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Optimisation of the Vegetable Bean Production Process by Selecting Cultivars and Using Drip Irrigation

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Abstract. For the agricultural sector, there is a current trend of expanding the range of vegetables. Modern agricultural production is impossible without the cultivation of legumes – a cheap source of vegetable protein and one of the important links on which depends the balance of organic matter in the soil. The purpose of the study conducted in 2019-2020 was to investigate the cultivar specifics and the influence of drip irrigation on the growth and yield of vegetable beans and the development of a symbiotic system. The research involved field, laboratory, statistical, and calculation-analytical methods. Studies have indicated that the use of drip irrigation contributed to an earlier emergence of seedlings, a reduction in interphase periods, and earlier arrival of vegetable products by 4-7 days, depending on the cultivar. The weight of green beans increased by 35.9-41.9 g, depending on the cultivar. Yields of green beans increased by 3.5 t/ha (32.1%) in Karadag cultivar, 3.6 t/ha (31.3%) in Windsor cultivar, and 4.2 t/ha (39.2%) in Ukrainian Sloboda and Windsor cultivars. Among the experimental variants, the most productive cultivar on the dry-farming lands was the Ukrainian Sloboda, and on irrigated lands – Belarusian, Ukrainian Sloboda, and Windsor. The results indicate that the most developed nodulation apparatus was established in the Ukrainian Sloboda cultivar, where the largest mass was developed, but nodules on the plant were small (0.9 g on dry-farming lands and 1.3 g on irrigated lands). In general, drip irrigation contributed to the improved development of legume-rhizobial symbiosis of vegetable bean plants. The mass of the nodules on the drip irrigation increased by 0.3 g/plant regardless of the cultivar, and their amount increased by 1.5-9.0 pcs/plant. The presented results give an idea of legume agrocenosis functioning and the impact of irrigation on the main quality indicators of the product. Further research lies in the examination of the modes (rates, timing, multiplicity) of irrigation and their impact on the productivity of vegetable bean plants

Keywords: biochemical+ parameters, weight of green beans, nodulation apparatus, yield of green beans

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INTRODUCTION

One of the most important problems of Agriculture in Ukraine nowadays is the shortage of vegetable protein, equal to animal protein. Beans are an important source of biological nitrogen in agriculture, the importance of which has increased in the conditions of environmental degradation and lack of nitrogen fertilisers. The share of biological nitrogen in the nitrogen balance is very small and amounts to approximately 5%, and if appropriate conditions are created for the functioning of the legume-rhizobial system, it can increase up to 30%.

In the context of increasing the cost of anthropogenic resources and environmental tensions, alternative approaches to the development of agricultural technologies based on the concept of biologisation of agriculture and providing it with a resource-saving and sustainable development direction are required to ensure the sustainable functioning of the agroecosystems. Based on this, the selection of bean varieties and their cultivation with drip irrigation is an urgent problem of horticulture and agricultural production in general.

Beans are a genus of annual herbaceous plants in the legume family. Beans belong to the order Fabales (ordo *Fabales Nakai*), Legume family (*Fabaceae*), *Faba* Medik genus, which is represented by two types: Pliny beans (*F. Plinina* Trabut.) and horse beans (*F. Bona* Medik.) (syn. *Vicia faba* L., *Faba vulgaris* Moench., *Faba sativa* Bernh.). *Vicia faba* major, coarse-grained (the mass of 1000 grains reaches 2500 g), also called beans or vegetable beans, are used in horticulture [1; 2].

In the modern world, the nutritional relevance of bean seeds increases with a high nutritional value [3]. Among vegetable crops, these are the leaders in protein and amino acid content. Beans in technical ripeness are a valuable food product. In this phase, beans contain 6-15% of protein (up to 35% in mature seeds), 4.2% of carbohydrates, including 2.6% of sugars, as well as a large amount of mineral salts, mainly potassium, calcium, phosphorus, magnesium, sulphur, and ferrum. Green beans are rich in B vitamins, which play an important role in preventing aging and sclerosis. Grains contain 1% of fibre, 0.7% of ash, and 80% of water. In terms of calories, beans are 3.5 times more nutritional than potatoes and 6 times more nutritional than corn [4; 5].

The saturation of the crop rotation with beans helps to improve the structure of the soil and its mineral composition. After harvesting legumes per 1 ha, 20-70 centners of root and crop residues remain in the soil, which contain 45-130 kg of nitrogen, 10-20 kg of phosphorus, and 20-70 kg of potassium. Nitrogen-fixing nodules are formed on the roots, but not all formed nodules fix nitrogen from the air equally intensively. Bacteria that form small nodules, as a rule, fix little nitrogen or do not fix it at all [6]. When favourable conditions are created for legume-rhizobial symbiosis, legumes can fix an average of 120-140 kg/ha of nitrogen [7; 8].

Today, when growing vegetables, optimisation of the irrigation regime is of paramount importance. It determines the efficiency of the technology and the quality of the yield, total costs, the need for water and energy resources [9; 10]. The experience of advanced farms and data from research institutions show that good management practices and optimal irrigation regime contribute to the development of high and stable yields of vegetable crops [11-13]. It is widely acknowledged that irrigation costs and plant productivity vary depending on irrigation methods. Therefore, drip irrigation is promising in the cultivation of vegetable crops [14]. Drip irrigation is more efficient than other types of irrigation, both in terms of crop yield and water savings [15].

With proper agricultural technology, there is an increase in the yield of many crops: lettuce [16]; sugar beet [17; 18]; watermelon [19]; onions [20], and beans [21]. Beans are usually grown without irrigation, but in unstable climate conditions, drip irrigation becomes a necessity and can considerably improve the efficiency of cultivation technology [22-24].

The purpose of this study is the identification of cultivar features of the development of a high level of green beans yield under drip irrigation and the development of a nodulation apparatus of plants in the forest-steppe conditions of Ukraine. For the first time in the conditions of the forest-steppe of Ukraine, experimental data related to the development of a commercial crop of vegetable beans with drip irrigation were obtained.

MATERIALS AND METHODS

The studies on the technology of growing vegetable bean cultivars in the conditions of the Right-bank forest-steppe of Ukraine were conducted in 2019-2020 on the experimental field of the Department of horticulture of the Training Scientific and Production Department of the Uman National University of Horticulture according to a scheme that included eight options. The scheme of the two-factor experiment included the following cultivars of vegetable beans: Karadag st (standard), Ukrainian Sloboda, Belarusian and Windsor, which were grown without irrigation and with drip irrigation, maintaining soil moisture at the level of 80% to the technical ripeness of beans. The experiments were performed by the method of randomisation. The experiment is repeated four times. The area of the experimental section is 10 m^2. Beans were sown on April 5 in 2019 and April 10 in 2020, according to the 60×10 cm scheme.

The soil of the experimental section is podzolic heavy loamy black soil with a humus-accumulated horizon (humus content of about 1.5%) with a thickness of 40-45 cm; pH (salt) – 6.65. The ploughing layer contains 108.7 mg/kg of easily hydrolysed nitrogen (according to Kornfield); 59 mg/kg of labile phosphorus (according to Chirikov); 120.5 mg/kg of exchange potassium (according to Chirikov). The volume mass of the soil is 1.26-1.34 g/cm^3, the lowest field moisture capacity is 16.2% in the ploughing and 14.6% in the subsurface layers [25].

In the experiment, records and observations were made according to generally accepted methods:

1. The area of leaves was calculated by cutting, the amount of leaves, pcs/plants. in the phase of technical ripeness (harvesting) [26].

2. Yield accounting was carried out by the method of section weighing during the period of technical ripeness in accordance with the UNECE DSTU FFV-27:2007 [27].

3. The average weight of beans and green bean fruits was determined according to the generally accepted method [26].

4. The dry matter was identified by drying at t° 105°C according to DSTU 7804:2015 [28];

5. Protein content – by the Keldal method according to DSTU ISO 5983-2003 [29];

6. The amount and mass of rhizobia on plant roots were determined by the method of G.S. Posypanov [30].

Weather conditions (Fig. 1) during 2019-2020 differed in the main indicators, so the effectiveness of the study was evaluated objectively, and the data obtained are reliable.

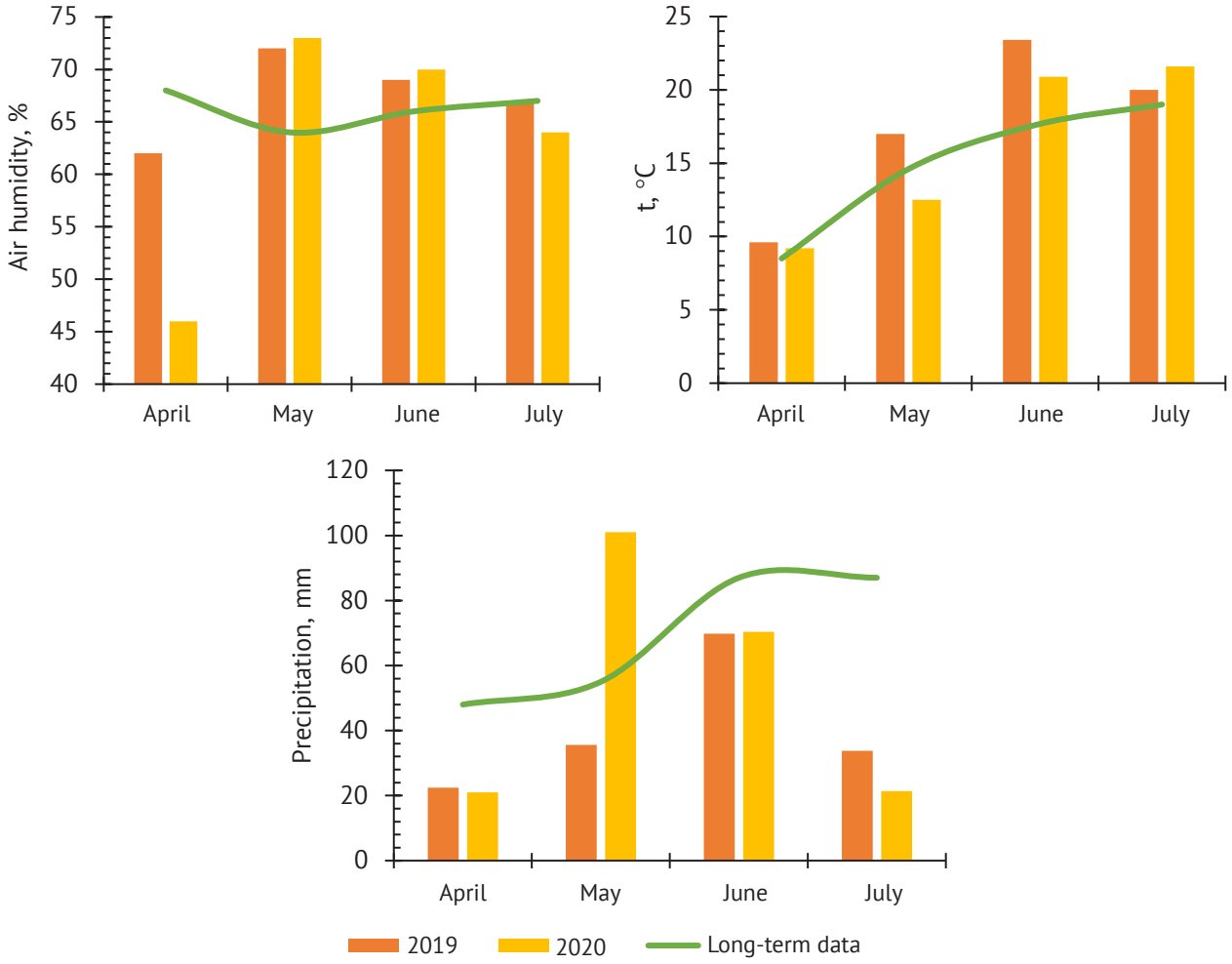

Figure 1. *Key indicators of climatic conditions for the growing season of vegetable beans (2019-2020)*

RESULTS AND DISCUSSION

The studied cultivars of vegetable beans belong to the mid-ripening group. The conducted studies have identified that the processes of growth and development of bean cultivars during the growing season differed slightly depending on the cultivar and irrigation.

On average of two years, the duration of the period from sowing seeds to the emergence of seedlings ranged from 10-17 days. In cases with drip irrigation, the duration of this period was reduced by 4-5 days for Karadag, Ukrainian Sloboda and Belarusian cultivars; for Windsor cultivars, the specified period was reduced by seven days relative to the variant of dry-farming lands. The interphase period of bean development – bean filling was unchanged under irrigation and lasted 10 days for the Ukrainian Sloboda, Belarusian, and Windsor cultivars, and 11 days for the Karadag cultivar. From the filling of beans to period of technical ripeness, seven days passed in all experimental versions. Drip irrigation contributed to an earlier arrival of products, and therefore to the reduction in the growing season of plants by 4-7 days. The standard Karadag cultivar with drip irrigation reduced the growing season of plants by seven days, the Belarusian cultivar – by six days, the Ukrainian Sloboda cultivar – by five days, and the Windsor cultivar – by four days (Table 1).

***Table 1**. Duration of interphase growing seasons of vegetable beans depending on the cultivar and irrigation (2019-2020)*

Variant		Duration of interphase periods, days						
		Sowing – emergence of seedlings	Emergence of seedlings – budding	Budding – flowering	Flowering – pod formation	Pod formation – seed filling	Bean filling – technical ripeness	Growing season
Average for 2019-2020								
Dry-farming land*	Karadag st	16	27	30	15	11	7	105
	Ukrainian Sloboda	15	26	30	15	10	7	103
	Belarusian	16	27	30	15	10	7	102
	Windsor	17	25	31	13	10	7	97
Drip irrigation	Karadag st	11	22	27	15	11	7	98
	Ukrainian Sloboda	11	22	27	15	10	7	98
	Belarusian	11	21	27	14	10	7	96
	Windsor	10	20	29	14	10	7	93

***Note**: * – control, st – standard*

The results of biometric analysis established that growing vegetable beans on irrigation contributes to an increase in plant height by 4.7-12.2% relative to the variants on dry-farming land. Thus, on average of two years, plants of the Ukrainian Sloboda, Belarusian, and Windsor varieties cultivated on dry-farming lands were considerably higher compared to the control by 11.7, 10.0, and 12.8 cm (*$p \leq 0.05 = 2.71$ cm*). When cultivating beans with irrigation, the difference increased to 14.8, 13.0, and 19.2 cm, respectively.

On average of over two years, the amount of shoots on one plant cultivated with irrigation increased by 17.3-30.0%, or 0.7-1.0 pcs/plant with *$p \leq 0.05 = 0.17$ pcs/plant*. A considerable intervarietal difference was observed in Belarusian and Windsor cultivars on dry-farming land +0.4-1 pcs/plant, Belarusian and Windsor with irrigation systems +0.7-0.9 pcs/plant; in other cultivars, the increase in this indicator was inconsiderable.

On average by cultivars, the leaf area of vegetable bean crops increased by 21.2-24.9% over two years with drip irrigation. Ukrainian Sloboda and Belarusian cultivars formed a leaf area smaller than the control by 1.0 and 1.7 thous. m^2/ha on dry-farming land (*$p \leq 0.05 = 1.31$ thous. m^2/ha*). On irrigation, the Ukrainian Sloboda and Belarusian cultivars were marked by a decrease in this indicator by 1.5 and 1.9 thous. m^2/ha. The Windsor cultivar formed a bigger leaf area of 0.3 and 1.0 thous. m^2/ha than control (Table 2).

***Table 2**. Plant growth and formation of the leaf area of vegetable beans depending on the cultivar and drip irrigation*

Variant		Height of plants, cm	Amount of shoots, pcs./plant	Leaf area thous. m^2/ha
Dry-farming land*	Karadag st	63.5±2.12	3.1±0.14	27.3±1.47
	Ukrainian Sloboda	75.2±2.47	3.2±0.14	26.3±1.75
	Belarusian	73.5±2.12	3.5±0.00	25.6±1.98
	Windsor	76.3±2.33	4.0±0.07	27.5±1.48
Drip irrigation	Karadag st	66.5±2.12	3.8±0.21	33.4±1.55
	Ukrainian Sloboda	81.2±5.23	3.9±0.14	31.9±0.71
	Belarusian	79.5±6.36	4.5±0.07	31.4±0.64
	Windsor	85.6±4.66	4.7±0.35	34.4±1.70
Results of statistical processing				
HIP_{05}	*A*	*1.29*	*0.07*	*0.50*
	B	*1.92*	*0.10*	*0.79*
	AB	*2.71*	*0.17*	*1.31*
	CV, %	*10*	*15*	*12*

***Note**: * – control, st – standard*

The amount of beans on average of two years increased on variants with drip irrigation by 47.8% for the Belarusian cultivar, by 50% for the Karadag and Ukrainian Sloboda cultivars, and by 62.5% for the Windsor cultivar relative to the variant without irrigation, which was considerable (*p≤0.05 = 0.50 pcs/plant*) (Table 3).

***Table 3**. Morphometric parameters of vegetable beans depending on the cultivar and drip irrigation*

Variant		Amount of beans, pcs/plant	Amount of seeds, pcs/bean	Articulation height of the 1st bean, cm
Dry-farming land*	Karadag st	13.0±1.41	2.3±0.14	13.0±1.41
	Ukrainian Sloboda	12.0±0.00	2.4±0.21	14.6±0.49
	Belarusian	11.5±0.71	2.5±0.00	12.0±0.00
	Windsor	12.0±0.00	2.3±0.14	9.9±0.14
Drip irrigation	Karadag st	19.5±0.71	2.8±0.28	13.7±0.42
	Ukrainian Sloboda	18.0±0.00	3.0±0.00	14.8±0.35
	Belarusian	17.0±1.41	3.8±0.21	12.3±0.49
	Windsor	19.5±0.71	3.7±0.35	11.0±0.00
Results of statistical processing				
HIP_{05}	*A*	*0.22*	*0.06*	*0.13*
	B	*0.35*	*0.09*	*0.22*
	AB	*0.50*	*0.12*	*0.31*
	CV, %	*23*	*22*	*14*

***Note**: * – control, st – standard*

Intervarietal difference was substantial in all variants. Thus, during dry-farming cultivation, the amount of beans in the Ukrainian Sloboda and Windsor cultivars was less by 1 pcs/plant regarding the standard. For the Belarusian cultivar, this indicator was less than the standard by 1.5 pcs. With drip irrigation conditions, the difference between the variants increased. Thus, in the Ukrainian Sloboda cultivar, a smaller amount of beans was noted relative to the standard by 1.5 pcs/plant, in Belarusian cultivar – a decrease against the Karadag

standard cultivar by 2.5 pcs. (*p≤0.05=0.12 pcs.*), the Windsor cultivar formed the same amount of beans as the standard. Similar results were obtained by Ashenafi and Makaria [31], where a considerable difference in the number of beans on the plant was noted. According to this, Evol et al. [32] and Tafer et al. [33] indicated that the amount of beans on a plant primarily depends on the cultivar.

The possibility of mechanised harvesting depends on the articulation height of the first bean. Thus, when growing with irrigation, the articulation height of the first bean increased by 0.2-1.1 cm relative to variants without irrigation. This phenomenon mainly depended on an increase in the length of internodes. Considerably higher values of this indicator against the standard were characterised by the Ukrainian Sloboda cultivar, where the articulation height of the first bean was higher by 1.6 and 1.1 cm (*p≤0.05=0.31*) against the control cultivar on dry-farming land and drip irrigation. In the Belarusian and Windsor cultivars, this indicator was less than the control by 2.6-2.5 and 2.1-1.3 cm.

Drip irrigation contributed to a considerable increase in the mass of green beans on the plant by 35.9-41.9 g/plant with *p≤0.05=4.02* (Table 4). Thus, the Belarusian cultivar had a lower bean mass compared to the Karadag cultivar by 1.9 g/plant for cultivation on dry-farming land and higher mass by 4.1 g/plant with irrigation. In Ukrainian Sloboda cultivars, this indicator prevailed over the control by 1.6 and 7.2 g, respectively, according to cultivation methods. In the Windsor cultivar, the mass of green beans increased by 3.4 and 4.0 g/plant according to the variant. Crop yield is the most important indicator of the effectiveness of cultivation technology. With drip irrigation, the commercial yield indicator increased by 3.5-4.2 t/ha (*p≤0.05=0.46*), or 31.3-39.2%. Thus, the Ukrainian Sloboda cultivar had a higher yield than the control cultivar by 0.2 t/ha on dry-farming land and by 0.8 t/ha with irrigation. The Windsor cultivar had a yield higher than the control by 0.4 and 0.5 t/ha, according to the growing method. The Belarusian cultivar was characterised by a lower yield compared to the control by 0.2 t/ha on dry-farming land and a higher yield by 0.5 t/ha with irrigation (Table 4).

From the results above, it is evident that Karadag and Belarusian cultivars have a better response to improved growing conditions (drip irrigation). Protein content with drip irrigation increased by 12.8-16.5%, depending on the cultivar (Table 5).

***Table 4**. The mass of green beans and yield of vegetable beans depending on the cultivar and drip irrigation*

Variant		Mass of green beans, g/plant	± to C*	Yield of green beans, t/ha	± to st
Dry-farming land*	Karadag st	92.0±9.98	0	11.0±1.20	0
	Ukrainian Sloboda	93.6±9.13	1.6	11.2±1.10	0.2
	Belarusian	90.1±5.86	-1.9	10.8±0.70	-0.2
	Windsor	95.4±6.33	3.4	11.5±0.76	0.4
Drip irrigation	Karadag st	127.9±10.14	0	14.6±1.16	0
	Ukrainian Sloboda	135.1±11.56	7.2	15.4±1.32	0.8
	Belarusian	132.0±12.78	4.1	15.0±1.46	0.5
	Windsor	131.9±7.91	4.0	15.0±0.90	0.5
PResults of statistical processing					
HIP_{05}	*A*	*1.80*	–	*0.20*	–
	B	*2.85*	–	*0.33*	–
	AB	*4.02*	–	*0.46*	–
	CV, %	*19*	–	*16*	–

***Note**: * – control, st – standard*

***Table 5**. Protein and dry matter content in green beans depending on the cultivar and drip irrigation*

Variant		Protein content, %	± to st	Dry matter content, %	± to st
Dry-farming land*	Karadag st	10.2±0.28	0	13.0±1.17	0
	Ukrainian Sloboda	10.9±0.14	0.7	13.3±1.13	0.3
	Belarusian	9.4±0.28	-0.8	12.6±0.70	-0.4
	Windsor	13.4±0.42	3.2	13.3±0.68	0.3
Drip irrigation	Karadag st	11.6±0.85	0	11.0±0.42	0
	Ukrainian Sloboda	12.3±0.71	0.7	11.5±0.42	0.5
	Belarusian	10.9±0.92	-0.6	11.3±0.42	0.3
	Windsor	15.5±2.12	3.9	11.7±0.35	0.7
Results of statistical processing					
HIP_{05}	*A*	*0.19*	–	*0.16*	–
	B	*0.30*	–	*0.25*	–
	AB	*0.42*	–	*0.36*	–
	CV, %	*16*	–	*8*	–

***Note**: * – control, st – standard*

Thus, when cultivated on dry-farming land, the protein content of the Windsor cultivar was considerably higher relative to the standard (3.2% at *p≤0.05=0.42%*), in the Ukrainian Sloboda cultivar, the protein content increased by 0.7%, and in the Belarusian cultivar, the content was 0.8% less than in the Karadag cultivar. When cultivated with irrigation, the Windsor bean cultivar accumulated more protein than the Karadag cultivar by 3.9%, the Ukrainian Sloboda cultivar – by 0.7%, and the Belarusian cultivar – less than the control by 0.6%. Growing beans with drip irrigation contributed to a considerable reduction in the dry matter content by 1.3-2.0% (*p≤0.05=0.36*). The lower dry matter content relative to the Karadag cultivar was characterised by the Belarusian cultivar – 0.8 on dry-farming land and 0.3% higher with irrigation. The Ukrainian Sloboda cultivar had a higher dry matter content by 0.3 and 0.5% according to the growing method. The Windsor cultivar surpassed the Karadag cultivar by 0.3 and 0.7% according to the growing method.

The studies of the development of the nodulation apparatus have shown that the cultivation of beans *with irrigation* contributed to a considerable increase in the mass of nitrogen-fixing nodules (rhizobia) from 34.2% in the Ukrainian Sloboda cultivar to 114.9% in the Belarusian cultivar at the level of *p≤0.05=0.03 g/plant* (Fig. 2).

