Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 19, Issue 3, 2019
PRINT ISSN 2284-7995, E-ISSN 2285-3952

APPROPRIATE CROP ROTATION – COMMERCIALLY A REASONABLE EFFORT

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Abstract

The aim of the article is to analyze optimization of cropping area of scientifically-based crop rotations in agriculture of Ukraine. Scientific solution of the set tasks required application of statistical data about cropping area in Ukraine, presentation of economic data of cultivated field crops in crop rotations. The authors of the article analyze long-continued research by the scientists of the Institute of Grain Crops of NAAS of Ukraine and suggest that yield capacity is much higher under scientifically-based crop rotations without application of fertilizers than under the variant of no crop rotation applied. The work studies optimization of the number of fields in a crop rotation. It is determined that efficiency of many-field crop rotation secures high level of agrarian production, and for enterprises with a small area of land use, it is the most reasonable to apply short crop rotation.

Key words**:** *crop rotations, agriculture, cropping area, agricultural crops*

INTRODUCTION

Considering area and land fund, Ukraine is a large European country. Ukraine takes the sixth position among the leading countries of the world concerning the area of agricultural lands per one resident, and the first place in Europe concerning the area of arable land. Plowing of territory is a negative factor. It exceeds all threshold ecological standards and constitutes 57% (for example, Steppe zone of Ukraine is 81% plowed), while that indicator in Germany and France constitute 32%, and in England – 29.6%, in the USA – 16.9%. In Ukraine, cropping area of field crops is fixed at the level of almost 26-27 million ha (for the recent 30 years, there has been a gradual reduction of the indicator from 32.66 million to 30.96 million ha) [8]. Cereals occupy the area of 14.6-16.2 million ha [5]. Ukraine has almost exhausted all possibilities to increase the area of arable lands. Hence, more efficient use of employed soil is the main direction for increase of the agrarian products output.

Optimization of the structure of cropping area with consideration of scientifically-based recommendations, optimization of the structure of cropping area and crop rotation to improve productivity of agricultural lands, prevent erosion processes and make reclamation of soil layer fertility [4] are one of the components for solution of current problems of arable farming. Under market conditions, it should secure high profitability of production. The amount of crop yield per unit area, such as the productivity of crops, depends on the whole set of environmental conditions as well as on the manager's experience, which can alter the natural factors or the crop's qualities to the best of the conditions natural [3]. However, the structure should be also mobile to consider urgent needs of production. Moreover, developing optimization of the structure of cropping area it is necessary to focus not only on the possibility of present economic benefit, but on setting of soil conditions, which support balanced use of biological and natural factors, and reclamation of soil fertility.

MATERIALS AND METHODS

The aim of the article is to analyze and make comparative characteristics of scientifically-based crop rotations, which supply the most complete employment of biological peculiarities of each crop, providing the opportunity to obtain permanent high yields.

Scientific solution of the set tasks applied the method of comparative analysis. The work

analyzes introduction of scientifically-based crop rotations and argues efficiency of arable land use in Ukraine.

RESULTS AND DISCUSSIONS

Nowadays, one observes considerable deviations from the recommended parameters of the structure of cropping area, which have both objective and subjective character. Thus, a great reduction of animal breeding production in Ukraine for the recent years has caused uncontrolled reduction of cropping area of fodder crops from 29-35% to 4-6%. Continuous growth of demand for sunflower seed both in Ukraine and in the world has caused ecologically dangerous extension of the area, occupied by oilseed. For that period, its cropping area increased from 10-12% to 34-37% (at some enterprises of southern area of Steppe – up to 50%). Permanently high prices for seed of that crop secures profitability of any agrarian enterprise and solution of the urgent problems of survival under market conditions. However, long-term effects of such phenomenon are not considered, particularly a heavy deterioration of phytosanitary conditions of soil and moisture supply on the cropping area of some following crops, causing reduction of their yield capacity. Many enterprises of Ukraine unwarrantedly reject application of a clean fallow, which, for example, in the Steppe is the only predecessor of winter wheat and secures obtaining of high grain yield regardless of autumn weather conditions. All this makes negative impact on the structure of crop rotations and forces the necessity to place winter wheat after unfavorable predecessor (particularly sunflower), causing considerable losses and deterioration of ecological conditions of soil.

