472	957	1288	794	2502	1058
Expenses to restore balance of nutrition elements [hrn/ha]	3214	1974	2757	2560	7951	8336
Losses [hrn/ha]	-1742	-1017	-1469	-1766	-5449	-7278

of straw and nutrient residues is equal to 5.6 t/ha, sales proceeds will be 1288 hrn/ha, and the cost to renew the balance of nutrient elements in the soil will make to 2757 hrn/ha, the losses will be 1469 hrn/ha. The average yield capacity of oats is 2.3 t/ha, the output of straw and nutrient residues is equal to 3.5 t/ha, sales proceeds will be 794 hrn/ha, and the cost to renew the balance of nutrient elements in the soil will make to 2560 hrn/ha, the losses will be 1766 hrn/ha. The average yield capacity of corn for grain is 6.8 t/ha, the output of straw and nutrient residues is equal to 10.9 t/ha, sales proceeds will be 2502 hrn/ha, and the cost to renew the balance of nutrient elements will make to 7951 hrn/ha, the losses will be 5449 hrn/ha. The average yield capacity of sunflower seeds is 2.3 t/ha, the output of straw and nutrient residues is equal to 4.6 t/ha, sales proceeds will be 1058 hrn/ha, and the cost to renew the balance of nutrient elements will make to 8336 hrn/ha, the losses will be 7278 hrn/ha.

The most promising kind of bioenergetics for Ukraine is phyto-energetics which is based on raw materials of plant origin. The raw materials for the manufacture of solid bio-fuel are the wastes of a woodworking industry (sawdust, chips), straw of grain and leguminous crops, sunflower husk, etc. However, the availability of this raw material is not stable and is of a seasonal nature which has a negative effect on the work performance of the plants which produce solid fuel. Which is why, a special attention should be given to

the trend which is connected with the supply of solid fuel produces with the raw material: the cultivation of new kinds of highly productive trees and perennial plants will make it possible to annually receive a required amount of bio-mass of proper quality⁹.

According to the statistics of the Institute of bio-energy crops and sugar beets of NAAS, a potential output of solid bio-fuel from perennial energy crops can make to 35.8 million t per year which is equivalent to 16.3 billion cubic m of natural gas¹⁰.

An energy willow is the most popular tree in Ukraine. It is important to take some stages, namely, a specific preparation, planting, energy cut (a plant has to look like a bush, not a tree, and later it will be harvested with special machinery). It is necessary to make capital investments once and then to get profits during 25 years. Producers confirm that they have stable demand of chips, a resource for burning in boilers, or they are changed into fuel granules or briquettes.

The highest level of profitability is achieved when willow chips are sold at 1085 hrn/t (without prior processing with 50% moisture), the profitability level is 216.2% (the 24th year of energy willow vegetation)¹¹.

Conclusions

Ukraine has a great potential of land and material resources to provide domestic and foreign markets with alternative energy material for the production of bio-fuel. By-products of crop production are an important source of nutrient substances for mineral plant nutrition both in its direct effect and after-effect. It is not relevant to use nutrient residues of agricultural crops only with an energy purpose. The cost of the balance renewal of nutrition elements in the soil is much higher than the sales proceeds of all nutrient residues of agricultural crops. Taking into consideration the needs of agriculture it is expedient to use 30–40% of nutrient residues of agricultural crops for balanced plant nutrition. In this case both energy and ecological tasks are solved. Nutrient residues can easily substitute the lack of traditional bedding manure of cattle. It is advisable to provide solid fuel produces with the raw material by means of growing new kinds of highly productive trees and perennial plants. To guarantee a stable development of agriculture and the market of alternative fuels, there is a necessity in the cooperation of two trends – the production of raw material for bio-fuel and a finished produce in the form of energy.

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