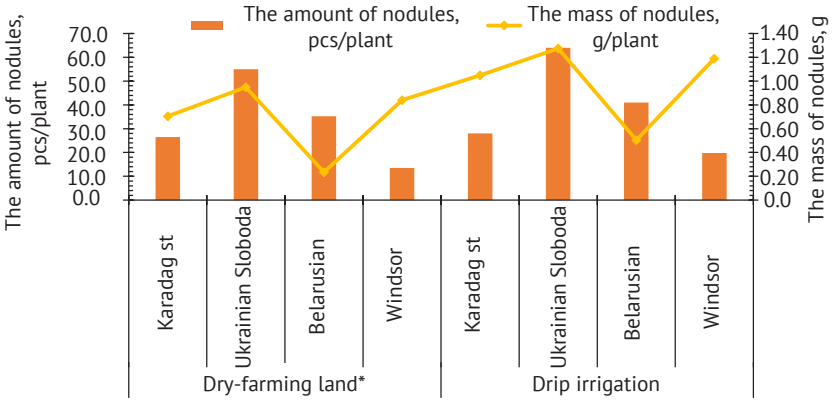

***Figure 2**. The development of the nodulation apparatus of vegetable beans depending on cultivars and drip irrigation*

Results of statistical processing		*Amount of nodules*	*Mass of nodules*
HIP_{05}	*A*	*0.58*	*0.01*
	B	*0.93*	*0.02*
	AB	*1.31*	*0.03*

***Note**: * – control, st – standard*

During the cultivation on *dry-farming land*, the standard Ukrainian Sloboda cultivar most considerably prevailed by weight of nodules (+34.8%), the difference was slightly lower for Windsor cultivar (+19.1%). The Belarusian cultivar formed lower masses of rhizobia by 66.7% compared to the Karadag cultivar. During the cultivation *with irrigation*, the same trend continued, but the difference between the variants decreased. Thus, Ukrainian Sloboda cultivar and Windsor cultivar formed rhizobia larger in weight by 21.4 and 13.3% relative to Karadag standard cultivar, the Belarusian cultivar had rhizobia 51.9% smaller in weight. Growing beans *with drip irrigation* contributed to a considerable increase in the number of rhizobia on the plant. Thus, Karadag cultivar increased their number relative to the variant without irrigation by 5.7%, Ukrainian Sloboda cultivar – by 16.4%, Belarusian cultivar – by 16.3%, and Windsor cultivar – by 46.7%. During the cultivation *on dry-farming land,* Ukrainian Sloboda and Belarusian cultivars formed by 28.5 and 8.7 pcs./plant more nodules relative to the Karadag cultivar, and the Windsor cultivar – less by 13.0%. During the cultivation *with irrigation*, Ukrainian Sloboda and Belarusian cultivars formed by 36.0 and 13.0 pcs./plant more nodules relative to the Karadag cultivar, and the Windsor cultivar – less by 8.2%. This means, the response of plants of Karadag cultivar was more positive to the growth of rhizobia, which helped to reduce the difference between the variants.

CONCLUSIONS

Thus, it can be stated that cultivating beans with drip irrigation improves the growth processes of plants, increases crop productivity, and improves soil conditions for the next crop by accumulating biological nitrogen in the ploughing soil layer. Cultivation of beans with drip irrigation contributed to an earlier arrival of products by 4-7 days, which in turn will be affecting the cost of production and profitability of production.

When cultivating beans with drip irrigation, the number of shoots on one plant increased by 17.3-30.0%, or 0.7-1.0 pcs/plant, the leaf area of plants increased by 21.2-24.9%, and the number of beans increased on variants with drip irrigation by 47.8% for the Belarusian cultivar, by 50% for the Karadag St and Ukrainian Sloboda cultivars, and by 62.5% for Windsor cultivar – relative to the variant with no irrigation.

Drip irrigation contributed to an increase in the mass of green beans on the plant by 35.9-41.9 g/plant, and the indicator of commercial yield increased by 3.5-4.2 t/ha, or 31.3-39.2%. The crude protein content with drip irrigation increased by 12.8-16.5%. Analysis of the data obtained indicates that drip irrigation contributes to an increase in the level of fulfilment of biological potential, which is especially high in Ukrainian Sloboda, Belarusian, and Windsor cultivars.

The cultivation of beans with drip irrigation contributed to a considerable increase in the number of nitrogen-fixing nodules on the plant by 34.2-114.9% and their mass by 5.7-46.7%, which, accordingly, increased the concentration of biological nitrogen in the soil. Cultivating beans with drip irrigation contributes to a substantial improvement in the formation of the legume-rhizobial system, which has a positive effect on the concentration of biological nitrogen in the soil.

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Оптимізація продукційного процесу бобу овочевого шляхом добору сортів і застосування краплинного зрошення

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Анотація. Для галузі землеробства актуальна тенденція розширення асортименту вирощування овочевих культур. Сучасне сільськогосподарське виробництво неможливе без вирощування бобових культур – дешевого джерела рослинного білка і однієї з важливих ланок, від якої залежить баланс органічної речовини в ґрунті. Метою досліджень, що проводилися у 2019–2020 рр., було вивчення сортових особливостей і вплив краплинного зрошення на ріст і урожайність бобу овочевого та формування симбіотичної системи. Для досліджень використовували польові, лабораторні, статистичні і розрахунково-аналітичні методи. Проведені дослідження дали змогу встановити, що застосування краплинного зрошення сприяло більш ранній появі сходів, скороченню міжфазних періодів і більш ранньому надходженню овочевої продукції на 4–7 діб залежно від сорту. Маса зелених бобів зростала на 35,9–41,9 г залежно від сорту. Урожайність зелених бобів збільшувалася на 3,5 т/га (32,1 %) у сорту Карадаг, 3,6 т/га (31,3 %) у сорту Віндзорські та 4,2 т/га (39,2 %) у сортів Українські слобідські і Віндзорські. Серед дослідних варіантів найбільш врожайним на богарі був сорт Українські слобідські, а на зрошенні – Білоруські, Українські слобідські та Віндзорські. Результати вказують, що найбільш розвинутий нодуляційний апарат формувався у сорту Українські слобідські, де формувалася найбільша маса, проте дрібних бульбочок на рослині (0,9 г на богарі та 1,3 г на зрошенні). Загалом краплинне зрошення сприяло покращеному розвитку бобово-ризобіального симбіозу рослин бобу овочевого. Маса бульбочок на краплинному зрошенні зростала на 0,3 г/росл. незалежно від сорту, а їх кількість – на 1,5–9,0 шт./росл. Представлені результати дають уявлення про функціонування бобового агроценозу та вплив зрошення на основні якісні показники продукту. Подальші дослідження полягають у вивченні режимів (норм, строків, кратності) зрошення та їх вплив на продуктивність рослин бобу овочевого

Ключові слова: біохімічні показники, маса зелених бобів, нодуляційний апарат, урожайність зелених бобів

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Structure of Forest Sites of the Green Belt of Zhytomyr City

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Abstract. Zhytomyr is one of the cities of Ukraine, which has large areas of green belts. Due to the lack of the latest integrated information on the characteristics of green belts around the city, an analysis of the forest fund of three enterprises was carried out, the area of which form the green zone. Based on the analysis of forest management information, it was determined that about 58% of the area of suburban forests belongs to forestry enterprises. Accordingly, the share of land plots in the forest-park part of the urban green belt amounts to 42%. The area of each part was divided into categories, predominant species, age groups, forest types, and the presence of specific features in the plot. Recreational forests are mainly represented by forested areas, the share of which reaches 91% against 89% in the plots of forestry enterprises. By age, stands in recreational forests are slightly older. It was found that the species and typological structure of forests in both zones differs. Forest-growing conditions in the forestry part are richer, which has led to the allocation of more forest types, more diverse species composition, and the predominance of oak stands. In general, more than a third of the areas of hayfields and more than half of the areas of swamps are overgrown with woody and shrubby vegetation in suburban forests, due to the overdrying. The areas of hayfields and bogs were categorised by type and use. Areas with important recreational features include areas with the presence of scenic overlooks, drinking water sources, monuments, landscaping elements, century-old trees, small glades, biotechnical objects, and forest areas that are monuments of landscape art, places of memorable events, places of settlement of rare animals and birds. It was found that the forest zones of Zhytomyr contain significant areas of plots with existing berry-bearing plants (430 ha) and medicinal plants of industrial significance (179 ha). Berry fields are represented only by blueberries and strawberries, the projective coverage of which varies from 5 to 35%. Future studies can be promising to determine the level of recreational use of plots that have valuable features, elements of landscaping, and berry fields

Keywords: recreational forests, forest site types, forest species composition, typological structure, berry field areas

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INTRODUCTION

The most important functions of the forest stand for society are health-improving and recreational. Recreation of Ukraine's population can take place on most forested areas that are suitable for their functional purpose and forest-growing conditions. One of the forest categories, which is entrusted with the function of health improvement and recreation of the population, is recreational forests. Forests of this category can be located both within and outside populated areas, which is regulated by the relevant decree [1]. According to this document, the areas of green belts (GB) and recreational forest plots are established depending on the natural zone, forest cover, and population size of the corresponding locality.

The analysis of the concepts of "green belt" and "complex urban green belt" with variants of interpretation by many scientists was carried out by I. Kuzyk [2]. The researcher noted that the category "urban green belt" should be understood as forest stands outside the city. Today, the structural elements of the urban green belt are recreational forests and forestry enterprises. In forest management, the forest-park part of the GB has been allocated under conditions of high anthropogenic loads since 1961, and the forestry part – since 1928 [3]. The areas of forests that belong to the latter are more remote from the city limits and belong to the so-called "restricted forests", in which principal use felling (PUF) can be carried out. Sections of the recreational part of the GB are classified as "special-use forests", which excludes the possibility of PUFs. In addition, the forests of both types differ in the age gradations of the age groups of tree species, since the exploitable age of the main forest-forming species in recreational forests is 10-30 years higher [4].

The key role in identifying the green belt around a city is played by the distance of forest areas from its border [5]. Due to the large distance to wooded areas, a large number of cities in the Steppe zone of Ukraine actually do not have green belt forests. As a rule, with the growth of forest cover, there is also a tendency to the increase of suburban forest areas. However, population density [6; 7], accessibility to wooded areas [8; 9], and the industrial load of cities [10] play a very important role in determining the area of green belts both in Ukraine and abroad. Air pollution in many major cities of the world, which is caused by the growth of the number of vehicles and the development of industry, increasingly negatively affects the microclimate of cities, which poses serious challenges in the design of the so-called "green frame" [11; 12]. Another serious problem in the development of urban green belts is ecological and climatic changes, which in recent decades have increasingly manifested themselves in the Eastern European region, in particular in the form of temperature anomalies [13].

A fairly large number of research papers by both Ukrainian researchers and scientists from neighbouring countries are devoted to the study of the structure of forests in the urban green belts [14-16]. In Ukraine, the main studies mainly concerned the green belts of large cities of the Forest-steppe [17-19] and Polissya regions [20-22]. Regarding the Zhytomyrska Oblast, which has significant areas of recreational and health-improving forests, unfortunately, recent studies were very limited [23].

Due to the lack of information on the characteristics and structure of forest sites in the green belt of Zhytomyr city, *the purpose of the study* was to carry out appropriate research. To achieve this goal, the following tasks were set: to investigate the distribution of forest sites by area, to determine the species, typological, and age structure of plantings, to find out the presence of berry fields, hotbeds of medicinal plants, the features that can affect the recreational use of territories in the context of forestry and recreational parts of the GB.

MATERIALS AND METHODS

The materials for the study were the forest inventory data of three forestry enterprises: SE "Zhytomyrske LH", SE "Zarichanske LH", and SE "Pulynskyi lishosp APK" as of 01.01.2016. Information on forest management was obtained and analysed using the VO "Ukrderzhlisproekt" inventory database using the SQL Server and "Lisovporiadnyk" software tools in accordance with the instructions [24]. At the first stage of the study, the analysis of forest management data was carried out separately for each forestry enterprise. All sections of the forest fund of forestry enterprises within the Zhytomyrska Oblast were taken into account. Filtering of database information was carried out by grouping the areas of green belts by a certain indicator. The analysis was carried out in the following sequence: categories of protectability of recreational forests; categories of sites of the forest fund; features of sites; forest sites (species, typological, and age structure); non-forest sites (types of hayfields and swamps, the degree of their overgrowth with woody and bush vegetation), berry fields and medicinal plants (types, coverage areas). First, the search was carried out for areas of the forest fund within two categories of protectability that form the urban green belt: "the forestry part of green zones" and "the recreational part of green zones". For plots within the corresponding functional part of suburban forests, the areas of forest and non-forest plots were determined. Among the forested areas, the distribution of areas by predominant tree species,

forest site types, and age groups was determined. The intensity of economic operations in the forests of both parts of the GB was determined by the share of certain categories of un-forested areas. Among the non-forested areas, only swamps and hayfields were analysed. The types of swamps, the predominant vegetation, the degree of overgrowth of trees and shrubs, and their species composition were determined. Regarding hayfields, the main users, types of land, quality, condition, degree of overgrowth, and species composition of tree and shrub vegetation were determined.

The analysis of the features of subcompartments, the presence of berry bushes and medicinal plants was carried out within the forest fund of both parts of the GB. Out of the total area of land plots that had certain special characteristics, only 23 categories of features that can potentially affect the recreational use of the territory (both positively and negatively) were logically filtered out. The total coverage areas of medicinal and berry plants were determined by the percentage of their projective coverage in a particular area.

RESULTS AND DISCUSSION

Within the Zhytomyrska Oblast and the city of Zhytomyr, there are more than 44 thousand hectares of forest plots, of which 33.4 thousand hectares belong to recreational and health-improving forests. About 25.98 thousand hectares of recreational and health-improving forests within the administrative district are subordinated to SE "Zhytomyrske LH" (Berezivske, Bogunske, Korabelne, Levkivske, Stanishyvske and Trigirske forestries); 3.36 thousand hectares belong to SE "Zarichanske LH" (Zarichanske and Korbutivske forestries) and about 4.08 thousand hectares belong to SE "Pulynskyi lishosp APK" (Zhytomyrske forestry).

Within the city limits of Zhytomyr, there are only 18 hectares of forest areas (Bogunske forestry), which belong to forests within localities. The remaining recreational forests of the Zhytomyrska Oblast form the green belt of the Zhytomyr city. Among suburban forests, the plots that belong to the forestry part of the GB predominate in terms of area – 19.37 thousand hectares (58%). The area of recreational forests themselves (the forest-park part of the GB) is about 14.04 thousand hectares (42%).

The structure of forest sites in different parts of the green belt differs, which is caused by forestry activities in the forestry part. The use of PUFs in these forests causes the appearance of cut area (2.2%) and, accordingly, free-growing plants (2.5%). In the forestry part of the GB of Zhytomyr, the share of forest vegetation is about 89%, including 50% of artificial origin. Non-forest areas are dominated by swamps (2.0%), other non-forested areas (1.6%) and hayfields (0.6%). The distribution of areas by compartment categories differs most from the general part of the GB in SE "Zarichanske LH", which is conditioned by the use of a significant part of the territory for military purposes and the presence of significant areas of non-forest areas (more than 300 hectares), including the most developed network of unpaved roads (Table 1).

***Table 1**. Distribution of forest areas in the forestry part of the GB by compartment categories*

Compartment categories	SE "Zhytomyrske LH"		SE "Zarichanske LH"		SE "Pulynskyi lishosp APK"		Total	
	Area, ha	%	Area, ha	%	Area, ha	%	Area, ha	%
Paved roads	24.7	0.2	–	–	–	–	24.7	0.1
Swamps	379.8	2.4	6.3	0.7	2.1	0.1	388.2	2.0
Other non-forest lands	–	–	308.2	32.1	–	–	308.2	1.6
Reclamation canals	–	–	0.6	0.1	–	–	0.6	0.0
Decorative glades	–	–	4.3	0.4	–	–	4.3	0.0
District boundaries	–	–	–	–	8.7	0.3	8.7	0.0
Glades	–	–	5.3	0.6	2	0.1	7.3	0.0
Economic and administrative buildings	1.7	0.0	–	–	–	–	1.7	0.0
Dirt roads	37.5	0.2	21.4	2.2	7.5	0.3	66.4	0.3
Failed plantations	2.4	0.0	–	–		0.0	2.4	0.0

Table 1, Continued

Compartment categories	SE "Zhytomyrske LH"		SE "Zarichanske LH"		SE "Pulynskyi lishosp APK"		Total	
	Area, ha	%	Area, ha	%	Area, ha	%	Area, ha	%
Cuttings	404.7	2.6	–	–	21.5	0.8	426.2	2.2
Forest borders	20.6	0.1	1.7	0.2	–	0.0	22.3	0.1
Electric lines	9.6	0.1	3.2	0.3	–	0.0	12.8	0.1
Communication lines	0.9	0.0	–	–	–	0.0	0.9	0.0
Forest plantations	8,190.3	52.2	418.2	43.6	1,023.8	37.6	9,632.3	49.7
Stands with an artificial admixture	1.1	0.0	5.3	0.6	–	0.0	6.4	0.0
Natural stands	5,774.4	36.8	171.4	17.9	1,621.6	59.5	7,567.4	39.1
Free-growing plantations	472.5	3.0	–	–	20.3	0.7	492.8	2.5
Lakes	1.5	0.0	–	–	–	0.0	1.5	0.0
Pastures and grasslands	3	0.0	–	–	–	0.0	3	0.0
Plantations	30.3	0.2	–	–	–	0.0	30.3	0.2
Compartment lines	135.5	0.9	2.6	0.3	2.4	0.1	140.5	0.7
Broadleaved plantings, bio-meadow, feeding sites	17	0.1	–	–	14.1	0.5	31.1	0.2
Rivers	6.6	0.0	–	–	–	–	6.6	0.0
Arable land	31.6	0.2	0.5	0.1	–	–	32.1	0.2
Forest nurseries	0.9	0.0	–	–	–	–	0.9	0.0
Gardens	1	0.0	–	–	–	–	1	0.0
Estates	31.3	0.2	0.3	0.0	–	–	31.6	0.2
Hayfields	100.5	0.6	8.4	0.9	–	–	108.9	0.6
Ponds	7.3	0.0	0.3	0.0	–	–	7.6	0.0
Streams	1	0.0	2	0.2	–	–	3	0.0
Total	15,687.7	100	960	100.0	2,724	100	19,371.7	100

***Source**: calculated based on forest inventory materials as of 2016 using the relational database of VO "Ukrderzhlisproekt"*

The most active forestry management is established in SE "Zhytomyrske LH", which is confirmed by the share of temporarily forested areas, namely cuttings and free-growing plantations. In the recreational part of the green zone, there is a correspondingly higher share of forested areas – 91%, but cuttings (0.8%) and free-growing plantations (0.8%) are less common due to the low-intensity farming. Artificial plantings, as in the forestry part of the GB, natural stands predominate in terms of area (57% vs. 34%). The swampiness of the territory of recreational forests is insignificant – about 1.4%. The road network is slightly better developed than in the forestry part, which is confirmed by almost twice the share of dirt roads – 0.7%. The best developed road network is the territory of forest parks, which is subordinate to SE "Zarichanske LH" – 2.8%. At the same time, within the recreational part of this enterprise there are significant areas of non-forested land – 2.6%.

Among non-forested areas, hayfields and swamps can be used for recreational purposes to a certain extent. About half of the hayfields in the suburban forests of Zhytomyr are used for hay harvesting. Most of these lands are dry (52%), the rest are swampy and floodplain (24% each). The vast majority of land areas (59%) are clean, but the share of land overgrown with shrubs and woody vegetation is 30%. About 11% of the land area has a bumpy structure. The percentage of overgrowth of hayfields with shrubs and trees is mainly from 5% to 35%. Most of the areas are overgrown with black alder (*Alnus glutinosa* (L.) Gaerth.), common birch (*Betula pendula* Roth.) and willows – *Salix caprea* L., *S. viminalis* L. and *S. Triandra* L. As for swamps, most of them are low-lying (83%), the share of areas of transition and upper swamps is significantly smaller (16% and 1%, respectively). According

to the type of vegetation, swamps in the suburban area are mainly sedge and sedge-sphagnum, the participation of which is 73% and 22%, respectively. The vast majority of swamps in suburban forests are overgrown with shrubs (shrubby willows) and trees up to a third of their area.

Large areas of land in suburban forests have certain characteristics that significantly affect their recreational assessment and use. For example, in SE "Zhytomyrske LH" such plots cover more than 6.5 thousand hectares (Table 2).

***Table 2**. Areas of land plots within the recreational and health-improving forests of SE "Zhytomyrske LH", which have special characteristics for recreation, ha*

Site features	Recreational forest part of the GB	Forestry part of the GB
Used for public recreation	1.4	3.0
Rocky outcrops on the area	0.9	11.8
Plantings of different ages	48.6	111.1
Stand density is uneven	554.9	1,259.5
Stand composition is heterogeneous	229.5	1,297.8
Monument of the garden art of local significance	–	0.6
The area is cut by small ravines	–	17.5
Place of memorable events	–	1.5
The compartment contains		
Bio-meadow	4.0	25.5
Overlook	4.9	1.1
Feeder	12.2	78.7
Small swamps	330.8	1,529.2
Small glades	174.9	224.7
Anthills	270.3	137.3
Badger burrows	1.5	–
Vacation site	29.7	9.5
Drinking source	12.1	–
Alkali soil	5.6	30.6
Artificial bird nests	8.4	68.4
Ancient tree	–	27.6
Monument	–	3.1
Black stork habitat	–	0.2
Fly camp for livestock	–	5.5
Total	1,691.9	4,844.2

***Source**: calculated based on forest inventory materials as of 2016 using the relational database of VO "Ukrderzhlisproekt"*

Some features of land plots negatively affect their patency and stability, for example, the presence of small swamps and ravines. A number of special characteristics that are associated with hunting, attracting and preserving avifauna can be effectively used in the design of functional zoning and ecological and educational routes. The most valuable in recreational terms are the forest plots that are used for recreation of the population, compartments with the presence of overviews, sources of drinking water, monuments, landscaping elements, ancient trees, and small monuments of landscape art, places of memorable events. The total area of such plots at the enterprise is more than 480 hectares, while they are represented both in the recreational and in the forestry parts of the FGM of Zhytomyr.

Due to the fact that the GB of Zhytomyr covers

a significant territory, which is located on the border of the natural zones of Polissya and Forest-steppe, the typological structure of forest sites is quite diverse. Forests of the forestry part of the GB differ from forest parks in richer forest-growing conditions. In forests of this category of protectability, 22 forest site types are established, among which the most common are wet hornbeam-oak-pine sudubrava (C_3hoP) – 16.6%, wet hornbeam dubrava (D_3hO) – 15.5%, wet hornbeam sudubrova (C_3hO) – 14.6%, fresh hornbeam-oak-pine sudubrava (C_2hoP) – 14.6%, and wet oak-pine subor (B_3oP) – 14.6% (Table 3).

***Table 3**. Typological structure of suburban forests in Zhytomyr*

Forest type	Forestry part		Recreational forest part	
	Area, ha	%	Area, ha	%
A_1P	–	–	32.4	0.2
A_2P	84.9	0.5	99.6	0.8
A_3P	0.4	0.0	–	–
B_2oP	1,757.5	9.7	3,859.1	29.3
B_3oP	2236	12.3	875.5	6.6
B_4oP	61.9	0.3	27.8	0.2
B_5bP	51.9	0.3	2.3	0.0
D_2hO	1,030.8	5.7	390.5	3.0
D_3hO	2,829.6	15.5	296.8	2.3
D_4BA	59.4	0.3	1.9	0.0
D_4hO	29.2	0.2	–	–
D_5BA	17.5	0.1	–	–
C_2hO	710.9	3.9	217.2	1.6
C_2hoP	2,653.1	14.6	3,869.8	29.4
S_2hpO	0.5	0.0	26.6	0.2
C_3hO	2,659.3	14.6	522.1	4.0
C_3hoP	3,016.4	16.6	2,314	17.6
C_3hpO	4.8	0.0	68.9	0.5
C_4BA	842.6	4.6	544.1	4.1
C_4hO	11	0.1	12.1	0.1
C_4hoP	22.6	0.1	7.2	0.1
C_5bP	0.7	0.0	–	–
C_5BA	120.7	0.7	11.9	0.1
Total	18,201.7	100	13,179.8	100

***Source**: calculated based on forest inventory materials as of 2016 using the relational database of VO "Ukrderzhlisproekt"*

If the forestry part is characterised by the dominance of wet edatopes, the share of which is 59%, then fresh conditions are more typical for the recreational part of the forest (61%). In total, 19 site types were found in recreational forests. The most common types of forest are C_2hoP – 29.4%, fresh oak-pine subor (B_2dP) – 29.3%, and C_3hoP – 17.6%.

The species composition in the forestry part of the urban green belt differs by three enterprises. For example, oak stands predominate in SE "Zhytomyrske LH" (48%), in SE "Zarichanske LH" and SE "Pulynskyi lishosp APK" – pine stands predominate (70% and 54%, respectively). In general, in the forestry part, common oak (*Quercus robur* L.) prevails on 40% of forested areas, Scots pine (*Pinus sylvestris* L.) – on 35%, common birch (*B. pendula* Roth.) – on 12%, black alder (*A. glutinosa* (L.) Gaerth.) – on 6%, other species – by 7% (Fig. 1).