Introduction of scientifically-based crop rotations, which consider biological particularities of each crop, is an important factor of arable soils employment. It secures obtaining of permanently high yields. That effect is commercially and ecologically argued and does not require additional capital investments. On the other hand, good management of the soil through crop rotation ensures adequate nutrient availability throughout the cropping season and maintain balanced soil ecosystem [6, 7]. Crop rotations should become a basic, essential link of the modern system of arable farming, which defines rational organization of the territory and procedure of rotation of crops in time and space.

Growing of field crops in crop rotations makes positive impact on regulation of nutritive and water regimes (due to more commercial use of productive moisture); prevention of the phenomena of soil fatigue; regulation of phytosanitary conditions of crops, reduction of the level of diseases and pests; rational use of bioclimatic potential of the region. Rotation of the crops causes changes of the factors of soil chemical, physical and biological properties.

The necessity to rotate crops is based on a different need for nutrients and water in some periods of growth and development, on the different level of competitive capacity in the fight against weeds for the main factors of living. Optimization of the conditions of growth, development and creation of crop yield requires from each crop to be proceeded by favorable ones in crop rotation.

The author of the work analyze long-continuous investigations by the scientists of the Institute of Grain Crops of NAAS of Ukraine (Dnipropetrovsk) which confirm that, comparing to growing of crop under many-field crop rotation, continuous growing (during 10 years) of agricultural crops on both unfertilized and fertilized grounds, results in a considerable reduction of yield capacity of almost all field crops. Hence, while growing winter wheat under the crop rotation without fertilizers, yield capacity of that crop is by 80% higher than on unfertilized fields. On the variant of organic-mineral fertilization, increase of yield in crop rotation constitutes 42%, the similar data for grain maize demonstrate 51 and 18.6% respectively, sunflower – 21.3 and 14.5, pea – 26.6 and 19.3%. Reduction of yield under continuous crop growing occurs due to soil fatigue, irrational use of nutrients, negative changes in the regimes of moisture use. The obtained data give a strong argument for prohibition of

continuous growing of one crop in production. Generally, introduction of crop rotations raises efficiency of arable lands employment minimum by 15-20%. Nevertheless, depending on the size of an enterprise and its specialization, it is possible to introduce both short (3-5 fields) and many-field (6-9 fields) crop rotation.

Considering importance of development and introduction of crop rotation for the following gradual development of agrarian production in Ukraine, scientific investigations on the issue are performed by some leading research institutions of NAAS. They are based on principal issues of improvement of the structure of crops and optimization of crop rotation, and on raise of efficiency of 7-8-field long-term and 3-5-field short field crop rotation on the variant of different systems of fertilization and soil treatment.

Analysis of efficiency of 8-field crop rotation in a long-lasting stationary field experiment confirms that the largest yield of grain is obtained on fertilized variants of cereal-fallow-row crop (2.71-2.83 tons per hectare) and cereal-row crop (2.66-2.80 tons per hectare) systems of crop rotation with 75% of cereals. Reduction of the share of cereals in the structure of cereal-grass-row crops rotation up to 50% results in reduced yield of grain, which constitutes 2.20-2.31 tons per hectare. Yield capacity of cereals is maximum in the variant of cereal-grass-row crop rotation (4.63-4.85 tons per hectare), and under cereal-fallow-row crop and cereal-row crop system, that indicator on the average is by 43 and 35% smaller that can be explained by different predecessors and structure of cereals.

Maximum yield of fodder units is obtained under cereal-row crop (5.51-5.78 tons per hectare) and cereal-grass-row crop rotation (5.26-5.37 tons per hectare), and under cereal-fallow-row crop system, it is only by 0.17-0.2 tons per hectare smaller than the indicators of cereal-grass-row crop rotation. Higher efficiency of the studied crop rotations is secured by the variants with organic-mineral or mineral system of soil fertilization (Table 1).