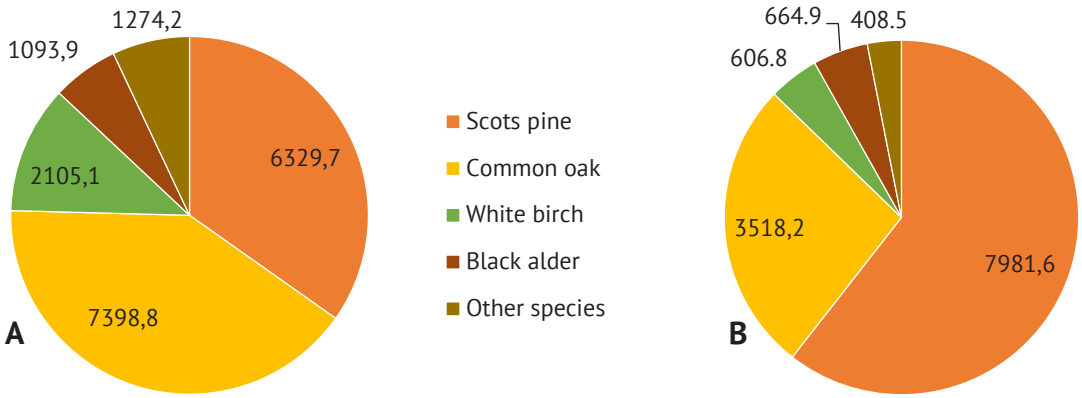

***Figure 1**. Distribution of forest areas of Zhytomyr by predominant species, ha. A – forestry part of the GB, B – recreational forest of the GB*

The recreational part of forests significantly differs from the forestry part in terms of species composition. In forests of this category of protectability, Scots pine prevails on 61% of the land area, common oak – 27%, white birch and black alder – 5% each, other species – 2%. The share of oak stands in recreational forests is higher in SE "Zhytomyrske LH" (30%) and SE "Zarichanske LH" (25%), relative to SE "Pulynskyi lishosp APK", oak stands here cover only 6% of the area. The age structure of forests in different parts of the GB has certain differences. According to the distribution areas by age groups, the share of young stands in recreational forests is very small – 3.5% against 9.2% in the forestry part. Furthermore, in the forests of this part of the green belt, the share of areas of ripening stands is almost twice as high (Table 4).

***Table 4**. Age structure of suburban forests in Zhytomyr*

Age groups	Forestry part		Recreational forest part	
	Area, ha	%	Area, ha	%
Young stands of the 1st class	619.2	3.6	129	1.0
Young stands of the 2nd class	972.1	5.6	326.1	2.5
Average age of stands	7,245.1	42.1	7,296.3	57.0
Average age of stands, included in the calculation	3,881.1	22.6	2,397.3	18.7
Ripening stands	2,671.7	15.5	889.5	6.9
Ripe stands	1,376.5	8.0	1,482.8	11.6
Overripe stands	440.4	2.6	285.1	2.2
Total	17,206.1	100	12,806.1	100

***Source**: calculated based on forest inventory materials as of 2016 using the relational database of VO "Ukrderzhlisproekt"*

But the share of stands of average age is higher in the recreational forest by more than 11%. In the recreational part of the GB, the share of ripe and overripe stands is slightly higher. The age structure in the context of enterprises also has significant differences. In SE "Zhytomyrske LH" in recreational forests, the share of ripening, ripe, and overripe stands is significantly higher, but in other enterprises, there are younger and average-aged forests.

The latest forest inventory data on the accounting of berries and medicinal raw materials in the suburban forests, on the example of SE "Zhytomyrske LH", suggests that within the urban green belt, there are more than 430 hectares of plots with the presence of berries and about 190 hectares of plots with medicinal plants. In recreational forests contain almost 208 hectares of plots with berry fields, among which their uneven distribution is observed on an area of 157 hectares. In the Forestry part of the forests of the green zone of the enterprise, the area of plots with berry fields is almost 224 hectares. As for plots with the presence of medicinal plants of industrial importance, their area in the recreational part of the GB is more than 103 hectares (among them almost 36 hectares with uneven distribution of plants), in the forestry part – 76, including 41 hectares with uneven distribution of plants on the

territory. Berry bushes are represented by only two types of plants – blueberries (*Vaccinium myrtillus* L.) and wild strawberries (*Fragaria vesca* L.) at the same time, wild strawberries are present only in the recreational forests (Fig. 2).

The projective coverage of strawberries on plots varies from 10% to 20% and averages about 16%. Blueberry coverage in recreational forests is almost twice as large. As a rule, blueberries cover within 10-30% of the area of plots, on average at the level of 19%. The area of land overgrown with blueberry plants in the forestry part of the green belt is much larger, while berry fields cover from 5% to 50% of the land area. As for medicinal plants, the growth of 8 plant species of industrial significance has been observed in the suburban forests of SE "Zhytomyrske LH". At the same time, the coverage areas of these plants are larger in recreational forests (Table 5).

The most common types of medicinal plants in the recreational forests are common yarrow and St. John's wort, and in the forestry part of the green zone – calamus root and Stinging nettle.

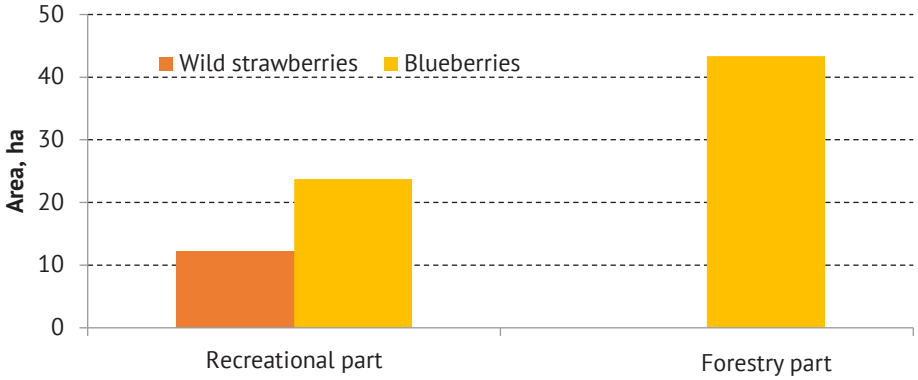

***Figure 2**. The area of berry fields in the GB of SE "Zhytomyrske LH"*

***Table 5**. Areas of coverage of medicinal plants within SE "Zhytomyrske LH", ha*

Medicinal plants	Recreational for-est part	Forestry part
Common yarrow (*Achillea millefolium* L. s.)	4.4	0.72
St. John's wort (*Hypericum perforatum* L.)	3.13	0.4
Stinging nettle (*Urtica dioica* L.)	–	2.42
Calamus root (*Acorus calamus* L.)	1.46	3.59
Erect cinquefoil (*Potentilla erecta* L.)	0.78	–
Wormwood (*Artemisia absinthium* L.)	1.22	1.32
Immortelle (*Helichrysum arenarium* L.)	1.39	1.32
Total	12.38	9.77

***Source**: calculated based on forest inventory materials as of 2016 using the relational database of VO "Ukrderzhlisproekt"*

CONCLUSIONS

The area of suburban forests in Zhytomyr is more than 33.4 thousand hectares, among which the plots of the forestry and recreational parts of the green belt cover 19.37 and 14.04 thousand hectares, respectively, which corresponds to the current standards. The distribution of forest areas by site category, including the species, age, and typological structure of stands in both parts of the green zone have differences. This is due to both forest-growing conditions and different forest management regimes. The share of forested areas in recreational forests is 2% higher due to the insignificant participation of free-growing plantations and cuttings, which are significantly higher in the forestry part of the green belt. By age, the recreational forests are on average slightly older, which is the result of a special farming regime. Due to the fact that the areas of the forestry part are more spatially dispersed, their typological and species structure is more diverse. Richer forest conditions in these stands have caused a greater species diversity of trees and a greater proportion of megatrophic plants in the species composition.

In both parts of the city's green belt, there are about 480 hectares of land with existing facilities and features that have a significant impact on the recreational

use of the surrounding area. More than 67 hectares are occupied by plots with various levels of landscaping, more than 235 hectares with habitats of rare animals and birds, and with existing biotechnical facilities. Plots with berry fields and medicinal plants of industrial significance are equally represented in the forests of the two zones. Only in suburban forests within SE "Zhytomyrske LH" blueberries and strawberries occupy an area of about 671.1 and 121.8 thousand m^2, respectively. As for medicinal plants, their coverage area is about 221.5 thousand m^2.

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Структура ділянок лісового фонду зеленої зони міста Житомира

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Анотація. Місто Житомир є одним із населених пунктів України, яке має великі площі лісів зеленої зони. У зв'язку із відсутністю актуальної інтегрованої інформації щодо характеристики приміських лісів міста, було проведено аналіз лісового фонду трьох підприємств, лісові масиви яких власне й утворюють зелену зону. За результатами аналізу лісовпорядної інформації було визначено, що близько 58 % площ приміських лісів належать до лісогосподарської частини. Відповідно, частка площ ділянок лісопаркової частини зеленої зони міста становить 42 %. Для кожної з частин було здійснено розподіл площ ділянок за категоріями, переважаючими породами, групами віку, типами лісу, наявністю особливостей у виділах. Ділянки лісопарків представлені здебільшого покритими лісом територіями, частка яких сягає 91 % проти 89 % у лісогосподарській частині. За віком деревостани у лісопарках є дещо старшими. Встановлено, що породна і типологічна структура лісів обох зон відрізняється. Лісорослинні умови у лісогосподарській частині лісів зеленої зони є багатшими, що зумовило виділення більшої кількості типів лісу, різноманітніший породний склад насаджень, переважання дубових деревостанів. Загалом у приміських лісах встановлене заростання деревною та чагарниковою рослинністю понад третину площ сіножатей і більше половини боліт, внаслідок їх пересихання. Проведено розподіл площ сіножатей і боліт за типами та використанням. До виділів із важливими для рекреації особливостями віднесені ділянки із наявністю видових точок, джерел питної води, монументів, елементів благоустрою, вікових дерев, дрібних галявин, біотехнічних об'єктів, а також урочища, які є пам'ятками садово-паркового мистецтва, місцями пам'ятних подій, місцями поселення рідкісних тварин і птахів. Досліджено, що в лісах зеленої зони м. Житомира є значні площі ділянок з наявними ягідниками (430 га) та лікарськими рослинами промислового значення (179 га). Ягідники представлені лише чорничниками та суничниками, проективне покриття яких варіює в межах від 5 до 35 %. Надалі є перспективними дослідження щодо визначення рівня рекреаційного використання ділянок, які мають цінні для рекреації особливості, елементи благоустрою та ягідники

Ключові слова: лісопарки, категорії ділянок, породний склад лісів, типологічна структура, площі ягідників

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Hereditary Burden in Poultry of Different Species of the Ukrainian Gene Pool

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Abstract. The relevance of the study is conditioned by the need to continually conduct anatomical pathology analysis of dead embryos as an integral part of genetic monitoring of harmful mutations, which may reduce the level of genetic burden in the gene pool of poultry. The study was conducted on poultry of various species of the Ukrainian gene pool: chickens of meat and egg area of productivity, turkeys of the original family lines of the Kharkiv crossing. The purpose of the study was to determine the spectrum and frequency of hereditary genetic defects in the development of embryos in land birds of various species, to establish the level of genetic burden. The spectrum and frequency of morphological and anatomical hereditary defects of chicken and Turkey embryos were established during anatomical pathology examination of incubation waste. Visual examination of the dead embryos allowed identifying morphological abnormalities in the structure of the skeleton, as well as various disproportions of its individual parts. In chickens of subpopulations with black-striped and white plumage, among the birds of all the studied groups, the widest range of morphological abnormalities of embryo development was discovered. In meat and egg hens with golden plumage, three anomalies with the same frequency of manifestation of 33.3% were found among the examined dead embryos. Only 1 anomaly "exencephaly" was found in birds with mottled plumage. Two cases of double mutation were found in birds with silver plumage among the examined dead embryos. The level of genetic burden in the studied subpopulations of meat and egg chickens was in the range of 3.45-8.72%. In birds with white and silver plumage, this figure was higher than the maximum allowed value, therefore it is necessary to carry out selection measures to eliminate lethal genes from these populations of chickens. In turkeys of the paternal line 5 and maternal line 6 of the Kharkiv crossing, 2 morphological anomalies of embryo development were found among the examined dead-in-shell embryos. The level of genetic burden in turkeys of related forms is low – 1.60-1.89%, which does not exceed the maximum allowed value (8.0%). This indicates a low share in the heredity of the used breeders of hidden carriers of "defective" genes. At this stage, the preservation of the gene pool of birds is not threatening its further breeding

Keywords: meat and egg chickens, turkeys of the Kharkiv crossing, Ukrainian poultry gene pool, anomalies, genetic burden

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INTRODUCTION

Any population of animals, including birds, contains a certain number of recessive harmful genes that arise as a result of mutational processes and are called the "genetic burden". As a consequence of its existence, abnormal individuals can be found in any batch of one-day-old birds. An even greater number and variety of them are found during the autopsy of incubation waste. According to G.K. Otriganiev et al. [1], among the "dead-in-shell" and "late dead" obvious abnormal individuals make up 3-4%. Some of the abnormal individuals die at an earlier age, in the first days of incubation. The frequency of various anomalies in the early stages in some cases reaches 7-10% [2]. On average, it is estimated that 5% of embryos that die during incubation are abnormal. In addition, most deformities of embryonic aetiology are inherited as a recessive trait, and therefore their frequency increases with closely related breeding [3-5].

To prevent harmful recessive mutations from spreading in a particular group of animals, it is necessary to organise genetic control (monitoring) for the manifestation of pathology in animals [6-8]. To develop effective methods for eliminating the genetic burden from poultry populations, special importance is attached to anatomical pathology analysis, which acts as an integral part of the genetic monitoring of harmful mutations [9-10]. Thus, for example, according to the anatomical autopsy of incubation waste from eggs that were stored for a long time, the number of different degenerations is found to be higher than the standard indicators. The number of acrania and ectopia also increases [11]. It was also established that among late dead poultry from eggs with a long keeping period, the number of embryos with doubled limbs (legs and wings), double and multiple degenerations increase. Other researchers were also engaged in research aimed at studying the expression of genetic mutations in farm animals of various species [12-16].

This issue becomes particularly relevant when preserving the small genetic resources of poultry of various species since it allows controlling and taking timely measures to eliminate "harmful genes" from a limited poultry gene pool. This will make it possible to identify individuals who carry lethal and semi-lethal genes, the further use of which should be abandoned in order to reduce the genetic burden in the population and achieve a real, genetically determined increase in reproduction rates. Since there are few scientific publications on genetic monitoring for the detection of hereditary defects in the development of poultry embryos of the Ukrainian gene pool, such research is of particular importance.

The genetic burden can be mutational, balanced, and transient. Mutational burden occurs as a result of mutation of the dominant allele *A* into recessive *a*. The more often this process occurs, the more saturated the population is with the allele *a*. Selection counteracts population saturation with recessive alleles, eliminating them through homozygous genotypes *aa*, as the least adaptable. The general genetic burden is formed by the total effect of the genetic burden of individual loci [17].

According to the existing classification, it is proposed to divide genetic mutations according to the degree of their penetrance: lethal genes that cause 100% death of organisms; sublethal genes (semi-lethal) that cause the death of 50-90% of individuals; sub-vital genes that cause death in less than 10% of individuals [18]. Most lethal genes in poultry are recessive, but the scientific literature describes cases of pathological forms of both dominant and incompletely dominant nature. Lethal and semi-lethal anomalies are mainly associated with the transition to a homozygous state of mutant recessive genes. This means that the parents of abnormal animals are heterozygous carriers of these mutations [19]. The main danger for animal populations is represented by lethal mutations (lethals), which, being in a heterozygous state, can persist for many generations until they disappear due to the death of heterozygous carriers or in the case of infertility of homozygous animals with a lethal gene [20].

The purpose of the study was to identify the spectrum and frequency of hereditary genetic defects in embryo development in meat and egg chickens and turkeys in order to establish the level of genetic burden in various species of poultry populations of the Ukrainian gene pool.

MATERIALS AND METHODS

The study was conducted in 2018 in the laboratory of breeding, technology, and innovation management of the state experimental poultry breeding station of the National Academy of Agrarian Sciences. The object of the study was chickens of meat and egg productivity of the gene pool flock (subpopulation G1 – with black-striped plumage, subpopulation G2 – with white plumage, subpopulation G3 – with golden plumage, subpopulation G4 – with mottled plumage, subpopulation C – with silver plumage), turkeys of the initial lines (paternal line 5, maternal line 6) of the Kharkiv crossing of the middle type. All poultry is kept on the experimental farm "Preservation of the state gene pool of poultry" of the State Research Station of Poultry of the National Academy of Agrarian Sciences: meat and egg chickens in a cage battery of 6 heads per cage, turkeys on deep unchanged bedding of 20 heads per section. Feeding is carried out

with full-fledged mixed feed in accordance with the type and age of the bird.

The total number of dead-in-shell embryos of meat and egg chickens of five subpopulations was 365 pieces, turkeys of two lines – 231 pieces. During the productive period, the incubation eggs of chickens and turkeys are subjected to an incubation process to produce daily young animals. At the end of the incubation process of eggs of meat and egg chickens and turkeys of the initial lines 5 and 6 of the Kharkiv crossing, dead-in-shell embryos, the so-called "late dead", were selected among the egg incubation waste. Using a scalpel, the egg shell was broken and the dead-in-shell embryo was taken out with tweezers. Visual examination of the embryos identified morphological disorders in the skeletal structure, as well as various imbalances in individual body parts. Morphological and anatomical hereditary defects of chicken and turkey embryos were identified during anatomical pathology examination of incubation waste in accordance with a known method [21]. The description of identified anomalies of embryo development was carried out in accordance with the classification of R. Soames [5]. The level of genetic burden in each group of birds studied was determined as the proportion of detected anomalies in the development of embryos to the total number of them studied.

RESULTS AND DISCUSSION

The spectrum and frequency of hereditary genetic defects in embryo development in chickens of the studied groups are shown in Table 1.

In chickens of subpopulations G1 and G2, among birds of all the studied groups, a wide range of morphological anomalies of embryo development were found. The triple anomaly "exencephaly + crossed beak + 4 legs" was found with the predominant frequency in black-striped chickens among the examined embryos (40.0%). At the same time, white chickens most often had the "Donald Duck" anomaly (with a frequency of 53.8% among other detected defects). With a high frequency (20.0-30.8%), this bird had such mutations as "exencephaly", "crossed beak", "shortened maxilla". Other detected anomalies in meat and egg chickens of the G2 subpopulation had the same low frequency of occurrence – 7.1%. The level of genetic burden in chickens of the G1 subpopulation was set at 6.85% (Fig. 1), not exceeding the maximum allowed value (8.0%). At the same time, in white chickens, the level of genetic burden (8.72%) was higher than this indicator and therefore requires attention in terms of taking breeding and genetic measures to identify and eliminate "defective" genes carriers from the breeding process.

***Table 1**. Frequency of occurrence (%) and spectrum of developmental anomalies of embryos of meat and egg chicken populations*

Anomalies	Group Code				
	G1	G2	G3	G4	C
"Exencephaly"	20.0	30.8	33.3	100.0	0.0
"Crossed beak"	20.0	0.0	0.0	0.0	0.0
"Shortened maxilla"	20.0	0.0	0.0	0.0	33.3
"Donald Duck"	0.0	53.8	0.0	0.0	0.0
4 legs	0.0	7.7	33.3	0.0	0.0
"Exencephaly + shortened maxilla"	0.0	0.0	0.0	0.0	66.7
"Exencephaly + crossed beak"	0.0	7.7	33.3	0.0	0.0
"Exencephaly + crossed beak + 4 legs"	40.0	0.0	0.0	0.0	0.0
Number of examined dead-in-shell embryos, pcs.	73	149	50	58	35
The number of anomalies, pcs.	5	13	3	2	3
Level of genetic burden, %	6.85	8.72	6.00	3.45	8.57

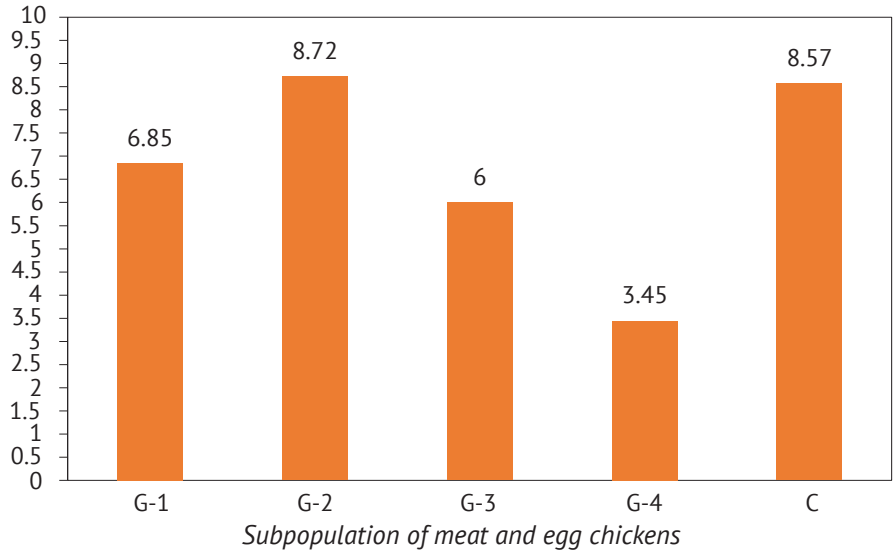

***Figure 1**. The level of genetic burden in the studied groups of chickens, %*

In chickens of the G3 subpopulation, three anomalies were found among the examined dead embryos ("exencephaly", 4 legs, "exencephaly + crossed beak") with the same frequency of manifestation of 33.3%. The level of genetic burden in this bird is low – 6.00%. Only 1 anomaly "exencephaly" was found in birds with mottled plumage. The level of genetic burden is minimal among the studied groups of meat and egg chickens – 3.45%.

In meat and egg chickens with silver plumage, two cases of the double mutation "exencephaly + shortened maxilla" and one "shortened maxilla" were found among the examined dead embryos. The frequency of manifestation of the first mutation was 66.7%, the second – 33.3%. The level of genetic burden in chickens of this group reached 8.57%, which is considered the maximum allowed, above which it is necessary to carry out breeding measures to eliminate lethal genes from the chicken population. It is worth noting that in chickens of different subpopulations, similarity in the spectrum of manifestation of hereditary embryonic developmental anomalies was noted. Thus, "exencephaly" was detected in chickens of all the studied populations, except for subpopulation C. The frequency of occurrence of this mutation is quite high – 20.0-100.0%. Embryos with a shortened maxilla were found in chickens with black-striped and silver plumage with a 20.0-33.3% frequency. Four legs were found in chickens of subpopulations G2 and G3 with a frequency of manifestation of 7.7-33.3%. The double mutation "exencephaly + crossed beak" was detected in birds with white and golden plumage with a frequency of 7.7-33.3%. The spectrum and frequency of hereditary genetic defects in embryo development in turkeys of the initial lines of the Kharkiv crossing are shown in Table 2.

***Table 2**. Frequency of occurrence (%) and spectrum of developmental anomalies of embryos in turkeys*

Anomalies	Line	
	Paternal 5	Maternal 6
"No beak"	50.0	–
"Giant eyes"	50.0	–
"Eye reduction"	–	50.0
"Exencephaly"	–	50.0
Number of examined dead-in-shell embryos, pcs.	106	125
The number of anomalies, pcs.	2	2
Level of genetic burden, %	1.89	1.60

In turkeys of the paternal line 5, among the examined dead-in-shell embryos, 2 morphological anomalies of embryo development were found – "no beak" and "giant eyes". These anomalies occurred with the same frequency – 50.0% each. The level of genetic burden in turkeys of the initial paternal line of the Kharkiv crossing is low – it is set at 1.89% (Fig. 2), not exceeding the maximum allowed value (8.0%). This does not pose a threat to this bird population. In turkeys of maternal line 6, among the examined dead-in-shell embryos with the same frequency of occurrence (50.0% each), 2 hereditary malformations were detected – "eye reduction" and "exencephaly". The level of genetic burden is generally insignificant at 1.60%.

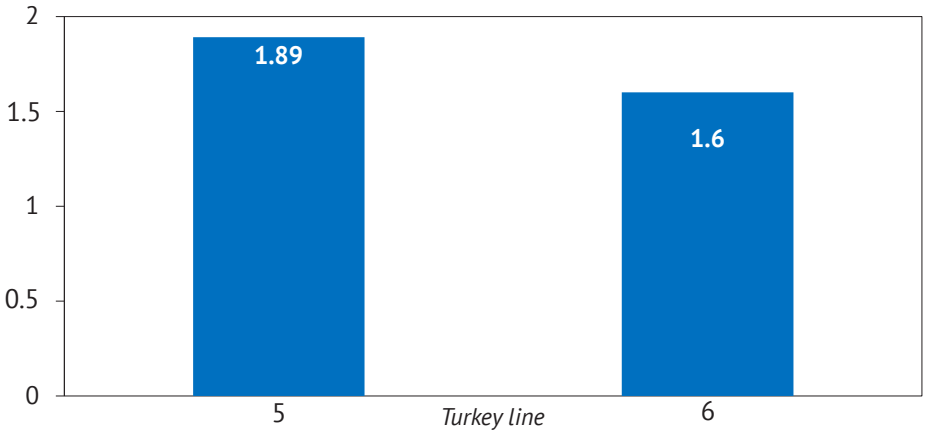

***Figure 2**. The level of genetic burden in the studied turkey lines, %*

Consequently, the established low level of genetic burden (1.60-1.89%) in turkeys of the initial related forms of the Ukrainian Kharkiv crossing indicates a low share in the heredity of the used breeders of hidden carriers of "defective" genes. At this stage, the preservation of the gene pool of birds is not threatening its further breeding. From the obtained experimental data, it can be concluded that breeding turkeys of each line "in itself" does not contribute to the accumulation and consolidation of "harmful genes" in their gene pool.

CONCLUSIONS

1. The widest range of morphological anomalies of embryo development was found in meat and egg chickens of subpopulations G1 and G2. The triple anomaly "exencephaly + crossed beak + 4 legs" was found with the predominant frequency in black-striped chickens (40.0%). White chickens most often had the "Donald Duck" anomaly (with a frequency of 53.8% among other detected defects).

2. In chickens of the G3 subpopulation, three anomalies were found among the examined dead embryos ("exencephaly", 4 legs, "exencephaly + crossed beak") with the same frequency of manifestation of 33.3%. Only 1 anomaly "exencephaly" was found in birds with mottled plumage. In meat and egg chickens with silver plumage, two cases of the double mutation "exencephaly + shortened maxilla" and one "shortened maxilla" were found among the examined dead embryos.

3. Among the studied subpopulations of meat and egg chickens of the Ukrainian gene pool, the lowest level of genetic burden (3.45%) was determined in the group of chickens with mottled plumage, while the highest (8.72%) was identified in white chickens.

4. In turkeys of the paternal line 5, among the examined dead-in-shell embryos, 2 morphological anomalies of embryo development were found – "no beak" and "giant eyes". Turkeys of maternal line 6 also had 2 hereditary malformations – "eye reduction" and "exencephaly".

5. In Turkeys of the initial Kharkiv crossing lines, the level of hereditary burden is low (1.60-1.89%), which is not of threatening importance for breeding poultry in closed populations.

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Спадковий тягар у сільськогосподарської птиці різних видів українського генофонду

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Анотація. Актуальність дослідження пов'язана з необхідністю постійно проводити патолого-анатомічний аналіз загиблих ембріонів як невід'ємної частини генетичного моніторингу шкідливих мутацій, завдяки чому можливе зниження рівня генетичного тягаря у генопулі сільськогосподарської птиці. Дослідження проведено на сільськогосподарській птиці різних видів українського генофонду: курях м'ясо-яєчного напряму продуктивності, індиках вихідних родинних ліній кросу Харківський. Метою роботи було визначити спектр і частоту прояву спадкових генетичних дефектів розвитку ембріонів у сухопутної птиці різних видів, встановити рівень генетичного тягаря. Спектр і частоту прояву морфологічних та анатомічних спадкових вад ембріонів курей та індиків встановлювали при патолого-анатомічному обстеженні відходів інкубації. При візуальному огляді загиблих ембріонів визначали морфологічні порушення у будові скелету, а також різні диспропорції окремих його частин. У курей субпопуляцій з чорно-смугастим і білим забарвленням оперення, серед птиці всіх досліджених груп, виявлено найширший спектр морфологічних аномалій розвитку ембріонів. У м'ясо-яєчних курей із золотистим забарвленням оперення серед обстежених загиблих ембріонів виявлено три аномалії з однаковою частотою прояву 33,3 %. У птиці з рябим забарвленням оперення виявлено лише 1 аномалію «екзенцефалія». У птиці зі сріблястим забарвленням оперення серед обстежених загиблих ембріонів виявлено два випадки подвійної мутації. Рівень генетичного тягаря у досліджених субпопуляціях м'ясо-яєчних курей знаходився у межах 3,45–8,72 %. У птиці із білим і сріблястим опереннням цей показник був вищим за максимально допустиме значення, тому необхідно здійснювати селекційні заходи щодо елімінації летальних генів з цих популяції курей. У індиків батьківської лінії 5 та материнської лінії 6 кросу Харківський серед обстежених завмерлих ембріонів виявлено по 2 морфологічні аномалії розвитку ембріонів. Рівень генетичного тягаря у індиків родинних форм невисокий – 1,60–1,89 %, що не перевищує максимально допустиме значення (8,0 %). Це свідчить про невисоку долю у спадковості використаних плідників прихованих носіїв «дефектних» генів. На цьому етапі збереження генофонду птиці не представляє загрозливого значення для її подальшого розведення

Ключові слова: м'ясо-яєчні кури, індики кросу Харківський, український генофонд птиці, аномалії, генетичний тягар

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Features of Protection of Row Crops Under Irrigation Conditions

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Abstract. Irrigation changes the ecological conditions of crop cultivation and modifies existing phytopathocenoses and entomocomplexes, having a complex and multi-vector impact, which requires significant changes in protection technologies, the development of new methods for controlling harmful organisms. It is important to select a modern range of chemicals that can be effectively used in chemicalisation. The purpose of the study was to identify promising active substances of pesticides for use in drip irrigation and develop schemes for their application. Field experiments to determine the effectiveness of certain groups of pesticides in drip irrigation were conducted in the conditions of the dry steppe of Ukraine. The studied preparations were applied on a drip irrigation system. To investigate the use of pesticides in drip irrigation, schemes were developed to protect row crops: corn, tomatoes and soybeans. The selected active ingredients, which are characterised by translaminar and acropetal movement through the plant, have a systemic nature of action and are highly effective when used in drip irrigation technologies. It was found that one of the significant disadvantages of applying plant protection products with irrigation water is the limitation of the time of application by irrigation modes. The highest effectiveness against the main pathogens was observed with the combined method of applying pesticides according to the developed schemes. This method involves the use of pesticides together with irrigation water and additional treatment with chemical preparations by conventional methods of application during the growing season. For its part, this method allows performing preventive treatments in a short time and adjust the treatment time depending on the phytosanitary situation

Keywords: drip irrigation, chemicalisation, corn, soybeans, tomatoes, pesticide efficiency, yield

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INTRODUCTION

In modern agriculture, irrigation systems are used not only for spreading water, but also for the application of fertilisers, insecticides, herbicides, fungicides, etc. The use of such technologies ensures even distribution and accurate placement of chemicals regardless of weather or field conditions, reduces the use of machinery, reduces soil compaction, and minimises operator contacts for mixing and dosing potentially hazardous materials. The cost of applying pesticides by pestigation is about one-third of the cost of conventional application methods [1].

In areas with long periods of draught, irrigation is the most important means of increasing crop productivity. It promotes the development of a denser herbage, changing the microclimate in the crop, reduces the temperature in the soil layer and increases the humidity and duration of leaf moisture, thus creating better conditions for the development of pathogens and contributing to their epiphytotic development. Irrigation affects the development of diseases by creating conditions that become more favourable for infecting plants, promotes sporulation and plays an important role in the spread of certain pathogens [1-3].

In accordance with the development of the disease, during irrigation, spores of the pathogen spread to neighbouring plants with water droplets, irrigation water, contributing to the development of epiphytotics. Plant pathogens identified from water resources include 17 species of the genus *Phytophthora*, 26 of the genus *Pythium*, 27 other genera of fungi, 8 types of bacteria, 10 viruses. Contaminated irrigation water is the main, if not the only, source of late blight inoculum for nursery gardens of fruit and vegetable crops [2-4]. In addition, irrigation promotes the development of diseases that require a warm, humid climate. In particular, the appearance of angular leaf spots, anthracnose, powdery mildew, fire blight of beans, black rot and melon anthracnose, fire blight of strawberries, late blight and bacterial diseases of tomatoes, black leg in cruciferous crops increases [4-10]. Irrigation also affects pests directly or indirectly. The use of water-charging irrigation allows regulating the number of soil pests, such as caterpillars, cut worms, bean aphids and others. The application of sprinkling irrigation contributes to the washing away and mass death of insect-like pests, namely aphids, leafhoppers, flea beetles. In addition, due to the improvement of the microclimate in plantings and optimisation of physiological processes in plants during irrigation, losses of the final crop due to damage by phytophages are minimised [11].

Changes in the soil moisture regime promote the development of leaf diseases and root rot, contribute to the spread of hygrophilic pest species, such as wireworms, corn borers, leaf aphids, ground beetles, grass sawflies. At the same time, there is a decrease in the number of locusts, bread beetles, and turtle beetles, which belong to xerophilous pest species. Therefore, by conducting irrigation by various methods, it is possible to directly or indirectly influence the number of different groups of phytophages and minimise their harmfulness on agricultural crops [2; 11]. Consequently, irrigation not only changes the ecological conditions of crop cultivation, but also modifies existing phytopathocenoses and entomocomplexes, while having a complex and multi-vector impact, which requires significant changes in protection technologies, the development of new methods for controlling harmful organisms. At the same time, the toxic load on the environment and humans is reduced, due to the fact that pesticides in drip irrigation conditions dissolve in water better than with conventional technologies. Therefore, the drift of the irrigation mixture to other non-target zones has a less toxic effect, and therefore, less pollutes the environment [12].

In particular, the use of such technologies significantly increases the production of vegetable products and reduces their cost. The use of herbicides together with irrigation water is usually effective for weed control, namely in the zone of moistening with irrigation water. Consequently, herbigation through irrigation systems is particularly effective in conditions of insufficient moisture. The movement of herbicides used in irrigation systems mainly depends on solubility, absorption, and volatility [13].

To date, the AEPA (American Environmental Protection Agency) has registered a large number of insecticides for use in drip irrigation on many crops. Their use together with irrigation water for drip irrigation provides more effective control of insect pests, compared to traditional leaf treatment, because due to root absorption, the drug is more evenly distributed throughout the plant. For vegetable crops, 1-2 single applications of insecticides by pestigation provide effectiveness at the level of several treatments by conventional methods. It was found that a single injection of chlorantraniliprole through a drip system was responsible for the effectiveness of 4 foliar treatments with lambda-cyhalothrin pyrethroid to control caterpillars that damage tomatoes [12]. G. Gidiou, T. Kuhar, J. Palumbo, D. Schuster [14] showed that 2 injections of chlorantraniliprole into the drip irrigation system had the same effectiveness as 7 standard leaf treatments, which amounted to 2 treatments with acephate (Orthene 97; United Phosphorus, Inc., Kingdom of Prussia, Pennsylvania) and 5 treatments

with indoxacarb (Avaunt 30WDG; EI DuPont de Nemours, Inc., Wilmington, Delaware) to control the corn worms on bell peppers.

Fungigation is a common practice for controlling fungal diseases in regions where irrigated agriculture is widely used. In closed irrigation systems, fungigation is most often limited to the use of systemic fungicides to control soil pathogens. However, to control diseases affecting aboveground parts, I. Katz, A. Cunha, A. Sousa, and E. Herdani [15] showed that the use of fungigation can effectively reduce the development of grey rot on ornamental plants. J. Araujo, E. Furtado, H. Filho, and A. Lombardi [16] found that the introduction of fungicides with irrigation water during drip irrigation effectively protects tomatoes from diseases. Thus, the selection of a modern range of chemicals that can be effectively used in chemisation against certain harmful organisms is now one of the most relevant areas of drip irrigation and requires studies in different soil and climatic zones of Ukraine.

The purpose of the study is to identify promising active substances of pesticides for use in drip irrigation and develop schemes for their application.

MATERIALS AND METHODS

Field experiments to determine the effectiveness of the use of certain groups of pesticides in drip irrigation were conducted during 2017-2018 in the conditions of the dry steppe of Ukraine at experimental sites in SE "DH Brylivske" of the Institute of Water Problems and Land Reclamation of NAAS of Ukraine. Soil characteristics of the experimental site: dark chestnut sandy loams, humus content 1.24-1.63% (low humus), ph 5.8 (reaction close to neutral). The application of the studied preparations took place on a drip irrigation system, a multi-year irrigation pipeline of the Panplast FL 16 mills type, the level of pre-irrigation humidity – 85-75% of the lowest soil moisture capacity by crop development phases. The introduction of pesticides in the conventional way was carried out using a knapsack motor sprayer Oleo-Mac AM190. Working fluid consumption is 350 l/ha.

Tillage and technology of growing experimental crops are generally accepted for drip irrigation conditions in the dry steppe subzone of Ukraine. Drip irrigation schemes were developed to investigate the use of pesticides to protect row crops: corn, tomatoes and soybeans. The weather conditions of the growing seasons 2017-2018 were relatively favourable for the growth and development of experimental plants, and the lack of moisture reserves in the soil was compensated by drip irrigation (Table 1). During the growing season of corn, tomatoes, and soybeans, the average temperature was higher by +1.84^{0}C (2017) and +3.3^{0}C (2018), and productive precipitation was received almost 2.0 times less or -105.2 mm (2017) and +3.7 mm (2018).

Weeds were counted on fixed model sites with a size of 1 m^2 (100x100 cm). Repetition – 4 times. Records of the effectiveness of herbicides at the experimental sites were carried out 14 days and 28 days after the introduction of drugs. The ground mass of annual gramineous and dicotyledonous weeds was determined on the 28th day after treatment. The effectiveness of insecticides and fungicides was studied at experimental sites with a size of 100 m^2 (10x10 m), the placement is randomised in four repetitions [17]. The calculation to determine the effectiveness of fungicides were carried out before the first treatment; 10 days after the first treatment; before the second treatment; 10 days after the second treatment. The number of registered plants – 10 pcs. in four repetitions. The development and spread of diseases were determined at the experimental site.

Table 1. *Characteristics of weather conditions of the growing season 2017-2018 (Khersonska Oblast, Oleshkivskyi district, Pryvitne village (SE "DH Brylivske" IWPLR NAAS)*

Main indicators	Vegetative season 2017, months						
	April	May	June	July	August	September (I-II ten-day intervals)	Total for vegetation period
Air temperature, ^{0}C a) long-time annual average	10.8	15.8	20.2	20.8	21.9	16.6	17.68
b) in 2017	10.1	14.9	21.7	23.5	25.1	21.8	19.52
Precipitation, mm a) long-time annual average	28	38	46	40	33	28	213.0
b) in 2017	9	44	22.2	32.6	0	0	107.8

Table 1, Continued

Main indicators	Vegetative season 2017, months						
	April	May	June	July	August	September (I-II ten-day intervals)	Total for vegetation period
Air humidity, % a) long-time annual average	71	68	64	60	54	66	63.83
b) in 2017	70.0	65.2	64.1	59.5	52.2	59.1	61.68
Main indicators	**Vegetative season 2018, months**						
	April	May	June	July	August	September (I-II ten-day intervals)	Total for vegetation period
Air temperature, ^{0}C a) long-time annual average	10.8	15.8	20.2	20.8	21.9	16.6	17.7
b) in 2018	15.2	19.5	21.9	22.9	25.5	21.0	21.0
Precipitation, mm a) long-time annual average	28	38	46	40	33	28	213.0
b) in 2018	0.0	12.8	8.2	112.1	62.0	15.6	216.7
Air humidity, % a) long-time annual average	71	68	64	60	54	66	63.8
b) in 2018	52	47	45	54	44	67	51.5

Studies of the effectiveness of protection systems were conducted on corn plant hybrids DKS 5276. Sowing scheme – 70+70x15 cm, plant density – 95.24 ths. pcs/ha. Irrigation of plots was carried out by drip irrigation, the level of pre-irrigation humidity – 85-90% of the lowest moisture capacity of the root-bearing soil layer (layer – 0-75 cm). In total, 29 vegetation irrigations were carried out during the growing season of corn with a rate of 135 to 165 g^3/ha (irrigation rate = 4,400 m^3/ha). The timing of vegetation irrigation was determined by the strain gauge method. Chemical protection of corn at the experimental site was carried out according to the scheme presented in Table 2.

***Table 2**. System of chemical protection of corn at the experimental sites in SE "DH Brylivske" IWPLR NAAS*

Vegetative stage on the BBCH-scale*	Object	Active ingredient	Consumption rate, l/ha
00	Annual dicotyledonous and gramineous weeds	Pendimethalin, 330 g/l	3.0-6.0
00	Annual gramineous and some annual dicotyledonous weeds	S-metolachlor, 960 g/l	1.0-1.6
00	Annual gramineous and dicotyledonous weeds	Acetochlor, 900 g/l	1.5-3.0
51-53; 60-61	European corn borer	Imidacloprid, 150 g/l+lambda-cyhalothrin, 50 g/l	0.12-0.14
16-18; 39-42	Fusarium, stem rust, helminthosporiosis	Pyraclostrobin, 62.5 g/l+epoxiconazole, 62.5 g/l	1.5-1.75
16-18; 39-42	Fusarium, stem rust, helminthosporiosis	Azoxystrobin 120 g/l+tebuconazole 200 g/l	1.0-1.2

***Note**: * – European coding system for phenologically similar development stages of all monocotyledonous and dicotyledonous plant species (BBCH-scale) [18]*

The objects of study were: beet moth (*Loxostege sticticalis*) and European com borer (*Ostrinia nubilalis Hb.*). The caterpillars were counted once in 2 days visually and by shaking each plant on a white gauze cloth. In addition, the calculation was carried out by counting wormholes in the stems, damaged stems were opened along and caterpillar records were made. The number of registered plants – 10 pcs. in four repetitions.

The objects of study of the effectiveness of fungicides were: helminthosporiosis (*Helminthosporium spp.*), fusarium (*Fusarium spp.*), stem rust (*Puccinia sorghi*). Studies of the effectiveness of soybean crop protection systems were conducted on the Oksana variety. Scheme of sowing on experimental plots 15+15x11 cm, plant density – 605-610 ths. pcs/ha. Irrigation of plots was carried out by drip irrigation, the level of pre-irrigation humidity – 90-80% of the lowest moisture capacity of the root-bearing soil layer (layer – 0-30 cm; 0-40 cm – according to the phases of plant development). In total, 35 vegetation irrigations were carried out during the growing season of soybean with a rate of 120 to 149 m^3/ha (irrigation rate = 4,650 m^3/ha). The timing of vegetation irrigation was determined by the strain gauge method.

The system of chemical protection measures for soybeans is shown in Table 3.

***Table 3**. System of chemical protection of soybean at the experimental sites in SE "DH Brylivske" IWPLR NAAS*

Vegetative stage on the BBCH-scale*	Object	Active ingredient	Consumption rate, l/ha
00	Annual gramineous and dicotyledonous weeds	Acetochlor, 900 g/l	1.5-3.0
00	Annual dicotyledonous and gramineous weeds	Pendimethalin, 330 g/l	3.0-6.0
00	Annual gramineous and some annual dicotyledonous weeds	S-metolachlor, 960 g/l	1.0-2.0
51-53; 60-61	Bean pod borer, tobacco thrips	Imidacloprid, 200 g/l	0.2-0.25
51-53; 60-62	Powdery mildew, stem rust, septoria, anthracnose	Pyraclostrobin, 62.5 g/l+epoxiconazole, 62.5 g/l	1.5
51-53; 60-62	Powdery mildew, stem rust, septoria, anthracnose	Azoxystrobin 120 g/l+tebuconazole 200 g/l	1.0-1.2

***Note**: * – European coding system for phenologically similar development stages of all monocotyledonous and dicotyledonous plant species (BBCH-scale) [18]*

The objects of study of the effectiveness of insecticides were: bean pod borer (*Etiella zinckenella*), tobacco thrips (*Thrips tabaci*). Caterpillars *Etiella zinckenella* were counted in the BBCH phase 51-53. Thrips *Thrips tabaci* were counted by visual examination of soybean plants. The objects of the study to determine the effectiveness of fungicides were: powdery mildew (*Erysiphe communis f. glycine*), stem rust (*Uromyces sojae*) septoria (*Septoria glycines*), anthracnose (*Colletotrichum glycines*).

Herbicides were tested on tomato plants of the Lampo F1 hybrid. Scheme of planting tomato plants – 152+152x20 cm, plant density – 32.89 ths. pcs/ha. Irrigation of plots was carried out by drip irrigation, the level of pre-irrigation humidity – 80-90-75% of the lowest moisture capacity of the root-bearing soil layer (0.20-0.30-0.35 m by phases of plant development). In total, 36 vegetation irrigations were carried out during the growing season with a rate of 80 to 130 m^3/ha (irrigation rate = 3,700 m^3/ha). The timing of vegetation irrigation was determined by the strain gauge method. The system of chemical protection measures for tomatoes at the experimental site is shown in Table 4.

***Table 4**. System of chemical protection of tomatoes at experimental sites in SE "DH Brylivske" IWPLR NAAS*

Vegetative stage on the BBCH-scale*	Object	Active ingredient	Consumption rate, l/ha
00	Annual dicotyledonous and gramineous weeds	Pendimethalin, 330 g/l	3.0-6.0
00	Annual gramineous and some annual dicotyledonous weeds	S-metolachlor, 960 g/l	1.0-2.0
19-22; 30-34	Colorado potato beetle, tomato and melon aphids	Imidacloprid, 200 g/l	0.2-0.25

Table 4, Continued

Vegetative stage on the BBCH-scale*	Object	Active ingredient	Consumption rate, l/ha
19-22; 30-34	Colorado potato beetle, tomato and melon aphids	Thiamethoxam, 240 g/l	0.07-0.09
19-23; 51-53	Late blight, Alternaria blight, septoria	Pyraclostrobin, 50 g/kg+metyram, 550 g/kg	2.0
19-23; 51-53	Late blight, Alternaria blight, septoria	Azoxystrobin, 250 g/l	0.6

***Note**: * – European coding system for phenologically similar development stages of all monocotyledonous and dicotyledonous plant species (BBCH-scale) [18]*

The objects of research on the effectiveness of insecticides were: Colorado potato beetle (*Leptinotarsa decemlineata*), aphids (*Aphidoidea*). Pest records were carried out at the stages of larval, adult, and reproductive stages of insect development. Accounting for the number of Colorado potato beetles (*Leptinotarsa decemlineata*) was carried out per one tomato bush, the economic threshold of harmfulness is 10% of the bushes inhabited by adults and larvae with a number of more than 10 individuals per tomato bush. Accounting for the number of tomato (*Macrosiphum euphorbiae*) and melon aphids (*Aphis gossypii*) was carried out per 100 leaves of tomato plants, the economic threshold of harmfulness is 10 individuals per 100 leaves of tomato plants. The objects of study on the effectiveness of fungicides were the pathogens of late blight diseases (*Phytophthora infestans*), alternariosis (*Alternaria solani*), septoria (*Septoria lycopersici*).

RESULTS AND DISCUSSION

Technologies for the use of pesticides in drip irrigation involve the use of chemical components that are characterised by translaminar and acropetal movement through the plant and have a systemic nature of the action. As a result of the analysis of literature sources [13-16], the following active substances were selected according to the mechanism of action on harmful organisms (Table 5).

***Table 5**. Active substances of pesticides promising for use with drip irrigation*

Insecticides	Fungicides	Herbicides
Chlorpyrifos	Azoxystrobin	Bromoxanil
Zeta-cypermethrin	Pyraclostrobin	Acifluorfen
Methyl parathion	Fluopyram	Lactofen
Gamma-cyhalorin	Boscalid	Atrazine
Karbofuran	Fluoxystrobin	Chlorosulfuron
Acetamiprid	Chlorothalonyl	
Flonicamide	Copper sulphate	
Imidacloprid	Ciproconazole	
Thiamotoxam	Methyl thiophanate	
Spinosad	*Bacillus pumulis* (Ballad PLUS preparation)	
Permethrin	*Bacillus subtilis* QST 713 strain (Serenade ASO preparation)	
Esphenvalerate		
Cyflutrin		
Bifentrin		
Lambda-cyhalothrin		

***Source**: compiled by the authors based on analytical data [13-16]*

As evidenced by previous studies, on vegetable crops, in particular carrots and onions, the use of fungicides of strobilurins and triazoles groups is most effective against a complex of diseases [19]. It was found that fungicides of the strobilurin group not only reliably protect crops from a complex of diseases and preserve a significant share of the crop, but are also cost-effective, and also have a pronounced physiological effect,

which consists in more active use of nitrogen by plants and countering adverse environmental factors. Thus, in carrot crops, the use of mixtures of fungicides Signum VG and Skor 250 EC reduced the development of alternariosis by 93%, powdery mildew – by 60%, under this condition, the yield increased by 49%, and the yield of marketable products – by 30%. It is shown that under irrigation conditions, the optimal time for treatment against fungal diseases of onion, carrot, and soy leaves is the period of appearance of the first symptoms of the disease. Pathogen detection and monitoring, and biological and economic thresholds, are essential tools for integrated protection and should be a priority in future research. Experiments should be conducted in combination with the introduction of pesticides in a coordinated and integrated approach, since they are interrelated components.