Application of those fertilization systems secures reclamation of soil fertility. The authors of the work have analyzed that in the similar experiments with 7-field crop rotation, the highest yield of grain is obtained on fertilized variants of cereal-grass-row crop rotation (2.41-2.66 tons per hectare), while yield capacity of cereals is higher in the crop rotation with fallow field (3.81-4.43 tons per hectare). Yield of fodder units and yield of digestible protein is some higher (by 6-10% on the average) under cereal-grass-row crop rotation. Higher indicators of crop rotation efficiency are secured by mineral and organic-mineral system of fertilization (Table 2).

Table 1. Efficiency of 8-field crop rotation, depending on the structure of crops and fertilization on the average for 2013-2018, tons per hectare

System of soil fertilization in crop rotation*	Indicators of crop rotation efficiency			
	grain yield	yield capacity of cereals	yield of fodder units	yield of digestible protein
Cereal-row crop rotation (75% of cereals)				
No fertilizers	2.57	3.55	4.80	0.426
Organic	2.71	3.74	5.06	0.450
Organic-mineral	2.83	3.90	5.25	0.469
Mineral	2.83	3.92	5.29	0.470
Cereal-fallow-row crop rotation (75% of cereals)				
No fertilizers	2.54	3.52	5.29	0.466
Organic	2.66	3.68	5.51	0.486
Organic-mineral	2.80	3.87	5.78	0.551
Mineral	2.78	3.84	5.68	0.503
Cereal-grass-row crop rotation (50% of cereals)				
No fertilizers	2.08	4.37	5.03	0.503
Organic	2.20	4.63	5.26	0.527
Organic-mineral	2.31	4.84	5.37	0.531
Mineral	2.31	4.85	5.32	0.517

*Applied per 1 hectare of crop rotation area under appropriate systems of fertilization: organic: manure – 12.5 tons per hectare; organic-mineral: manure – 7.5 tons per hectare.

Source: Completed by the authors.

Hence, results of the research of the efficiency of many-field crop rotations confirm that they secure a high level of agrarian production efficiency and can be applied at agrarian formations of different specialization, employing large area.

For enterprises with small area of land use it is the most reasonable to use short crop rotations. For example, on ordinary black land fertile soils of Kirovohrad research station,

they tested efficiency of 5-field crop rotation with 20, 40, 60 and 100 % of soybean (Table 3).

Table 2. Efficiency of 7-field crop rotation, depending on the structure of crops and fertilization of soil on the average for 2013-2018, tons per hectare

System of soil fertilization in crop rotation*	Indicators of crop rotation efficiency			
	grain yield	yield capacity of cereals	yield of fodder units	yield of digestible protein
Cereal-fallow-row crop rotation				
No fertilizers	1.90	3.33	4.12	0.34
Organic	2.17	3.81	4.58	0.34
Organic-mineral	2.43	4.25	4.85	0.37
Mineral	2.53	4.43	4.90	0.39
Cereal-grass-row crop rotation				
No fertilizers	2.03	2.98	4.67	0.38
Organic	2.41	3.37	4.78	0.42
Organic-mineral	2.60	3.64	5.08	0.44
Mineral	2.66	3.73	5.25	0.44

*Applied per 1 hectare of crop rotation area under appropriate systems of fertilization: organic: manure – 14.3 tons per hectare.
Source: Completed by the authors.

Table 3. Efficiency of crop rotations, depending on the share of soybean and fertilization system on the average for 2010-2018, tons per hectare of crop-rotation area

Crop rotation	Fertilization system	Cereal units	Fodder units	Digestible protein
Cereal-fallow-row crop (20% of soybean)	no fertilizers	4.38	4.92	0.57
	mineral	4.54	5.07	0.60
	organic-mineral	5.04	5.81	0.71
Cereal-row crop (40% of soy bean)	no fertilizers	4.39	5.37	0.52
	mineral	4.71	5.72	0.56
	organic-mineral	4.71	5.77	0.56
Cereal-row crop (60% of soy bean)	no fertilizers	4.69	5.45	0.61
	mineral	4.57	5.30	0.59
	organic-mineral	4.50	5.24	0.58
Continuous growing of soy bean for 9 years	no fertilizers	3.08	2.66	0.52
	mineral	3.44	2.96	0.58
	organic-mineral	3.16	2.73	0.54

Source: Completed by the authors.