Studies were conducted in 2017, involving the following factors: various options for applying soil herbicides, systemic fungicides and insecticides, doses of applying plant protection products to improve the technology of applying pesticides under drip irrigation conditions, which would allow using the full potential of drip irrigation methods for row crops. The conducted studies of the effectiveness of herbicides have shown that preparations with the active substance S-metolachlor (960 g/l) with consumption rates of 1.0 and 1.6 l/ha are the most promising in irrigation conditions against monocotyledonous annual weeds and show low phytotoxicity on row crops with a consumption rate of 1.0 l/ha and an average phytotoxicity of up to 4 points with a consumption rate of 2.0 l/ha.

It was found that the introduction of herbicides with active substances acetochlor (900 g/l) with consumption rates of 1.5 and 3.0 l/ha and pendimethalin (330 g/l) with consumption rates of 3.0 and 6.0 l/ha with irrigation water has certain disadvantages: weak drift over the entire area of sowing and phytotoxicity for cultivated plants. On corn, with irrigation water and using traditional application technology, insecticides with active ingredients imidacloprid, 150 g/l+lambda-cyhalothrin, 50 g/l with consumption rates of 0.12 and 0.14 l/ha provided an effective action against stem moth in the range of 75.3-84.7%. On soybeans and tomatoes, preparations with the active substance imidacloprid, 200 g/l with consumption rates of 0.2 and 0.25 l/ha had an effectiveness of 69.8-83.2% and 67.9-82.7%, respectively. On tomatoes, a higher efficiency was noted during treatment with thiamethoxam, 240 g/l (consumption rates of 0.07-0.09 l/ha) – 67.1-86.6%. Phytotoxicity was not observed. Fungicides with active ingredients pyraclostrobin, 62.5 g/l+epoxiconazole, 62.5 g/l with consumption rates of 1.5 and 1.75 l/ha and azoxystrobin 120 g/l+tebuconazole 200 g/l with consumption rates of 1.0 l/ha and 1.2 l/ha on corn showed high effectiveness against pathogens of fusarium and helminthosporiosis. At the experimental soybean sites, these drugs also showed good effectiveness of 60.9% and 70.3%, respectively, against septoria at maximum consumption rates. When applying the fungicides pyraclostrobin, 50 g/kg+metyram, 550 g/kg (consumption rate 2.0 l/ha) and azoxystrobin, 250 g/l (consumption rate 0.6 l/ha) with irrigation water, their sufficiently high technical effectiveness against pathogens of late blight (48.6% and 50.8%) and alternary fungus (42.7% and 47.3%) was established on tomatoes that were grown by seedling method and phytotoxicity was not detected.

The results obtained showed that one of the significant disadvantages of applying plant protection products with irrigation water is the limitation of the application time by irrigation regimes. Therefore, a combined scheme for the protection of row crops was applied, which provides for preventive treatment in a short time by conventional methods, depending on the phytosanitary situation of crops (Table 6). The results of the analysis of the final crop of experimental plots showed that the greatest effectiveness against the main pathogens on corn, tomatoes, and soybeans was observed with the combined method of applying pesticides according to the developed schemes. The use of this method of application provided an increase in yield in the range of 3-4% compared to other methods of application due to the share of the preserved crop (Table 7).

***Table 6**. Systems of protection of row crops (Khersonska Oblast, Oleshkivskyi district, Pryvitne village (SE "DH Brylivske" IWPLR NAAS, 2018)*

Crop	Conventional	Pestigation	Combined
Corn Soybean Tomatoes	Soil herbicides Systemic and contact insecticides Systemic and contact fungicides	Soil herbicides Systemic insecticides Systemic fungicides	Soil herbicides: conventional pestigation Insecticides: conventional+pestigation Fungicides: conventional+pestigation

***Table 7**. Influence of various systems of protection of row crops on yield (Khersonska Oblast, Oleshkivskyi district, Pryvitne village (SE "DH Brylivske" IWPLR NAAS, 2018)*

Crop	Protection system	Yield, t/ha	Increase in yield, %
Corn	Control	14.65	–
	Conventional	18.49	27.0
	Pestigation	18.26	25.4
	Combined	18.76	28.8
Soybean	Control	4.84	–
	Conventional	5.96	23.1
	Pestigation	5.67	17.1
	Combined	6.12	26.4
Tomatoes	Control	72.61	–
	Conventional	96.38	32.7
	Pestigation	95.23	31.2
	Combined	98.81	36.1

Thus, the combined scheme of protection of row crops would allow producers to use pesticides more effectively by pestigation and expand the range of effective preparations that are applied by spraying if additional crop treatments are needed.

CONCLUSIONS

Studies of the effectiveness of applying herbicides with irrigation water have shown that preparations with the active substance S-metolachlor (960 g/l) and consumption rates of 1.0 and 1.6 l/ha are the most promising in irrigation conditions against monocotyledonous annual weeds and show low phytotoxicity on row crops. Significant effectiveness against stem moth on corn was found in insecticides with active substances imidacloprid, 150 g/l+lambda-cyhalothrin, 50 g/l with consumption rates of 0.12 and 0.14 l/ha in the range of 75.3-84.7%. On soybeans and tomatoes – preparations with the active substance imidacloprid, 200 g/l (consumption rates of 0.2-0.25 l/ha). On tomatoes, the greatest effectiveness against the Colorado potato beetle and aphids was found when applying thiamethoxam with irrigation water, 240 g/l (consumption rates of 0.07-0.09 l/ha). High effectiveness against pathogens of fusarium and helminthosporiosis of corn was observed when pyraclostrobin, 62.5 g/l+epoxiconazole, 62.5 g/l (consumption rate 1.5-1.75 l/ha) and azoxystrobin 120 g/l+tebuconazole 200 g/l (consumption rate 1.0-1.2 l/ha) were applied with irrigation water. These drugs also showed good effectiveness on soybeans against septoria at maximum consumption rates. On tomatoes, the fungicides pyraclostrobin, 50 g/kg+ metyram, 550 g/kg (consumption rate 2.0 l/ha) and azoxystrobin, 250 g/l (consumption rate 0.6 l/ha) were found to have a fairly high technical efficiency against pathogens of late blight and alternariosis.

As a result of the conducted experiments, it was established that one of the significant disadvantages of the pestigation method is the limitation of the time of application of plant protection products by irrigation regimes. The tested combined scheme of protection of row crops, which provides for preventive treatments in a short time by traditional methods, depending on the phytosanitary situation of crops, the use of this method of application provided a yield increase of 3-4% compared to other methods. Therefore, further studies on improving the method of pestigation on row crops should be aimed at optimising and developing the combined application of plant protection products depending on changes in the phytosanitary condition of crops.

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Особливості захисту просапних культур в умовах зрошення

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Анотація. Зрошення не тільки змінює екологічні умови вирощування культури, але й модифікує наявні фітопатоценози й ентомокомплекси, справляючи комплексний і різновекторний вплив, що потребує істотних змін у технологіях захисту, розробки нових методів контролю шкідливих організмів. Важливим є добір сучасного асортименту хімічних речовин, які можливо ефективно використовувати у хімізації. Метою досліджень було визначити перспективні для застосування за краплинного зрошення діючі речовини пестицидів і розробити схеми їх внесення. Польові досліди щодо визначення ефективності використання певних груп пестицидів за краплинного зрошення проводились в умовах Сухого Степу України. Внесення досліджуваних препаратів відбувалось на системі краплинного зрошення. Для планування досліджень із використання пестицидів за краплинного зрошення були розроблені схеми для захисту просапних культур: кукурудзи, томатів і сої. Відібрані діючі речовини, які характеризуються трансламінарним та акропетальним рухом по рослині, мають системний характер дії і високоефективні під час застосування у технологіях краплинного зрошення. Розглянуто, що одним із вагомих недоліків внесення засобів захисту рослин із поливною водою є обмеження строків внесення поливними режимами. Найвища ефективність проти основних патогенів спостерігалась при комбінованому способі внесення пестицидів згідно з розробленими схемами. Такий спосіб передбачає застосування пестицидів разом із поливною водою та додаткову обробку хімічними препаратами традиційними методами внесення упродовж вегетації. Зі свого боку це дозволяє провести профілактичні обробки у стислі терміни та корегувати терміни обробок залежно від фітосанітарної ситуації

Ключові слова: краплинне зрошення, хімізація, кукурудза, соя, томати, ефективність пестицидів, врожайність

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Violation of the Structure of the Forest Biocenosis Under the Action of Stem Pests and Methods of Controlling Their Numbers

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Abstract. The study of the forest ecosystem as an integral part of the erosion preventive system is related to a number of issues. The forest is the most powerful and effective tool in the prevention of soil erosion, droughts, and hot winds, as well as an environmental stabilising factor in general. Human forestry activities in the fight against the drying of coniferous plantations from an outbreak of mass reproduction and spread to large areas of stem pests under the influence of a complex of ecological and climatic factors, is one of the serious factors disrupting the structure of the forest biocenosis. The search for alternative solutions to the localisation of this problem requires a detailed study of the behaviour of the most common bark beetles of coniferous trees in climatic and environmental conditions that developed during 2011-2020. During the period of active temperatures in 2019, namely from the second decade of April to the third decade of October, work on stationary supervision and laboratory field work was carried out to solve the problem of localisation of stem pests of Polissya and Forest-steppe pine plantations. Methods of laying out trap trees and pheromone traps were used. In practice, the pest did not inhabit trap trees and only a few representatives in very small numbers and entomophages fell into traps. Instead, it inhabited healthy trees where the catchers were located. It was established that from the scientific and practical standpoint, the studied regularity of pine drying centres is clearly confined to highways and timber roads, as well as the area of distribution of relevant species of stem pests and weakening zones of pine stands in some areas for other reasons. It is proved that to preserve the ecological potential of coniferous plantations and reduce the negative impact of xylophagous insects, it is necessary to design preventive and biological methods of control of the main stem pests of coniferous trees

Keywords: entomophages, coniferous plantations, stationary supervision, pheromone monitoring, Polissya, Forest-steppe

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INTRODUCTION

Scientists seek to solve the problem of pine engraver beetle foci on coniferous plantings, but for millions of years of its existence and constant development, nature has created its own strategies for anatomical and chemical protection [1-6] and methods of controlling to maintain the balance of its processes [1; 7-9]. People always interfere and disrupt this balance by creating artificial plantings to meet their own needs. Ecological and climatic factors [2; 3] contribute to mass reproduction and, as a result, to an increase in the population of harmful insects. For their part, coniferous plantations, weakened due to high temperatures and other important factors, are subject to destructive effects and, as a result, are a good food base for coniferous pests. Controlling stem pests of coniferous plantations is one of the important aspects of preserving their ecological potential.

During 2018, in the forest stands of the Polissya zone, namely Zhytomyr Regional Department of Forestry and Hunting (hereinafter – Zhytomyr RDFH) foci of Ips engraver beetle were found on an area of 28.8 thousand hectares. Due to the pressure of natural factors regulating the pest population (entomophage activity, improvement of climatic and hydrological conditions of common pine growth, etc.) and measures taken to improve the sanitary condition at the beginning of 2019, the area of plantings damaged by bark beetle in Zhytomyr RDFH decreased to 5.8 thousand hectares or by 7.2 times compared to 2017 [10-12].

As is shown in the analysis of mensurational characteristics of pine stands that died as a result of damage by stem pests of the bark beetle family and were eliminated by continuous sanitary cutting, high-quality pine stands of 60-120 years old that grew in fresh conditions (B2, C2) are most damaged. The general trend in age is the inability of the root system of premature and mature pine stands to transform (adapt) under changing climatic factors [10-13]. The situation that has developed with the drying of pine stands in the region can lead to such negative changes in forestry [14-17]:

– reduction of cutting volumes of developing forest stands;

– reduction of the overall density of forest stands;

– provided that the trend of drying continues, the age structure of stands will change with a further decrease in the volume of estimated felling.

The problem of mass drying of coniferous plantations caused by stem pests has a global nature [7; 18; 19]. The study of the features of damage by coniferous pests, the dynamics of their number and dissemination of species has been covered in a number of scientific publications of both Ukrainian and foreign experts in this field. In particular, by V.L. Meshkova [20], M.M. Padiy [13], M.M. Rimsky-Korsakov [21], P.A. Gaichenya [22], E.G. Mozolevska [23], B.J. Benz [21], R. Linakowski [24], E. Christiansen [25], B. Vermelinger [26], Y. Yamaoka [27], J. Muller [28], J.A. Byers [29; 30], T. Noma [31]. Foreign scientists' studies on this issue are the result of a deep study of features of the development and reproduction of stem pests on coniferous trees against the background of modern ecological and climatic changes [32].

To preserve the ecological potential of coniferous plantations and determine methods of controlling stem pests, it is necessary to study in more detail the features of populations of this group of pests, their dissemination, behaviour, and nutrition features of imago of different generations based on the results of stationary monitoring, pheromone monitoring of pests and their natural enemies.

The main objectives of this paper are:

1) study of the development features of bark beetle pest populations, their dissemination, behaviour, and nutrition features of imago of different generations;

2) pheromone monitoring analysis of pests on coniferous trees (*Ips accuminatus, Blastophagus minor, Ips sexdentatus, Ips typographus*) and their natural enemies within Polissya and Forest-steppe;

3) study of the reasons for the expansion of the harmful insects' food base;

4) design of preventive methods and methods of controlling the main stem pests of coniferous trees to preserve their ecological potential.

The purpose of the study is the development and scientific substantiation of strategic methods for controlling the main stem pests of coniferous trees in order to preserve their ecological potential.

MATERIALS AND METHODS

To substantiate the features of the development of bark beetle populations, obtain objective quantitative data reflecting the state of damaged plantings and the dynamics of the pest population, methods of exploratory forest pathological examination, stationary monitoring, and detailed forest pathological examination of stem pest foci were used [33]. Ground exploratory (visual) survey is carried out along computation lines (clearances, forest roads and trails, and sometimes route lines that are set by compass in such a way as to enter all sections with the advantage of the main forest-forming species). All areas, the damage of which is reported in forestry, are also inspected, in particular: in forest management materials; in the record book of pests and diseases, in alarm sheets and the acts of their inspections which are formed by forestries, informing about the emergence of

the pests and diseases foci in the forest; in the acts of surveys for the current and previous years, their results; in cartographic materials characterising the sanitary condition of plantations, the spread of pests and diseases, forest protection measures and their effectiveness; in materials of the autumn inventory. Computation lines and detected foci of pests and diseases are plotted to the duplication of the forest plantation plan. The results of the survey enter the journal of forest pathologies.

Stem pests are also divided into two phenological groups according to the time of a forest stand attack or unprotected products: spring and summer. Among the most common stem pests, the spring group includes lesser pine shoot beetle, Ips engraver beetle, six-toothed bark beetle, spruce bark beetle. The summer phenological group consists of secondary and related generations of the Ips engraver beetle, six-toothed bark beetle, spruce bark beetle. Detailed monitoring is carried out from the moment of detection of an outbreak of mass reproduction to its complete attenuation due to the death or improvement of plantings. Detailed control of stem pests is divided into two stages:

1) accounting for the condition of plantings and current pathological decline;

2) accounting for the number and state of populations of the most important harmful insects.

When determining the phase of the focus, the researchers were guided by the ratio of trees of different state categories, the amount of current pathological loss and the number of stem pests, comparing them with the same indicators inherent in a healthy forest. With detailed supervision, biological control is carried out over the development and overall survival of individual most dangerous pest species, for which data from the analysis of model trees, current surveys are used, control trap trees are laid out, or beetle catch data is evaluated with pheromone traps. Especially dangerous is the second generation of spruce bark beetle, six-toothed bark beetle, Ips engraver beetle, and others.

The use of pheromones for monitoring is advisable in the general system for detecting foci of forest stem pests and monitoring their development. Since pheromones are biologically active substances, there is a danger of provoking the emergence of new foci. They should be used strictly in accordance with the instructions, recommendations of manuals, and under the strict control of the Forest Pathology Service. During laboratory and field studies, to determine the concentration of bark beetles and emergence periods during the growing season of 2019 (from April to October), the method of "trap (model) trees" and laying out "pheromone traps" IBL-3 (Ipsodor pheromone dispenser) was used. During the application of these methods, mass collection of material in the form of pest imagos and entomophages was carried out, which led to partial localisation of the focus in the study area.

RESULTS AND DISCUSSION

Features of the development of bark beetle foci

During the survey of spruce and pine stands in Polissya and Forest-steppe, it was identified that recently they have been functioning in radically changed forest-growing conditions, as evidenced by the analysis of a complex of characteristics of habitats and the actual state of vegetation. During field work, certain patterns of distribution and development of foci have also been established. In the vast majority of cases, drying spreads from the focus in the northern and western directions. The first younger generation is quite healthy and strong, which allows it to spread over a long distance (from 3 to 30 km). Due to this, it is impossible to predict the territory of dissemination of the population (Fig. 1).

Figure 1. *Drying of pine stands damaged by Ips engraver beetle*

The second younger generation is somewhat weaker and usually inhabits adjacent plantings. It was established that in the vast majority of cases, the spread of the focus mostly coincides with the western and northern directions (up to 30-40 m from the wall of an existing focus), in the eastern and southern directions it is less frequent and less intense (up to 5-10 m) [10-12; 32; 34-35].

The zone of active dissemination of the focus is characterised by the predominance of trees of the third-fourth state categories, the crown of which is at the initial stage of drying and is characterised by a change in the colour of the needle-foliage (blanching of colour intensity, flavescence), branch fall and "shorn shoots" under the crowns of trees, frass on the stems of freshly populated trees as a result of the vital activity of the Ips engraver beetle and pine shoot beetle, as well as frass of spruce bark beetle in the spruce stands [10-12; 32-35].

A branch fall in the area of active focus dissemination under the projection of the crown of freshly populated trees and Ips engraver beetle imago present in it indicates a high concentration of the pest in the plantings. The identified feature should be taken into account by forest protection workers during the examination and planning of appropriate sanitary and health measures (Fig. 2).

Figure 2. *Branch fall in the zone of active focus dissemination under the projection of the crown of freshly populated trees and Ips engraver beetle imago present in it*

Features of development of Ips engraver beetle foci:

1. Ips engraver beetle and other stem pests are in constant symbiosis with a number of pathogenic fungi [36], which, getting into the wood tissues of living trees, lead to their drying out and a rapid decrease in the commercial quality of wood. That is, in addition to irreversible environmental losses, forestry and the state suffer large material losses.

2. The process of pine stands drying does not stop, so it is gaining signs of an ecological disaster. According to forecasts of scientists, forest protection specialists, and foresters, the area of damaged plantings will only increase in the coming years. This is confirmed by the results of analysis of forest pathological examinations and entomological samples for determining quantitative and qualitative indicators of populations of such stem pests: Ips engraver beetle, six-toothed bark beetle, lesser pine shoot beetle in pine forest stands of Zhytomyr, Khmelnitsky, and Vinnytsia regions.

3. One of the main criteria for assessing the qualitative state of the stem pest population is the reproduction energy, which makes it possible to characterise the dynamics of development and spread of stem pest foci. Thus, according to the authors' own analysis of model trees, the reproduction energy of the Ips engraver beetle ranges from 1.4 (average) to 2.3 (strong) in the spring and summer period. In the autumn and winter period, it averaged up to 1.9, which corresponds to an average degree and allows stating that at the time of the examination, the foci of this type of pest have certain signs of decreasing activity. Additionally, this fact is confirmed by the average length of the collective feeding tunnels. Thus, if in previous years the average length was from 12 to 16 cm, in some places up to 20 cm, already at the end of 2018, the average length decreased to 4-6 cm (short tunnels), which allows talking about a decrease in the fertility of females. There is also a certain decrease in the number of females per 1 mating chamber – from 8-12 pcs. in previous years, up to 4-6 pcs. at the end of 2018. In general, these are favourable signs of a decrease in

quantitative and qualitative indicators of Ips engraver beetle populations. But at the same time, the negative effect of stem pest foci also manifested itself with the onset of the growing season in 2019, taking into account the previous scale of drying out and the accumulation of a large amount of pests in previous years. The overall qualitative and quantitative state of the populations of these pests is influenced by a number of factors, both related to economic activity, and biotic and abiotic – climatic conditions of the autumn and winter period of 2018-2019, the activity of diseases, entomophages [10-12; 32; 34; 35].

Results of pheromone monitoring

Also, during the year, laboratory and field work was conducted to solve the problem of foci localisation by laying out trap trees and pheromone traps IBL-3 (Ipsodor pheromone dispenser) in plantings bordering with those damaged by bark beetles. Pheromone surveillance did not reflect the real picture of the pest's vital activity in plantings – in practice, bark beetles did not inhabit trap trees and only a few representatives fell into traps in very small numbers. Instead, it populated healthy trees where pheromone traps were located. The fact is that at the time of laying out trap trees and traps, the population of stem pests was in the active phase of the outbreak – qualitative and quantitative indicators were actively growing, and, as a result, the beetles were disoriented, and the presence of pheromone in the traps was minor, compared to its concentration in the air. A similar situation developed in Polissya and Forest-steppe for all representatives of the bark beetle family (Fig. 3-8).

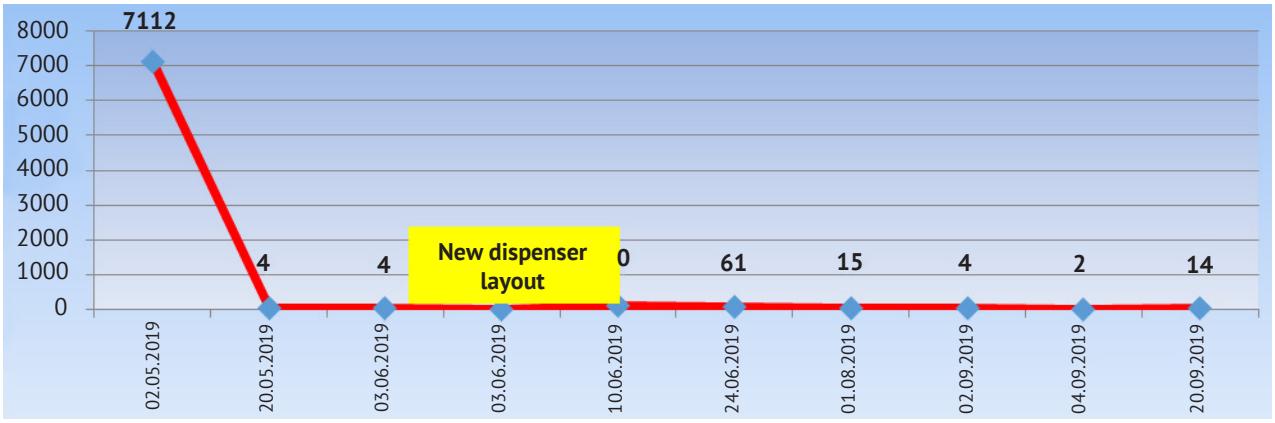

Figure 3. *The results of pheromone monitoring on the occurence of Ips engraver beetle imago (Ips acuminatus). State enterprise "Malynske LG", Malynske forestry as of 01.10.2019*

Source: *developed by the authors based on their own research*

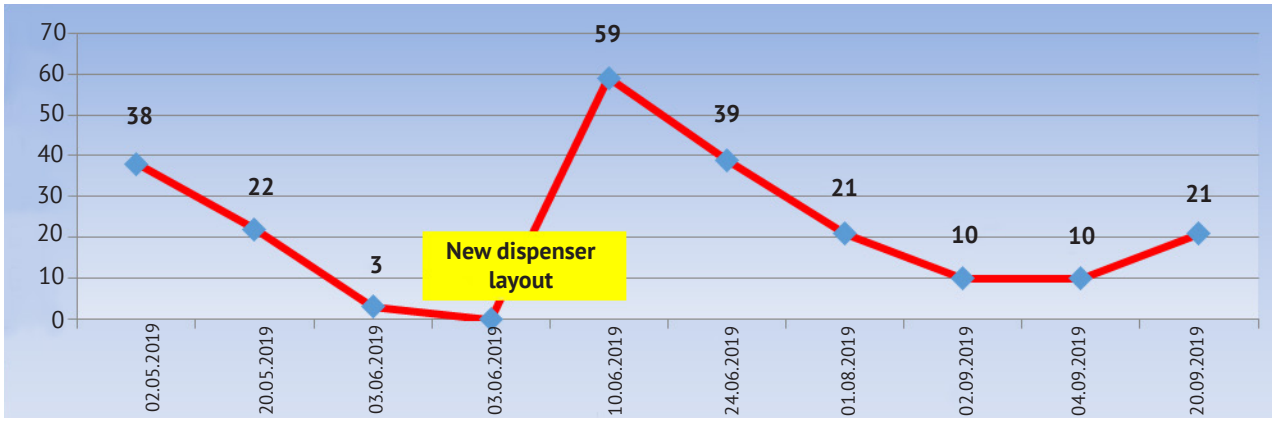

Figure 4. *The results of pheromone monitoring for the occurence of six-toothed bark beetle imago (Ips sexdentatus). State enterprise "Malynske LG", Malynske forestry as of 01.10.2019*

Source: *developed by the authors based on their own research*

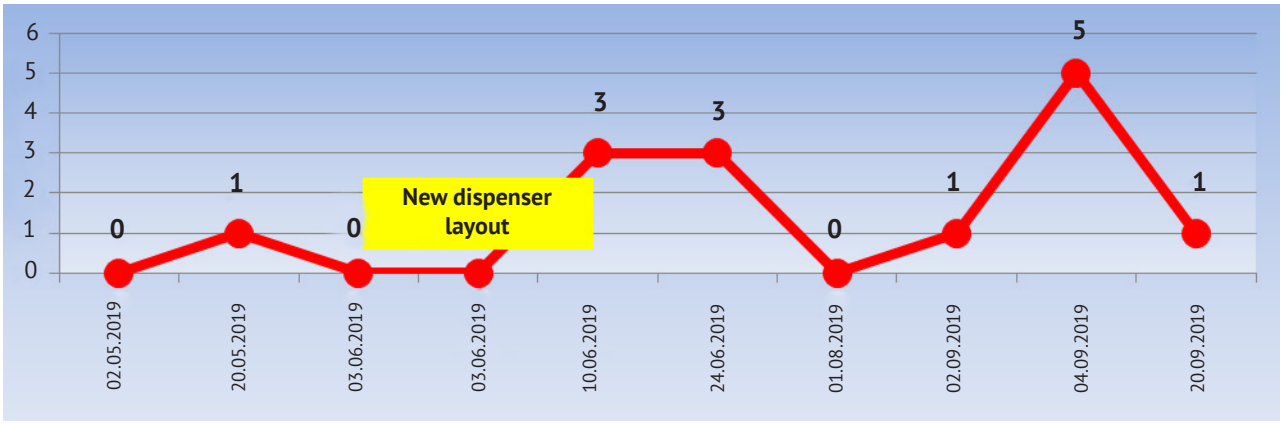

Figure 5. *The results of pheromone monitoring for the occurence of ant beatle imago (Thanasimus formicarius). State enterprise "Malynske LG", Malynske forestry as of 01.10.2019*

Source: *developed by the authors based on their own research*

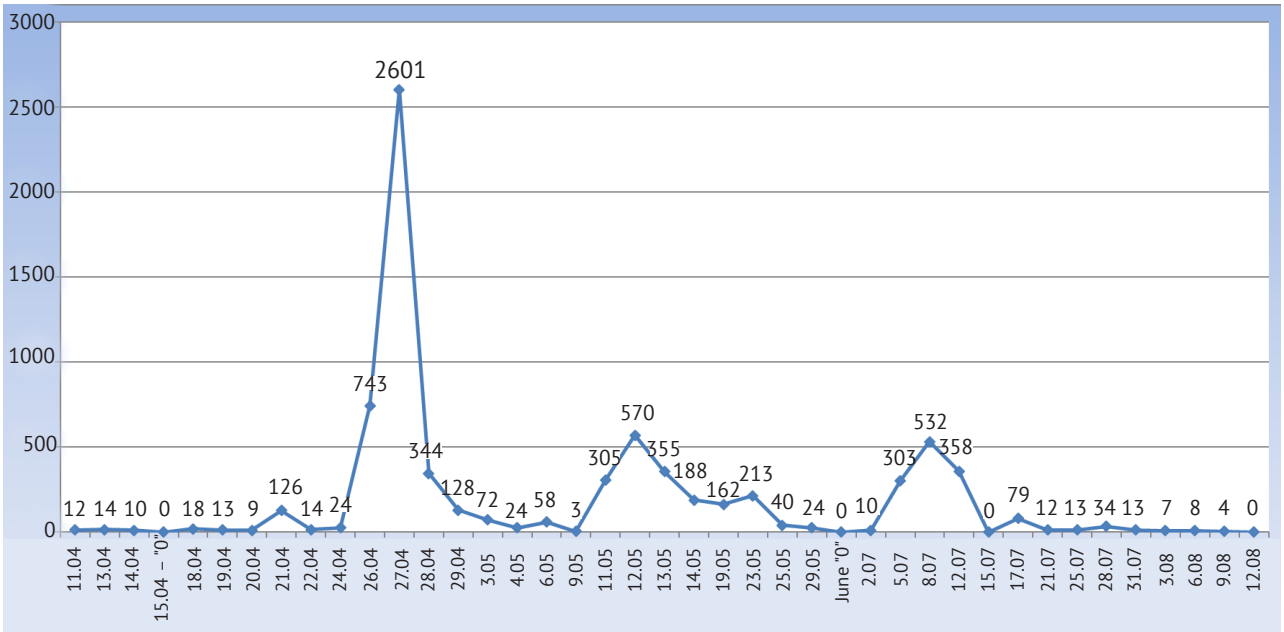

Figure 6. *The results of pheromone monitoring on the occurence of Ips engraver beetle imago (Ips acuminatus). State enterprise "Slavutske LG", Golytske and Komarovske forestries as of 20.08.2019.*

Source: *developed by the authors based on their own research*

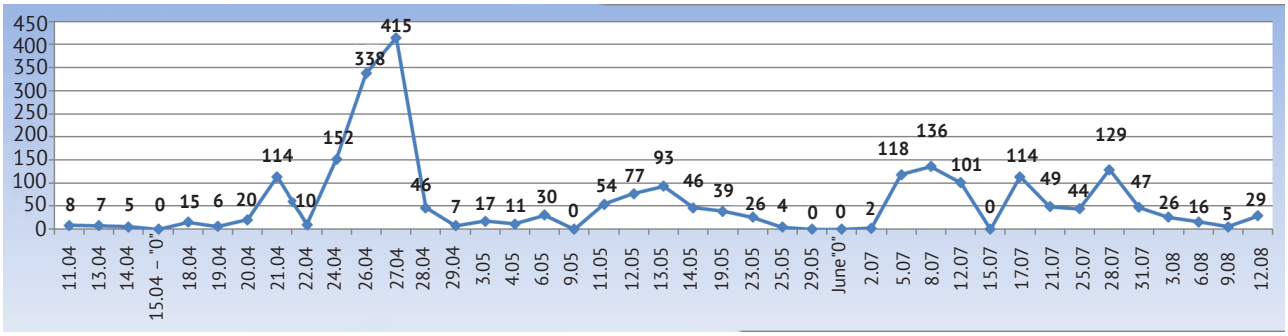

Figure 7. *The results of pheromone monitoring for the occurence of six-toothed bark beetle imago (Ips sexdentatus). State enterprise "Slavutske LG", Golytske and Komarovske forestries as of 20.08.2019*

Source: *developed by the authors based on their own research*

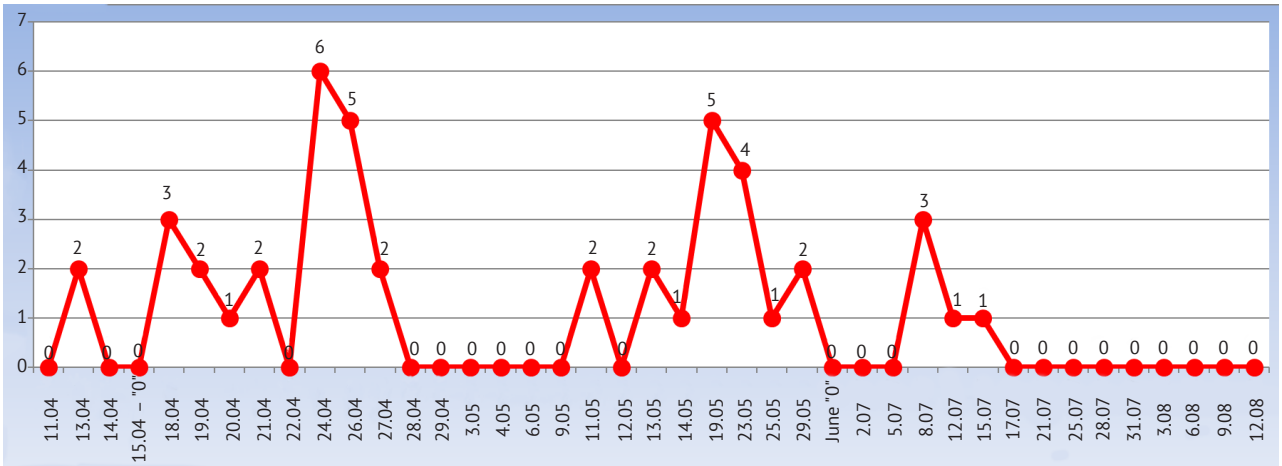

***Figure 8**. The results of pheromone monitoring for the occurence of ant beatle imago (Thanasimus formicarius). State enterprise "Slavutske LG", Golytske and Komarovske forestries as of 20.08.2019*

***Source**: developed by the authors based on their own research*

Another important factor is the indicator of the number of entomophage imago – ant beetle (*Thanasimus formicarius*) – per unit of drying pine forest area and the frequency of occurrence of the species (constant presence) in all drying foci. It was established that the greatest number and frequency of occurrence is observed in the drying foci of pine forests affected by bark beetles.

After analysing the general forest pathological and sanitary conditions of coniferous plantations, a certain pattern of occurrence of pine drying foci was identified, which are concentrated along highways and roads laid in the forest and along which the harvested wood is transported. Furthermore, the distribution area of the main types of stem pests lies within pine stands weakened by specific harmful factors. These are the following types of stem pests: Ips engraver beetle (*Ips acuminatus*) and the lesser pine shoot beetle (*Blastophagus minor*). They are characterised by the attack of the tree crown top. They are most common in the plantings of eastern and south-eastern Zhytomyr region. In these plantings, the crowns of trees are weakened by chronic foci of needle-eating insects, snowbreaks, and suffer from overheating of the thin bark zone of tree stems of plantings thinned as a result of selective sanitary cutting. The northern and north-western parts of the region "suffer from root rot (pine fungus and honey mushroom), changes in the hydrologic regime due to frequent droughts, mining, and fires, have a weakened root system and crown, are distinguished by the simultaneous type of pest colonisation, and are damaged mainly by the six-toothed bark beetle (*Ips sexdentatus*), in combination with the above" [34].

Signs of degradation of pine stands "due to the dissemination of stem pests with subsequent damage by tracheomycosis is the intensive nature of drying of the forest stand (group and entire), the spread of drying from South to North, that is, first of all, trees die on the most exposed to light edges, forest walls, and cutting areas, as well as trees that are adjacent to the active drying foci from the North. The areas of drying foci vary from 0.1 to 2.0 ha" [34]. Thus, the ultimate cause of drying out of scots pine trees is a complex of factors, namely the reproduction and spread of stem pests (mainly bark beetles) and pathogens of tracheomycosis (ophiostomy fungi), which are their integral part [10]. The species composition and rate of reproduction of forest insects depend on the quality and physiological state of plantings and forestry, on climate fluctuations, on the volume of insect predators and parasites, on the presence of insectivorous birds, and a number of other environmental conditions.

The state of the forest biocenosis in the context of an outbreak of mass reproduction of stem pests

The main conditions and factors affecting the life of insects and the development of biocenoses are divided into two main groups:

1) abiotic factors – temperature, humidity, light, soil conditions [1];

2) biotic factors – the influence of the surrounding organic world.

For each type of insect, and especially for each stage of their development, there is a certain favourable temperature, or optimum, according to which the vital activity of an organism (nutrition, metabolism, vagility, reproductive activity) is most intense. The more the temperature deviates from the optimum, the less favourable it becomes for physiological processes in insect's body. This explains the ability of bark beetles to produce several generations a year instead of one, but there are exceptions. Thus, for example, a lesser pine shoot beetle always gives one generation. This constancy of the cycle is

explained by the species specificity of the insect, which has historically developed under the influence of natural selection.

Humidity, which is present in the bark and wood of a tree, affects the development and metabolism of insects that live in the wood. The dryness of the environment increases the loss of water by evaporating it from the surface of the body of an insect imago, or by breathing movements through the spiracles, especially during an increase in temperature. The limits of optimal humidity in different insects and their stages are different: some bark beetles develop well on the sunlit sides of tree stems not avoiding strong drying of the damaged tree (Ips engraver beetle, six-toothed bark beetle); other species need shaded sides with a high moisture content for their development (lesser pine shoot beetle) and quickly die when the bark dries up [14; 18]. The influence of climate on the dissemination of insects is quite substantial. Heavy precipitation and lack of sunny days limit the development of insects. Most species appear in large numbers during droughts and begin to disappear during the rainy season, especially when the latter are accompanied by a decrease in temperature.

The relation of pests to tree species and the nature of the forest stand may vary:

– polyphage group;
– selective;
– a single-species group.

Stem pests of coniferous species can change their belonging to groups depending on the insect's habitat and changes in external conditions, especially if there is insufficient food supply during mass outbreaks; for example, the spruce bark beetle (a single-species group) often inhabits pine trees if there is not enough spruce suitable for its development. Quite often, there is a competition between species for existence, which sometimes has a strong impact on the number of this species, its reproduction, and further existence in the biocenosis. But predatory, parasitic beneficial insects (entomophages), and insectivorous birds have a greater impact on the number of pests. Only ants of one anthill destroy up to 100 thousand insects per day. One of the serious factors that disrupt the structure of the forest biocenosis is human economic activity. Improper forestry activities directly lead to the development of harmful entomofauna.

Strip cuttings, which were practised in the past, were almost always accompanied by an increased attack of pests on them. A similar pattern is observed during selective cutting when most of the stock is excessively cut down, and thereby the growth conditions of the remaining forest stand are being dramatically changed. The number and dissemination of harmful insects are increasing most rapidly in forests, where cutting operations are continuously conducted without compliance with sanitary requirements. If timber harvest and felling residues are left in the forest for the summer period, the attacks of harmful species increase sharply. In such conditions, many species of bark beetles and longhorn beetles, which usually inhabit felled forest, attack growing trees.

It is worth remembering that in mixed forests, the mass spread of pests is less frequent, and the resistance of such complex forest stands affected by insects is much greater. Therefore, artificial clean plantings (especially coniferous monocultures) periodically suffer from the reproduction of harmful insects [34].

CONCLUSIONS

The above data of exploratory forest pathology survey, stationary, and pheromone monitoring allow designing preventive and other methods of controlling the main stem pests of coniferous trees in order to preserve their ecological potential, namely:

1. Create a single national electronic database for accounting for foci of forest pests and diseases with the possibility of its constant updating, filling, and correcting data by representatives of forest pathology enterprises.

2. All cuttings in plantings damaged by stem pests of the bark beetle family must be carried out before April 1 (before the emergence of stem pests). The cut timber must be barked, the bark and felling residues burned since the vast majority of the pest (wintering) is concentrated under the bark of trees. The order of cutting should be as follows:

– first of all – plantings damaged in the second half of the year, where the largest mass of the pest is concentrated (this will also help preserve the technical quality of forest products);
– plantings damaged at the beginning of the year;
– dead standing trees of previous years.

3. Provide for a set of measures to prevent the movement and storage of unbarked (untreated with pesticides) forest products in the period from April 1 to November 1. Strictly prohibit the uplift of bark to the territory of forest stands from the facilities of processing and storage of forest products.

4. Implement a set of measures for introducing the use of pheromone preparations against Ips engraver beetle, six-toothed bark beetle, and lesser pine shoot beetle into forestry production in order to control their number.

5. Introduce machines and mechanisms into forestry production for disposing of felling residues in cutting areas.

6. Conduct experimental treatment of forest stands

with insecticides using aerosol technology (GARD) and motor sprayers of the "SOLO" and "STIHL" types to reduce the number of stem pests and mycosis vectors in the foci (during the period of emergence and additional nutrition).

7. Consider the possibility of using drone aircraft to quickly detect foci of drying out and other damage, determine their coordinates and previous areas using GIS technologies.

8. Use of stationary fire-preventing video surveillance to detect foci of drying.

9. Develop guidelines for forestry of pine stands damaged by stem pests based on the accumulated experience of recent years, supported by the results of experiments.

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Порушення структури біоценозу лісу під дією стовбурових шкідників та методи контролю їх чисельності

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Анотація. Дослідження лісової екосистеми, як невід'ємної складової частини протиерозійної системи, пов'язане з низкою питань. Ліс є найбільш могутнім і дієвим засобом у боротьбі з ерозією ґрунтів, посухами і суховіями, а також екологічним стабілізуючим чинником загалом. Лісогосподарська діяльність людини в боротьбі зі всиханням хвойних насаджеь від спалаху масового розмноження і розповсюдження на значні території стовбурових шкідників під впливом комплексу еколого-кліматичних факторів, є одним із серйозних факторів, що порушують структуру біоценозу лісу. Пошук альтернативних рішень локалізації цієї проблеми вимагає детального вивчення поведінки найпоширеніших короїдів хвойних порід дерев у кліматичних та екологічних умовах, що склались в період з 2011 по 2020 роки. У період активних температур 2019 року, а саме з II декади квітня до III декади жовтня, проводились роботи по стаціонарному нагляду та лабораторно-польові роботи з метою вирішення проблеми з локалізації осередків комплексу стовбурових шкідників соснових насаджень Полісся та Лісостепу. Використовувались методи викладки ловчих дерев і феромонних пасток. На практиці шкідник не заселяв ловчих дерев і потрапляли у пастки лише поодинокі представники в дуже малій кількості та ентомофаги. Натомість він заселив здорові дерева виділів, де були розташовані уловлювачі. Визначено, що з науково-практичної точки зору досліджувана закономірність виникнення осередків всихання сосни чітко приурочена до автомобільних шляхів і лісовозних доріг, а також ареалу поширення відповідних видів стовбурових шкідників і зон ослаблення соснових деревостанів на окремих територіях з інших причин. Доведено, що задля збереження екологічного потенціалу хвойних насаджень і зменшення негативного впливу комах-ксилофагів необхідно запроектувати профілактичні та біологічні методи боротьби з головними стовбуровими шкідниками хвойних порід дерев

Ключові слова: ентомофаги, хвойні насадження, стаціонарний нагляд, феромонний нагляд, Полісся, Лісостеп

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Environmental Efficiency of Post-Harvest Grain Processing in Combined Photovoltaic/Wind Power Systems

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Abstract. In the context of increasing production of grain and leguminous crops, the amount of energy used during their post-harvest processing also increases, and, consequently, greenhouse gas emissions from the consumption and production of such energy increase. Since the post-harvest grain processing is one of the energy-intensive processes in the production of agricultural products, and the largest use of energy in this process falls on the drying of grain, the purpose of this study was to reduce greenhouse gas emissions from electricity consumption upon post-harvest grain processing by using hybrid photovoltaic/wind power systems to meet the needs of low-temperature grain drying. Installations that use this process are aerated bins. Power supply of such systems from the power grid accompanies indirect carbon dioxide emissions from electricity consumption. It was established that one of the ways to reduce the emission of such gases, as well as to ensure reliability and energy efficiency for low-temperature grain drying in aerated bins is the use of wind and solar radiation energy. To compare environmental efficiency, it was determined that the criterion for the efficiency of using hybrid photovoltaic/wind power systems to improve low-temperature grain drying is a direct environmental criterion for reducing greenhouse gas emissions from electricity consumption. It was established that the environmental effect of reducing carbon dioxide emissions depends on the levels of autonomy of the use of hybrid photovoltaic/wind power systems and the amount of electricity consumed during low-temperature grain drying. It is theoretically calculated that the use of such systems to power active ventilation bunkers can reduce greenhouse gas emissions from 122.7 to 16,564.5 CO^2 kg for low-temperature drying of grain from 25 to 225 tonnes of grain per year. The practical value of this study was to reduce greenhouse gas emissions during low-temperature grain drying by using combined photovoltaic/wind power systems

Keywords: renewable energy sources, low-temperature grain drying, agricultural production, environmental criteria

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INTRODUCTION

An increase in acreage, which according to the State Statistics Service of Ukraine [1] amounted to 27.97 million hectares at the end of 2020, has a great anthropogenic impact on the environment. Thus, according to the source [2], agriculture accounts for 23% of the world's total anthropogenic greenhouse gas emissions. Apart from this, there are direct and indirect carbon dioxide emissions upon energy consumption in agricultural production processes. Indirect greenhouse gas emissions into the atmosphere occur during electricity consumption by installations that are used in various agricultural processes. Thus, referring to the Law of Ukraine "On the Fundamental Principles (Strategy) of the National Environmental Policy of Ukraine for the period up to 2030", it is necessary to use renewable energy sources to reduce carbon dioxide emissions. Electricity consumption from such sources should provide 17% of total electricity consumption in 2030 [3].

One of the most important processes in agricultural production is post-harvest grain processing. The main component of this process is grain drying. Grain drying, for its part, is one of the most energy-intensive post-harvest processes. It accounts for up to 70% of operating costs in the current lines of post-harvest grain processing [4; 5].

The use of a low-temperature grain drying process reduces the use of energy for drying grain. This drying method is used in aerated bins. In agriculture of Ukraine, active ventilation bunkers are used at complexes and post-harvest grain processing points. They are designed for pre-drying and storage of freshly picked grain before the main drying, cooling of grain after high-temperature drying, temporary and long-term storage. In aerated bins, the grain is dried with air. At the same time, the air in the bins is heated by an electric heater. Today, various types of aerated bins are used in agriculture. Such bunkers use electric heaters with a capacity from 2.3 to 49 kW. The capacity of the bins ranges from 1.5 to 50 tonnes of grain, depending on the type of bins [6; 7].

To reduce carbon dioxide emissions into the atmosphere, it is necessary to solve the issue of using alternative energy-saving technical and technological solutions upon post-harvest grain processing. Thus, the use of solar and wind energy is a possible way to reduce greenhouse gas emissions, as well as increase the reliability and energy saving for grain drying in active ventilation units. The use of technical means that convert such energy into electricity is rational, since the period of post-harvest grain processing in the territorial and time interval coincides with a considerable intensity of solar radiation and wind speed. In addition, the use of these types of energy combined to meet the needs of low-temperature drying increases the reliability of such a process and increases the economic efficiency of agricultural production. Thus, it is advisable to use hybrid photovoltaic/wind power systems to power aerated bins. The use of these systems reduces greenhouse gas emissions into the atmosphere, thereby increasing the environmental efficiency of post-harvest grain processing.

The purpose of this study was the efficiency improvement of the post-harvest grain processing through the use of hybrid photovoltaic-wind power systems.

MATERIALS AND METHODS

To preserve the high quality of agricultural products with minimal greenhouse gas emissions into the environment, modern environmental conditions of the post-harvest grain processing were selected. Therefore, pursuant to the Law of Ukraine "On the Fundamental Principles (Strategy) of the National Environmental Policy of Ukraine for the period up to 2030", reduction of the load on the environment, reliability of power supply (autonomy) and reducing its cost should be carried out using hybrid photovoltaic/wind power systems for powering active ventilation bunkers. The selection of hybrid photovoltaic/wind power systems for typical active ventilation installations is based on the calculated parameters of energy flow, stochastic characteristics of meteorological conditions for a given territory, as well as their absence; zoning and cost of electricity, cost of equipment and duration of low-temperature grain drying. Statistical meteorological data on solar and wind energy receipts in the Kyivska Oblast were collected in the branch State Archive of the Hydrometeorological Service of Ukraine for 11 years. The duration of the low-temperature grain drying process was determined by the Hakkila calculation method.

Next, to ensure an increase in the efficiency of post-harvest grain processing, namely low-temperature drying in aerated bins, it is necessary to determine the efficiency criteria based on which the use of hybrid photovoltaic/wind power systems will be compared. Based on sources [3; 8], the main efficiency criterion is the environmental criterion. This criterion quantitatively reflects the amount of greenhouse gases released into the environment, which decreases upon the use hybrid photovoltaic/wind power systems (HPWPS) during low-temperature grain drying. This criterion acts as a direct environmental effect, which indicates the amount of CO^2 emissions, that can be eliminated in case of electricity consumption not from the electric grid, but from

a hybrid photovoltaic/wind power installation. The calculation of the direct environmental effect of reducing greenhouse gas emissions from electricity consumption is calculated as follows:

$$E_{ec} = (R_{CO^2} \cdot W_{gen} \cdot K) - (R_{CO^2} \cdot W_{gen}) \quad (1)$$

where W_{gen} is the total electricity consumed for grain drying, kWh; K is the coefficient of used power of aerated bins from the network (K<1); R_{CO^2} is the national coefficient for CO^2 emissions for the production of 1 kWh of electricity, kg (R_{CO^2} = 1,227 kg CO^2/kWh) [9].

Thus, to calculate the direct environmental effect, it is necessary to determine the total electricity consumed for low-temperature grain drying and determine the required level of autonomy. In addition, along with the direct environmental criterion, one can also indicate an indirect environmental effect. It is based on the absence of any costs for preventing morbidity of the population as a result of a decrease in the quality characteristics of air and the cost of compensating for the consequences of global warming [10].

RESULTS AND DISCUSSION

The environmental effect is determined by comparing the basic version of the heat energy source – a mains-operated electric air heater, as well as a new version – an HPWPS and mains-operated electric air heater. For the basic version, the BV-25 aerated bin was chosen, which is equipped with a 25-kW electric air heater, and for the new version – the same bin with the same power of the electric air heater, but operated by an HPWPS.