Estimation of the efficiency of short crop rotation reveals gradual reduction of their productivity effected with increase of the share of soybean. The highest level of efficiency was secured under cereal-fallow-row crop rotation with 20% of soybean (black or green-manured fallow – winter wheat – soybean – grain maize – sunflower) under application of organic-mineral system of fertilization. Continuous growing of soybean is the least efficient system.

Negative effect of increased concentration of black fallow is revealed in growth of the deficiency of humus balance (on the average for 2013-2018). Under total gathering of by-products with the yield, deficiency of the estimated humus balance on the average on the grounds of nutrition constituted 997 kilogram per hectare. Positive balance of humus is marked on fertilized variants with 20% of green-manured fallow.

According to the obtained data, the most perspective is the variant of crop rotation with 20% of fallows, 50% of cereals (including the food group from 20 to 40%) and industrial – 30% (including 10% of sunflower and 20% of winter rape). In the structure of field crop rotation, it is necessary to reduce the share of sunflower to scientifically-based norms by means of substitution of a share of its crops with maize and rape (10 and 20% respectively), that enables increase of the group of profitable industrial crops in crop rotation of short system up to 30%.

It is worth mentioning that efficiency of crop rotation sufficiently depends on the structure of crops and correlation of field crops in them (Table 4). The largest yield of grain, fodder units and digestible protein is secured by the crop rotation with pea.

Thus, mineral fertilizers contribute to increase of the output of products, but deteriorate the main parameters of commercial efficiency of crop rotation due to high cost of the fertilizers and necessity of extra costs for their application, as well as not high growth of yield by means fertilization of some crops in crop rotation. However, the described phenomenon does not mean that one can recommend growing of crops in crop rotation with no fertilizers applied, because it causes losses of fertility and deterioration of agro-chemical and agrophysical parameters of soil. Hence, under disparity of prices of industrial and agricultural products, it is necessary to

secure effective governmental support for commodity-producers in the form of laws, working in the European Union.

Table 4. Efficiency of crop rotation, depending on the structure of crops on the average for 2013-2018, tons per hectare of cropping area

Crop rotation			Indicators of crop rotation efficiency		
First field	Sec-ond field	Third field	grain yield	yield of fodder units	yield of digestible protein
Black fallow	Winter wheat	barley	1.99	3.21	0.28
		sorgo	2.28	3.52	0.32
Pea		barley	2.24	3.76	0.35
		sorgo	2.50	3.71	0.38
Seeded fallow		barley	1.54	3.02	0.30
		sorgo	1.80	3.29	0.33
Green-manured fallow		barley	1.52	2.52	0.22
		sorgo	1.76	2.77	0.25
Sun-flower		barley	1.42	3.32	0.26
		sorgo	1.63	3.45	0.28

Source: Completed by the authors.

Crop rotation is an important and efficient constituent of rational use of arable lands in Ukraine to obtain high and permanent yields, raise profitability of agricultural production and reclaim soil fertility [1, 2]. Scientific institutions of the NAAS have developed and recommended crop rotations for enterprises with different area of land use and specialization. Application of such crop rotations will support effective solution of technological tasks and consequently will supply maximum yield with the following both domestic consumption and export to the world market of competitive agrarian products.

CONCLUSIONS

Thus, introduction of scientifically-based crop rotations is the most important factor of efficient employment of arable soils. It secures the most completely engagement of biological peculiarities of each crop, supporting permanent high yields. That method is economically and ecologically argued and does not require additional investments. Crop rotation should be basic, essential link of the modern system of arable farming, which determines rational organization of the territory and order of rotation of the cultivated crops in time and space.

It is substantiated that under introduction of crop rotation, efficiency of arable land employment increases by 15-20%. However, introduction of short (3-5 fields) and many-field (6-9 fields) crop rotation should be specified by sizes of enterprises and their specialization.

Application of crop rotation is an important and efficient constituent of rational use of arable lands in Ukraine for obtaining of high and permanent yields, increase of profitability of agricultural production and reclamation of soil fertility.

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