To determine the environmental efficiency criterion for reducing greenhouse gas emissions during electricity consumption, the authors calculated the amount of electricity consumed during low-temperature grain drying. To determine the amount of energy consumed by active ventilation during low-temperature grain drying, it is necessary to identify the duration of aeration and the total power consumption of installations [11-13]:

$$W = \sum P_{inst} \cdot t \quad (2)$$

where ΣP_{inst} is the total power consumption of installations, kW; t is the duration of aeration, h.

The total power consumption is calculated as the sum of the power consumption of all electrical installations. Thus, if one bin (with one three-phase asynchronous electric motor) is used for aerated-bin low-temperature grain drying, then its power consumption is defined as follows [14; 15]:

$$\sum P_{inst} = \sqrt{3} \cdot U \cdot I \cdot \cos\varphi = \sqrt{3} \cdot P \cdot \cos\varphi \quad (3)$$

where R is the electric motor power, kW.

Calculated data on the amount of electricity consumption during low-temperature grain drying in aerated bins are presented in Table 1.

Table 1. *Power consumption during low-temperature drying, kW*

Number of bin loads	Duration of low-temperature drying, h			
	0	20	40	60
1	0	500	1,000	1,500
3	0	1,500	3,000	4,500
6	0	3,000	6,000	9,000
9	0	4,500	9,000	13,500

Analysing the results of calculating electricity consumption during post-harvest grain processing, it is evident that the amount of electricity consumed directly depends on the amount of grain and the duration of aeration itself. One bin load equates to 25 tonnes of grain. Thus, upon drying 225 tonnes of grain, which equates to 9 bin loads and the duration of low-temperature grain drying is 60 hours, which is added for each bin load, the amount of energy consumed will equate to 13,500 kWh.

Equation 1 is used to calculate the direct environmental effect of reducing greenhouse gas emissions during electricity consumption. Table 2 presents the results of the amount of greenhouse gas emissions into the atmosphere from electricity consumption at different levels of autonomy of the hybrid photovoltaic/wind power system. These data are the result of calculating the first half of Equation 1.

***Table 2**. The amount of carbon dioxide emissions into the atmosphere from electricity consumption at different levels of autonomy, kg*

Autonomy level	Number of bin loads	Duration of low-temperature drying, h				Autonomy level	Duration of low-temperature drying, h			
		0	20	40	60		0	20	40	60
Without HPWPS	0	0	0	0	0	K=0.2	0	0	0	0
	1	0	613.5	1,227	1,840.5		0	490.8	981.6	1,472.4
	3	0	1,840.5	3,681	5,521.5		0	1,472.4	2,944.8	4,417.2
	6	0	3,681	7,362	11,043		0	2,944.8	5,889.6	8,834.4
	9	0	5,521.5	11,043	16,564.5		0	4,417.2	8,834.4	13,251.6
K=0.4	0	0	0	0	0	K=0.6	0	0	0	0
	1	0	368.1	736.2	1,104.3		0	245.4	490.8	736.2
	3	0	1,104.3	2,208.6	3,312.9		0	736.2	1,472.4	2,208.6
	6	0	2,208.6	4,417.2	6,625.8		0	1,472.4	2,944.8	4,417.2
	9	0	3,312.9	6,625.8	9,938.7		0	2,208.6	4,417.2	6,625.8
K=0.8	0	0	0	0	0	K=1	0	0	0	0
	1	0	122.7	245.4	368.1		0	0	0	0
	3	0	368.1	736.2	1,104.3		0	0	0	0
	6	0	736.2	1,472.4	2,208.6		0	0	0	0
	9	0	1,104.3	2,208.6	3,312.9		0	0	0	0

The table 2 demonstrates that during the increase in the autonomy of using hybrid photovoltaic/wind power systems to power low-temperature grain drying in aerated bins, the amount of CO^2 emissions is substantially reduced. According to calculations, the volume of emissions amounts to 16,564.5 CO^2 kg when the aerated bin is powered from the mains and 3,312.9 CO^2 kg at 20%, the bunkers are powered from the grid and 80% are powered from a hybrid photovoltaic/wind power system. Under the condition of full autonomy, i.e., 100% powered by HPWPS, emissions amount to 0.

Table 3 presents the theoretical calculation of the reduction of greenhouse gas emissions depending on the duration of low-temperature aeration, the amount of dried grain (bin loads) and the levels of power supply autonomy from the hybrid photovoltaic/wind power system.

***Table 3**. Reduction of CO^2 emissions depending on the autonomy level, the amount of dried grain, and the duration of low-temperature grain drying*

Autonomy level	Number of bin loads	Duration of low-temperature drying, h		
		20	40	60
K=0.2	1	-122.7	-245.4	-368.1
	3	-368.1	-736.2	-1,104.3
	6	-736.2	-1,472.4	-2208.6
	9	-1,104.3	-2208.6	-3,312.9
K=0.4	1	-245.4	-490.8	-736.2
	3	-736.2	-1,472.4	-2208.6
	6	-1,472.4	-2,944.8	-4,417.2
	9	-2208.6	-4,417.2	-6,625.8

Table 3, Continued

Autonomy level	Number of bin loads	Duration of low-temperature drying, h		
		20	40	60
K=0.6	1	-368.1	-736.2	-1,104.3
	3	-1,104.3	-2208.6	-3,312.9
	6	-2208.6	-4,417.2	-6,625.8
	9	-3,312.9	-6,625.8	-9,938.7
K=0.8	1	-490.8	-981.6	-1,472.4
	3	-1,472.4	-2,944.8	-4,417.2
	6	-2,944.8	-5,889.6	-8,834.4
	9	-4,417.2	-8,834.4	-13,251.6
K=1	1	-613.5	-1,227	-1,840.5
	3	-1,840.5	-3,681	-5,521.5
	6	-3,681	-7,362	-11,043
	9	-5,521.5	-11,043	-16,564.5

Results of reduction of CO^2 emissions depending on the autonomy levels of the aerated bin power supply from the hybrid photovoltaic/wind power system indicate that the use of such systems in post-harvest grain processing reduces greenhouse gas emissions from -122.7 to -16,564.5 CO^2 kg. Figure 1 demonstrates the dynamics of reducing emissions with a duration of 60 hours and different amounts of aerated bin loads.

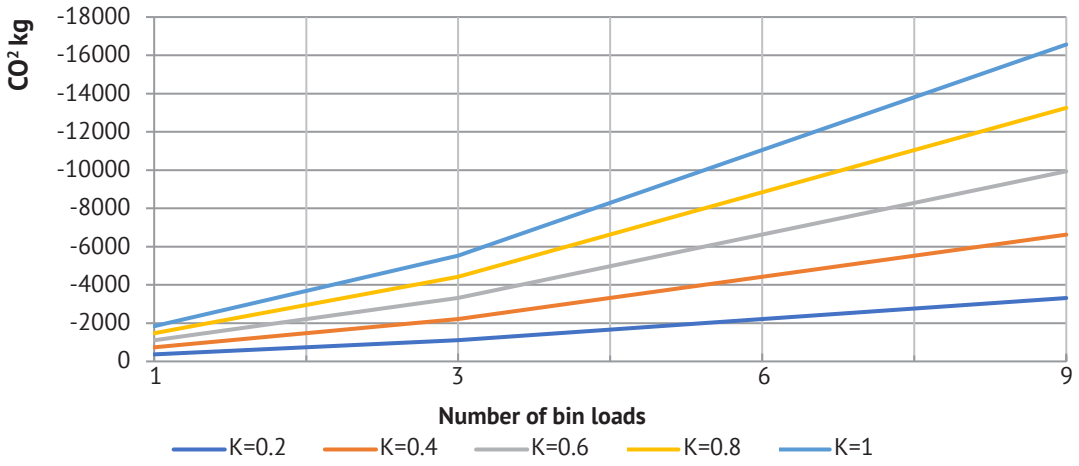

***Figure 1**. Dynamics of reducing greenhouse gas emissions with a low temperature grain drying time of 60 hours and different amounts of aerated bin loads*

The above dynamics graphically illustrate that the more grain is dried, the less greenhouse gas emissions are produced during post-harvest grain processing, and, as a result, its efficiency increases. in addition, the reduction of these emissions depends on the autonomous power supply of aerated bins.

CONCLUSIONS

An increase in grain production leads to an increase in the energy consumed upon post-harvest grain processing. At the same time, such energy includes electricity. The consumption of electricity leads to indirect emissions of carbon dioxide into the atmosphere. Thus, to reduce these emissions, it is rational to use hybrid photovoltaic/wind power systems for powering aerated bins upon post-harvest grain processing, namely low-temperature grain drying.

To compare environmental efficiency, it was determined that the criterion for the efficiency of using hybrid photovoltaic/wind power systems to improve low-temperature grain drying is a direct environmental criterion for reducing greenhouse gas emissions upon electricity consumption. It was established that the environmental effect of reducing carbon dioxide emissions depends on the levels of autonomy of the use of hybrid photovoltaic/wind power systems and the

amount of electricity consumed during low-temperature grain drying. It is theoretically calculated that the use of such systems to power active ventilation bunkers can reduce greenhouse gas emissions from 122.7 to 16,564.5 CO^2 kg for low-temperature drying of grain from 25 to 225 tonnes of grain per year.

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Екологічна ефективність процесу післязбиральної обробки зерна під час застосування комбінованих фотовіроенергетичних систем

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Анотація. В умовах збільшення виробництва зернових і зернобобових культур зростає й кількість енергії, використаної під час їхньої післязбиральної обробки, а, отже, збільшуються викиди парникових газів за споживання та виробництва такої енергії. Оскільки процес післязбиральної обробки зерна є одним з енергоємних процесів у виробництві сільськогосподарської продукції, а найбільше використання енергії в цьому процесі припадає на сушіння зерна, то метою даної роботи є зменшення викидів парникових газів при споживанні електроенергії в процесі післязбиральної обробки зерна шляхом застосування комбінованих фотовітроенергетичних систем для забезпечення потреб процесу низькотемпературного сушіння зерна. Установками, які використовують такий процес, є бункери активного вентилювання. Живлення таких систем від електромережі супроводжує непрямі викиди вуглекислого газу від споживання електричної енергії. Встановлено, що одним із шляхів зниження викиду таких газів, а також забезпечення надійності та енергоефективності на низькотемпературну сушку зерна в установках активного вентилювання є використання енергії вітру та сонячного випромінювання. Для порівняння екологічної ефективності було визначено, що критерієм ефективності застосування комбінованих фотовітроенергетичних систем для підвищення процесу низькотемпературного сушіння зерна є прямий екологічний критерій зниження рівня викидів парникових газів при споживанні електроенергії. Встановлено, що екологічний ефект від зменшення викидів вуглекислого газу залежить від рівнів автономності застосування комбінованих фотовітроенергетичних систем і кількості спожитої електроенергії в процесі низькотемпературного сушіння зерна. Теоретично розраховано, що для живлення бункерів активного вентилювання застосування таких систем може зменшити викиди парникових газів від 122,7 до 16564,5 кг CO^2 за низькотемпературного сушіння зерна від 25 до 225 т зерна в рік. Практична цінність даної роботи полягає у зменшені викидів парникових газів під час низькотемпературного сушіння зерна шляхом застосування комбінованих фотовітроенергетичних систем

Ключові слова: відновлювальні джерела енергії, низькотемпературне сушіння зерна сільськогосподарське виробництво, екологічний критерій

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Influence of the Eco-Brand of Oil Flax on the Development of Production of Safe Products

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Abstract. In modern competitive conditions, the eco-brand is one of the main prerequisites for the effective development of the country's economy. In an unstable economic situation, the reformatting of Ukrainian society is too sluggish, problems are growing rapidly, which is unquestioningly used by dishonest players in the consumer market. This study examines the trends in internal and global commodity markets, points out the need to develop the market for environmentally friendly goods based on oil flax, improve the quality of flax-containing products by the use of advanced technologies and innovative equipment. The research methods were: monographic, comparison, analysis, mathematical planning, and graphic. It is determined that the main prerequisite for sustainable development of the country in the context of economic globalisation, limited resources, and technology development is the use of eco-branding. To increase the efficiency of fibre processing, a method for processing flax has been developed, which allows expanding the range of products for processing flax straw and creating a waste-free technology. A method for obtaining the uniform fibre from bast-fibre crops has been developed, which allows processing the stems of oil flax. Prospects for using the considered technical and technological developments can contribute to the modernisation of the processing industry, its further development, expansion of the Ukrainian market, increase jobs and attract highly qualified specialists in the relevant field, increase the competitiveness of Ukrainian products on the world market

Keywords: flax straw, fibre, competition, non-fibrous impurities, breaking rollers, scutching node, swingling device

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INTRODUCTION

The instability of the consumer market of Ukrainian goods cannot ensure compliance with the requirements of regulatory documentation for fibrous products and contribute to improving the level of its quality. The national economy of the country is weak, it is influenced by various social, political, and economic factors. At the same time, along with the aggravation of competition for the consumer in the market, the lack of clear norms and rules in regulatory matters, the loss of the raw material base for industry, and the unwillingness of the state to develop high-tech sectors of the economy complicates its general crisis state. With the growth of the global economy in society, the issues of providing the population with high-quality food and non-food environmentally friendly safe goods, which, along with other products, have a certain set of valuable functional properties, come to the fore.

Today, to dominate the Ukrainian and international consumer markets of goods, it is necessary to have a clear strategy for the development of the enterprise, a certain well-developed system of processing raw materials, in which it would be possible to program clear actions in advance in the direction of saving material and labor resources, improving the quality of final products, reducing costs for production transitions and developing the image of a modern high-tech manufacturer [1].

Creating such a brand takes time, and most importantly – significant investments in the development of advanced technologies and equipment. Today, in the context of environmental disasters and the spread of pandemics, it is especially valuable to promote the eco-brand and form the foundations of eco-branding. According to S. M. Ilyashenko, "environmental branding should be considered as a complex process of developing an environmental brand and maintaining voluntary communication between consumers through a stable and reliable set of product differences, offering high quality and satisfaction of needs, attracting the attention and interest of manufacturers, and sustainable social responsibility to prevent negative impacts on the environment" [2].

Promotion of new ideas, expansion of the innovative component in the manufacture of new safe products, which cover a wide range of activities, including product modification, provides an opportunity to ensure the commitment of consumers to the chosen eco-brand and maintain a reliable link between the preservation of the environment and the economic development of society [3].

The development of an eco-brand and eco-branding for a Ukrainian manufacturer is quite a significant tool in the struggle for consumers. This facilitates access to new and developed markets for goods whose modern product quality requirements are strictly regulated and strict, especially when it comes to safety and environmental properties [4; 5].

At the same time, outdated technologies, globalisation, the contradiction of the provisions of regulatory regulation of economic activity, the crisis in the financial sector do not allow the state to actively influence the quality of goods and the cleanliness of the environment. In such business conditions, special attention should be paid to the environmental component of Ukrainian and imported goods from abroad, since low-quality and counterfeit products, in addition to financial losses in the absence of objective information support, can be dangerous for consumers and the environment. In such a situation, it is necessary to develop a radically new concept of eco-social policy in the country.

The analysis of monographic studies [2; 6] and research papers [7; 8] indicates that in recent years technological, commodity science and economic aspects of the establishment, and assessment of the level of environmental safety of raw materials and products, have been widely discussed. At the same time, the issues of increasing the quality requirements and environmental requirements for textile raw materials, individual stages of textile production and textile products themselves are also raised [9].

The need to address the issues of greening textile materials of the main groups of non-food products is dictated by the need to bring the production of any type of Ukrainian goods to compliance with the requirements of international environmental standards, harmonise the system of Ukrainian environmental standardisation in accordance with international and expand the product range relative to modern consumer demand. Currently, in the international relations market, the level of environmental safety of goods has become one of the main factors determining the level of its competitiveness [10; 11].

Therefore, for Ukraine, which is rapidly moving towards deepening its activities with the European Union, this is especially important and relevant. This issue requires the creation of innovative products that meet the market requirements of developed countries and have certain properties that give it competitive advantages in the fight for the consumer. Thus, *the purpose of the study* is to define directions and technologies for forming markets for safe goods based on the development and distribution of eco-branding of products obtained as a result of processing oil flax.

MATERIALS AND METHODS

During the study, experimental samples of equipment for extracting fibre from the stems of the flax straw were designed and manufactured, with the help of which the processes of breaking were analysed and factors that significantly affect the processing of bast-fibre raw materials were identified. Based on the planning of experiments with matrices of rotatable planning of the second-order according to Box's plans, the relationship between the technological parameters of the processing of the stem mass and the quality and quantity of the obtained fibre was determined.

To conduct experimental studies on the processing of bast raw materials, oil flax straw of the Pivdenna Nich variety was used, which was prepared using roll-to-roll technology in the climatic conditions of the SE EF Askaniyske in the Khersonska Oblast. The preparation of flax straw was carried out using dew-retting technology, and studies on the processing of bast raw materials were carried out under the same conditions for preparing the material for processing. In the process of processing bast raw materials, precise control was carried out over the process of mechanical processing of stem material by sampling raw materials and instrumental measurement of indicators of separation of the fibrous layer from wood, breaking load, fibre yield, maximum permissible content of shives and garbage impurities. To check the quality properties of bast raw materials and fibrous products, the methods of regulatory documentation specified in DSTU 4149-2003 "Flax straw. Technical specifications", DSTU 5015-2008 "Short linen fibre. Technical specifications".

General scientific and specific research methods were used in the course of the study. To determine the quality properties of samples of raw materials used in the manufacture of environmentally friendly products, the study compared the length and thickness of the stems, the color of the straw, the fibre content, its flexibility and breaking load. To determine the nature of the influence of technical and technological parameters for setting up the operation of equipment during the processing of flax stems, an analysis of changes in the initial characteristics of the fibre was carried out. A graphical method and methods of mathematical statistics were used to process the obtained experimental data and assess changes in the content of impurities in the fibrous product during the raw material processing, determine the percentage of fibre yield and the average weight-length relation of fibres. Mathematical planning of the experiment allowed obtaining regression models of the raw material processing, and the abstract-logical method provided a theoretical generalisation of the findings and the generation of conclusions. The results obtained indicate the possibility of expanding the range of products based on the stems of bast crops.

RESULTS AND DISCUSSION

Analysis and generalised assessment of the impact of flax on the economic, social, and environmental development of Ukraine

When forming an overall industrial development strategy aimed at creating environmentally friendly products, it is necessary to adhere to methods of preserving the valuable properties of raw materials at various production stages using innovative technologies and equipment for their implementation. Today, flax is almost the only renewable source of cellulose textile raw materials on the European continent. The fabric made from linen is characterised by significant elasticity, strength and moderate hardness, durability, and resistance to rot. Linen clothing has a positive effect on the emotional and physical state of a person, increases resistance to various ailments and contributes to maintaining health. Today, technical linen products are indispensable in various industries, especially those related to construction, textile, defence, automotive and other areas of Ukrainian economy. Notably, the range of doublings and nonwovens fabrics made of flax, including dressings and medical cotton wool, is not only not inferior in their properties to similar products made of cotton, but sometimes exceeds them [12].

Natutal flax components have different functional properties and can be used simultaneously in various sectors of the light industry. The use of flax components requires, in addition to a comprehensive study of the exceptional safe qualities of fibre, also the study of the safe component of mixtures of flax with other types of fibres that are used in the manufacture of goods for various functional purposes. With this approach, it is possible to most rationally substantiate the areas of application of the expanded range of updated materials of flax. The use of oil flax components in the light, pulp and paper industries, construction, and medicine requires partial and comprehensive economic, technological, social and environmental substantiation. Considering the areas of such research, Ukraine should develop a radically new concept of an ecosocial policy for the development of the state.

Bast-fibre plants are among the most important industrial crops that are of great national economic importance. Despite the significant development of the chemical industry towards obtaining fibre products, the value of such crops as sources of fibre production, especially

environmentally friendly ones, does not decrease, and in some areas of the national economy the need for them is quite high and tends to increase. The fibres of bast crops are located in the stems, consist of a large number of elongated cells. Bast crops are difficult to process, as a result of harvesting processes, seeds and stem material of straw or trusts are obtained separately, which are formed into special packaging – rolls or piles. The efficiency of fibre production in modern conditions cannot be ensured without the use of machines with low metal and energy intensity, which indicates the inexpediency of using existing overall technological equipment at Ukrainian enterprises.

In Ukraine, among the group of bast-fibre crops, which includes: flax, hemp, ambary, abutilon, nettle, jute, ramie – mainly the flax and hemp are cultivated. The climatic conditions that have developed on the territory of Ukraine allow growing these plants and get fairly high yields of seeds and fibre. The composition of these crops includes about 75-90% cellulose, 1-3% lignin, and as a result of their processing, strong fibres up to 10 mm and more are obtained [13]. According to statistics on the volume of flax fibre production over the past century, it is clear that the position of Ukraine in the world, as one of the leading producers, has changed to an outsider [9]. Trends in recent years indicate an increase in the acreage of flax, but this valuable crop is not used enough on an industrial scale. This is mainly due to the greater prevalence, technological advancement in the processing of flax and socio-economic circumstances that have developed in Ukraine and the world. The decline in the production of flax fibre is due to changes in the structure of Ukrainian business, insignificant innovation activity of enterprises, lack of incentives, noticeable technical and technological lag of the Ukrainian textile industry from the major countries, increased energy and material consumption, labour intensity of production, lack of working capital and low organisation of economic activity.

The main countries whose natural and climatic zones allow growing flax are: France, China, Ukraine, Russia, Belarus, Poland, India, the Baltic states, etc. According to the food and Agriculture Organization of the United Nations (FAO), currently about seven million hectares of flax are sown annually in the world [14]. The main trend of the last ten years in the development of the global flax complex is the desire of countries to increase the share of flax among other fibres and deepen the degree of its processing. Due to its natural properties, products made from both long flax and oil flax and their processed products are in demand both in the domestic and foreign markets of Ukraine [13; 15]. By the middle of the 20th century, the sown area of flax was about 100 thousand hectares, which indicates a sufficient prevalence of this crop in Ukraine. With the change in the climatic conditions of growing flax, the areas of its cultivation were reformatted, the main regions were the south-eastern regions of Ukraine, namely: Zaporizka, Dnipropetrovska, Khersonska and Mykolaivska oblasts.

Trends in recent years indicate an increase in acreage for this crop, but it is worth noting that flax is still insufficiently used on an industrial scale in the manufacture of various types of goods. Today, there is practically no deep processing of Ukrainian flax in Ukraine, and there are very few producers of finished products. The main consumer of oil flax *in the light industry* are the Kirovograd twine and rope factory and the Kharkiv rope factory, *in the food industry* – OJSC "Nizhinsky Zhirovyi Kombinat", *pharmaceutical* – "Liktravy", *chemical* – LLC "Factoria". In addition, the companies "Zhytomyrskyi Lyon" and "Galereya Lyonu" use the fibrous product of oil flax in the manufacture of insulation materials, "Lintex" – in construction and in the automotive industry as sound and noise insulation materials. This is mainly due to the greater prevalence, technological advancement in the processing of flax and socio-economic circumstances that have developed in Ukraine and the world.

With the growth of export prospects for the sale of oil flax seeds, the issue of processing significant volumes of stem material of this crop arose. There is simply not enough capacity in Ukraine for processing significant volumes, especially given that the state of processing equipment is in an extremely neglected state. Only a small number of manufacturers use suitable equipment. Technological equipment of plants for primary processing of bast plants is currently unsuitable, since it is physically and morally obsolete. Today, the production of fibre products in Ukraine requires the development of innovative technologies and advanced efficient equipment that can improve the quality of a safe commercial product, its environmental friendliness, expand the range of popular goods, and give the country independence in the supply of estimated raw materials.

Research on obtaining oil flax fibre and expanding the range of environmentally friendly products

In order to spread the production of oil flax, expand the range of environmentally friendly products and eco-brand in Ukraine, a study was conducted on the introduction of modern design ideas for obtaining fibrous products that can meet the requirements for its use in various industries. Current trends in in-depth processing of bast fibre material have significantly affected the scope of its use. Short fibre is much more widely used in the

textile industry, in the production of various textiles, modern composite materials, flax cotton, bat wool, insulation materials, etc. [16]. All this has caused changes in the technologies of collecting and obtaining fibre products aimed primarily at resource conservation and safety of use [17]. Therefore, the study used the technology of obtaining the same type of fibre, which is less expensive compared to conventional and improves the overall processing culture of the agricultural plant.

The development of technological equipment and nodal connections for efficient processing of oil flax without dividing it into long and short fibres simplifies technological processes for collecting raw materials and further mechanical processing, provides an opportunity to increase equipment productivity and improve working conditions in production. The possibility of forming the uniform type of raw materials significantly reduces the cost of its collection, preparation, transportation, and processing, which reduces the metal and energy intensity of equipment and reduces the cost of the resulting fibrous products. For the effective application of the technological line for processing flax straw with a chaotic arrangement of stems in the mass, the study used the developed effective nodal connections of the scutching part of the machine, which allows obtaining uniform purified fibre from the stem material, without shives and other non-fibrous impurities. The Pivdenna Nich variety of oil flax was taken for experimental studies.

The combination of innovative technical and technological developments included a method that consists of unwinding rolls on roll rewinders, breaking with rollers of various types with the passage of processes of pulling, scutching and cleaning of bast fibre material from impurities on swingling machines at the end of raw material processing. In accordance with the developed method, straw stems are formed in the breaking part of the unit, the raw layer is scraped and thinned using disc, plank, and comb-type cleaning rollers. The cleaning efficiency of raw materials is ensured by the complex interaction of the developed components with the swingling and vibrating device installed between the breaking and scutching machines. In this case, the process of scutching is carried out with the simultaneous action of beater bars and knives installed on the scutching drum [18].

The essence of the developed device is explained in Figure 1, which shows the technological scheme of an experimental unit for obtaining the uniform fibre from oil flax, where *I* – packaging unwinding part; *II* – drying part; *III* – ball forming part; *IV* – breaking part; *V* – swingling part; *VI* – scutching part. The following equipment was used: 1 – decoiler; 2 – drying machine, if necessary; 3 – spiked roller; 4 – breaking machine with a pair of rolls of increased diameter; 5 – breaking machine; 6 – pre-cleaning swingling machine with a vibrating device; 7 – scutching nodes; 8 – swingling machines equipped with a vibrating device [18].

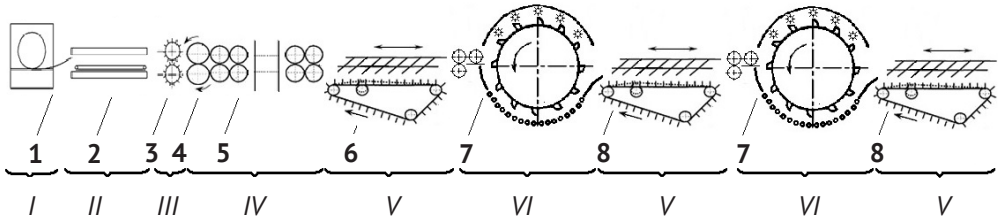

Figure 1. *Technological scheme of an experimental unit for obtaining the uniform fibre from oil flax, where I – packaging unwinding part; II – drying part; III – ball forming part; IV – breaking part; V – swingling part; VI – scutching part. The following equipment was used: 1 – decoiler; 2 – drying machine, if necessary; 3 – spiked roller; 4 – breaking machine with a pair of rolls of increased diameter; 5 – breaking machine; 6 – pre-cleaning swingling machine with a vibrating device; 7 – scutching nodes; 8 – swingling machines equipped with a vibrating device*

The Pivdenna Nich oil flax is sent to decoiler 1 and then to drying machine 2. From the drying node, the stem material is fed evenly through the spiked roller 3 to the first pair of rollers 4 of the breaking machine 5 of the considered device. Due to the increased diameter, these rollers provide retraction of the flax straw with various physical and mechanical properties. Next, the raw material goes to a set of rollers of the breaking machine 5. Due to the use of developed rollers, parallelisation and ordering of stems take place during scutching, and intensive breaking with simultaneous scraping, stretching and thinning of the raw layer is carried out. After that, the washed and partially cleaned layer of the flax straw is sent to the pre-cleaning swingling machine 6, which is equipped with a vibrating device. The raw material is enriched, ordered, and the shives and other non-fibrous impurities are further removed [19].

In the future, the prepared raw layer is fed to the scutching node 7, where an intensive process of cleaning the fibrous mass from the shives takes place. At the same time, considering the initial condition and quality of the flax straw, it is possible to adjust the intensity of raw processing by changing the size of the gap between the beater bars and scutching knives, as well as between

the grid and the scutching drum of the scutching node 7. After the scutching, the fibrous mass enters the swindling machine equipped with a vibrating device 8. Due to its use, the final cleaning of the fibre from foreign impurities takes place [19].

The complex interaction of meat Rollers of various types during the kneading of the stem layer of the trust with a shaking and vibrating device during the shaking of raw material, which is carried out between the processes of crumpling and tipping, allows for preliminary cleaning of the fibrous mass from free fire formed during the passage of raw material through the meat machine, and other non-fibrous impurities.

The use of a swingling machine with a vibrating device after the scutching removes the remaining shives from the fibrous product. The vibrating device of the needle conveyor leads to additional vibrations of the fibrous mass, so that the shives are intensively separated, which increases the efficiency of cleaning the fibrous product. Double processing of linen material with a scutching node and a swingling machine are used to obtain the fibre with the lowest content of foreign impurities.

As a result of processing the Pivdenna Nich flax straw, fibre of varying degrees of purity was obtained depending on the condition of the flax raw material, the number of processing transitions, and the adjustment parameters of processing equipment. Thus, depending on the above factors, due to mechanical processing of the stem material of flax, a different yield of the final product and its characteristics were obtained (Tables 1; 2).

***Table 1**. Yield of fibre and shives processing products from the Pivdenna Nich flax straw after mechanical processing of the stem material*

Processing cycle	Output of processed products, %		
	Fibre	Shives in fibre	Shives + irreversible waste
Incomplete straw processing cycle	17.57	4.77	77.66
Complete straw processing cycle	17.44	2.62	79.94

***Table 2**. Properties of the fibrous product from the flax straw of the Pivdenna Nich variety at different stages of processing*

Processing cycle	Properties of the fibre product		
	Breaking load of the fibre, daN	Fibre output, %	Shives content, %
Incomplete straw processing cycle	16.09	17.57	4.77
Complete straw processing cycle	15.14	17.44	2.62

According to an incomplete processing cycle of the stem material, the obtained fibre has lower values of quality indicators than that of fibrous products obtained when passing a layer of flax raw materials through all nodes of the experimental unit. At the same time, the quality properties meet the requirements of regulatory documentation for the production of doublings, nonwoven fabrics, cotton batting, geotextiles and can be used in the construction and automotive industries as fillers, reinforcing and heat-insulating materials, for stuffing upholstered furniture and mattresses. It should be noted that when choosing the scope of use of fibre products, the value of the average weight-length of fibre is also considered. The distribution of the resulting fibre from flax of the Pivdenna Nich variety along the length obtained by mechanical processing of straw indicates the presence of a significant number of short fibres (Fig. 2).

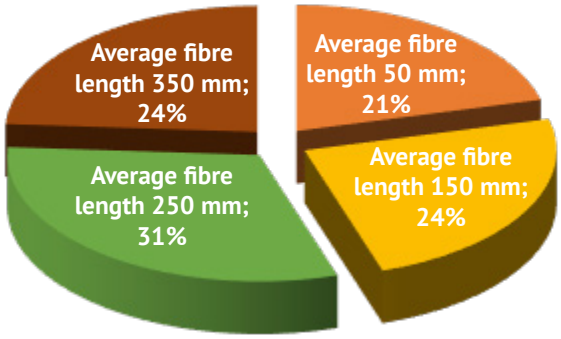

***Figure 2**. Fibre length distribution diagram of the Pivdenna Nich variety of oil flax straw*
Source: authors' personal research

Analysis of the study results indicates that in the case of full-cycle mechanical processing of flax straw of the Pivdenna Nich variety, the obtained fibre, in addition to doublings and nonwoven fabrics, also

meets the requirements of regulatory documentation for the production of textile materials, sanitary and hygienic, cellulose-containing products. Thus, the developed technical and technological solutions allow processing the oil flax straw, expanding the scope of its functional purpose, which strengthens the position of using this crop as a raw material in the manufacture of environmentally friendly types of non-food products.

The combination of ecological properties of oil flax with the properties of other constituent materials to spread environmentally friendly characteristics in the designed products and prevent environmental pollution due to disposal of products can be an actual contribution to the design of a new possible assortment composition of modern safe products that will take a worthy place in the distribution of the eco-brand in the consumer market of the country.

CONCLUSIONS

In the context of fierce competition, globalisation, liberalisation of markets and a changing external environment, those enterprises that quickly implement modern trends in the production of safe goods will be effective. The creation of high-quality safe products should take place, first of all, through the development of flax-containing materials with new properties and modern product designs based on advanced technical solutions, preserving the original valuable characteristics of plant raw materials. It is under such conditions that it is possible to increase the level of competitiveness of environmentally friendly products, spread eco-branding among producers, and provide the Ukrainian market with cheap renewable raw materials that would meet the growing demand of consumers in eco-products in both manufacturing and nonmanufacturing activities.

The development of the consumer market of environmentally friendly food and non-food products made from oil flax components, which are able to meet the growing demand of consumers in eco-products in various areas of activity, can become a prerequisite for a long-term strategy for the establishment and expansion of eco-branding in Ukraine.

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Вплив екобренду льону олійного на розвиток виробництва безпечної продукції

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Анотація. У сучасних умовах конкурентної боротьби екобренд виступає однією із основних передумов ефективного розвитку господарства країни. У нестабільній економічній ситуації переформатування суспільства України проходить надто мляво, проблеми швидко наростають, чим беззаперечно користуються недоброчесні гравці на споживчому ринку товарів. У статті розглядається напрям внутрішнього та світового товарних ринків, вказується на необхідність розвитку ринку екологічно безпечних товарів на основі льону олійного, поліпшення якості льоновмісної продукції внаслідок використання передових технологій та інноваційного обладнання. Методами дослідження стали: монографічний, порівняння, аналіз, математичне планування та графічний. Визначено, що основною передумовою сталого розвитку країни в умовах глобалізації економіки, обмеженості ресурсів і розвитку технологій є застосування екобрендингу. З метою підвищення ефективності процесів обробки волокнистого матеріалу розроблено спосіб переробки олійного льону, який дозволяє розширити асортимент продуктів переробки трести льону олійного та створити безвідходну технологію. Розроблено спосіб одержання однотипного волокна з лубоволокнистих культур, який надає можливість переробляти стебла льону олійного. Перспективи використання представлених технічних і технологічних розробок можуть сприяти модернізації переробної галузі легкої промисловості, її подальшого розвитку, розширення ринку України, збільшенню робочих місць і залученню висококваліфікованих фахівців у відповідну сферу, підвищити конкурентоспроможність української продукції на світовому ринку

Ключові слова: треста, волокно, конкуренція, неволокнисті домішки, м'яльні вальці, тіпальний вузол, вібруючий пристрій

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Ecosystem Approach in the Context of Economic Interest Management

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Abstract. The relevance of the study was conditioned by the necessity of seeking solutions of environmental security issues and ensuring its effective management. The purpose of the study was to structure the national security system with the allocation of environmental and economic subsystems, constructive and critical analysis of the main opinions and positions of researchers on the essence and areas of the ecosystem approach concerning the solutions of environmental security issues, further development of the ecosystem approach based on economic management methods. The study was based on the use of system and matrix approaches, methods of generalisation, modelling, analysis and synthesis, and content analysis. It was proved that the national security system includes, in particular, environmental and economic subsystems and that there is an objective internal system connection between these subsystems, which, if used correctly, should ensure the effective functioning and development of both subsystems. The study outlined the functional and subject matrix of the environmental security system, which will contribute to the systematisation of various areas in its research. It was established that from the standpoint of management theory, the ecological subsystem is defined as the managed one, and the economic subsystem is defined as the managing one. Management is ensured by the fact that the first one includes not only natural, but also human resources (consumers of ecosystem services, managers in the environmental sphere or performers of environmental functions). It was proved that the effective solution of environmental issues necessitates the consideration of the economic interests of these people, since economic interests constitute the basis of an economic (effective) management method. The practical value of the study was to develop an economic method for managing the environmental security system and substantiate the role of economic interests, which would contribute to the practical solution of environmental issues in Ukraine

Keywords: national security, environmental problem, economic security, environmental security management, natural resources

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INTRODUCTION

Modernity is described by many issues, the rapidly increasing number of which demands timely and adequate solutions from humankind. In the conditions of a changing and unpredictable present, there is a need to ensure the safety of humanity and the environment of its functioning. Therefore, it is logical and timely to actualise research on practical issues of protecting the humankind and the environment of its functioning. This subject is also very relevant for modern Ukraine. The increased attention to this subject is evidenced by the fact that over the past 1.5-2 decades, a considerable number of studies by Ukrainian and foreign specialists have already been developed; many of these articles are conditioned by different angles of such research, when researchers address the same category from different standpoints.

An insight into the subject area of publications on national security proved that research concerns its various structural components, to the list of which researchers (generalisation of scientific approaches in this regard is provided in [1]) include: political, economic, state, social, socio-cultural, demographic, information, technological, environmental, humanitarian, military, defence, public, fire, environmental, food, epidemic, and financial safety. Specific components of national security become more or less relevant in view of a certain scenario of factors affecting them. It is worth paying attention to the statements of experts on this matter, who noted the current growth of environmental risks for the development of national economies, while the actual economic and political risks have become secondary in importance [2].

Environmental issues are fundamentally based on the so-called "green economy" and "green development". Back in 2012, Cameron Allen (UN Sustainable Development Division) prepared a document that addressed the green economy issues and examined the experience of developing and implementing green growth strategies in different countries. He pointed out that political priorities should include reforming the system of economic incentives, promoting the development of sustainable investment infrastructure and promoting investment in natural capital [3, p. 6]. The development of environmental security of the country is defined by the Law of Ukraine "On the Fundamental Principles (Strategy) of the National Environmental Policy of Ukraine for the Period up to 2030", which makes provision for the introduction of international standards of environmental management systems in enterprises and companies, which will contribute to the development of the environmental management system and the implementation of international environmental initiatives in Ukraine [4]. However, despite the demand for these studies and related reforms, numerous issues remain unresolved, even with some unidentified issues concerning the application of a systematic management approach for effective implementation of reforms and achievement of the intended results. Considering the economic interests of stakeholders, there are no studies of the ecosystem approach in science.

Thus, *the purpose of this study* was to investigate the structuring of the national security system with the allocation of environmental and economic subsystems in it, the implementation of constructive and critical analysis of the main opinions and positions of researchers on the essence and areas of applying the ecosystem approach in solving the problem of ensuring environmental security, the justification of the management approach to the use of economic methods as the basis for further development and the essential content of the ecosystem approach. The authors of this study set the following tasks: to investigate the developments of researchers regarding the structuring of national and environmental security systems and related areas of scientific research; to determine the essence and development of the ecosystem approach and the practice of its application; to "chart the contours" and justify their vision of the essence of the ecosystem approach based on the concept concerning the consideration of the economic interests of all subjects relating to or taking part in ecosystem development, and with the division of the latter into subjects and objects of management, as well as the development of methods for influencing the latter (objects) by the former (subjects).

METHODOLOGICAL REASONING

Classical and special methods of scientific cognition were used in this study. To identify the essence of environmental security, the study used a systematic approach, which makes provision for its consideration, firstly, as a system element of a larger system (namely, national security), and, secondly, as a complex ecological, extensive system, which, for its part, includes internal system components. Functional and subject components were identified as internal components requiring the use of a system-matrix approach. A systematic approach also allowed combining research on the environmental and economic components of security, as well as determining the critical points of their intersection.

The systematic approach is associated with the objective necessity of employing the classification method, which was applied in this study to determine

the classification components of the national security system. The portfolio (matrix) research method was used to provide a compelling development of the environmental security format. This allowed presenting the environmental security system as a matrix with two parameters – functional and subject.

The paper focused on the environmental and economic components of safety and their mutual impact. It is this influence that determined the use of factor analysis, which allowed evaluating their causation. The interdependence and interrelation between them suggested that further development of the ecosystem approach is possible only if these components are integrated. The integrative combination of environmental and economic components of security has led to the need and possibility of applying a transdisciplinary approach, that is, the transfer of research methods from one scientific area to another. Notably, in this case, this approach is based not so much on classical transdisciplinary transfer, but on an essential integrative combination.

Consideration of the integrated ecological and economic system in this study was based on the modern theory of management, and, in particular, on the correlation of the managing (as the economic subsystem is perceived by the authors) and the managed (as the ecological subsystem is perceived by the authors) subsystems, where attention is focused on the fact that the management is improved at a more dynamic pace. This underlies the statement on the primary importance of applying economic incentives to the influence of the managing subsystem on the managed one, that is, consideration of the economic interests of the latter.

The content analysis method was used to identify the essence of the ecosystem approach category, which allowed comparing its interpretation by different authors. Furthermore, heuristic and associative methods were also used in the development of an original definition and interpretation of the essence of the ecosystem approach, considering the economic interests. The combination and mutual influence of two components in the ecological and economic system implied the need to monitor economic and environmental development and their comparative analysis, which is theoretically formed by the so-called decoupling method, the function of which is to maintain the gap between economic growth and to reduce the anthropogenic load on the environment [5, p. 31].

RESULTS AND DISCUSSION

Systematic relationship of environmental and economic components in the structure of national security

The national security system constitutes a sophisticated, complex, and interconnected combination of a considerable number of conditionally separate subsystems. The authors generalised the types of subsystems of national security, demonstrating the structural place of each of them in the hierarchical security systems and highlighting the connecting role of scientific security (Fig. 1) [1].

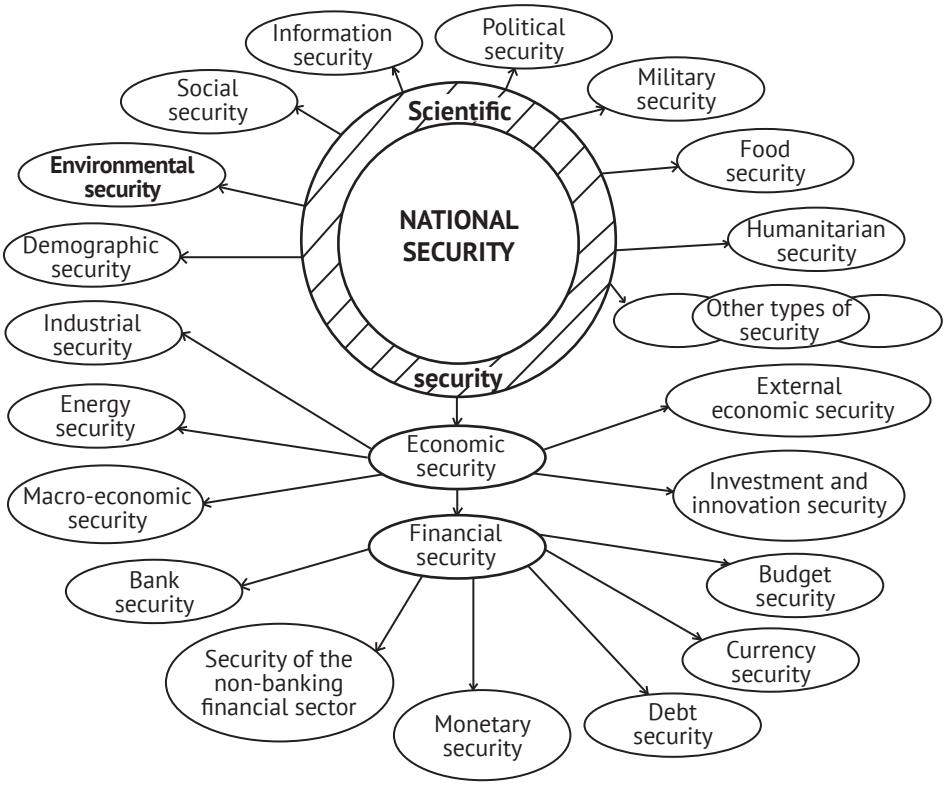

***Figure 1**. Structuring of the national security system with identification of the place of environmental and economic subsystems in it*

***Source**: developed by the author V.M. Antonenko*

Narrowing down the scope of the study and focusing on the environmental and economic components of security, the authors had to properly identify them. Notably, the environmental component of a security system cannot be separated from the other components of this system. Most importantly, according to the authors, it is worth focusing on the systemic relationship between environmental and economic security. In the specialised literature, the term "ecosystem" can be interpreted both from the standpoint of environmental and economic content, and, consequently, has a systemic combination into a unified security system.

The study considered their connection through the managerial aspect. From the standpoint of classical management, the management has managing and managed subsystems, between which the purposeful influence of the former is exerted on the latter. Applying the transdisciplinary method of transferring management elements to the essence of the security system, the authors considered the economic subsystem to be the managing one, while the environmental subsystem is the managed one (Fig. 2).

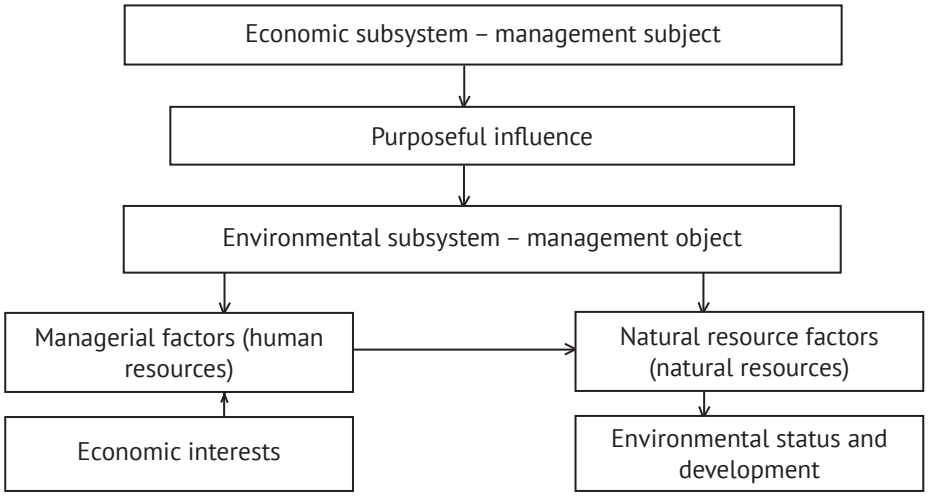

***Figure 2**. Mechanism of influence of the economic system on the environmental one*
***Source**: developed by the author V.M. Antonenko*

Such a statement certainly requires scientific evidence and an appropriate explanation. The fact is that the environmental security system, according to the authors, makes provision for the study of both purely physical problems of nature management (natural resources, their state and development), and human factors (developers and performers of environmental programmes, projects, performance of functions, environmental measures, etc.), which, due to the presence of their personal economic interests, can treat and react to the purposeful influence on the environmental system differently.

Research of environmental security as an object of management

Environmental security is a complex concept, and therefore is studied by researchers in various functional and subject formats. Functional formats, according to the authors, can be called precisely functions in ensuring and maintaining such security, that is:

– development of an appropriate strategy;

– organisation of infrastructure for its practical implementation;

– environmental risk management, establishment and implementation of standards, limits, quotas, payments for special use of natural resources and fines for environmental pollution;

– planning and organisation of work on the sparing use of natural resources, keeping records of their reserves and consumption volumes;

– environmental control, etc.

The fundamentally functional interpretation of environmental security is officially defined by the Law of Ukraine "On the Fundamental Principles (Strategy) of the National Environmental Policy of Ukraine for the Period up to 2030" [4] and is stipulated in the Regulation "On the State Environmental Inspectorate of Ukraine" [6]. In particular, the above law sets important strategic tasks to strengthen the efficiency and effectiveness of these functions, namely:

– "strengthening institutional capacity to plan, monitor, and evaluate the effectiveness of environmental policy implementation;

– introduction of environmental accounting to evaluate the effectiveness of policy and management;

– provision of scientific and informational and innovative support for the managerial decision-making process;

– strengthening the ability of environmental management to conduct comprehensive monitoring of the state of the natural environment and state control concerning environmental security, rational use, reproduction, and protection of natural resources;

– differentiation of functions for environmental

protection and economic activities for the use of natural resources;

– ensuring a clear distribution of powers concerning environmental protection at the state, regional, and local levels;

– improvement of personnel policy and professional training of specialists in the system of environmental protection and nature management" [4].

The subject format concerns the consideration of the management of natural resources of a certain, particular type: land, namely landscape resources, for example: [7-10]; water resources, specifically marine and river ecosystems [11-13]; forests, namely wood and plant resources [14-16]; atmospheric air, even bees [17]. A combined, i.e., functional-subject approach to ensuring the functioning of the environmental security system is developed by special departments and assigned to particular executors. Thus, the environmental security system in the understanding of the authors can be presented as a combined matrix, which unites functional and subject formats (Table 1).

***Table 1**. A combined matrix that unites the functional and subject formats of an environmental security system*

Parameter	Natural resources				
Functions	**Land**	**Water**	**Forest**	**Atmospheric air**	**Other**
Environmental strategy development					
Environmental infrastructure organisation					
Environmental risk management					
Establishment and implementation of standards, limits, quotas, payments, and fines					
Planning and organisation of sparing use of natural resources					
Accounting for reserves and consumption of natural resources					
Environmental control					

***Source**: developed by the author V.M. Antonenko*

It is clear that for each type of natural resources, all the functions listed in the figure must be performed. In general, environmental measures should contribute to improving the environmental situation, positively affecting the state and development of the ecological system, but the authors also emphasised that all functions can be implemented only through the involvement of specialists – their executors, who would perform them if they have their personal economic interests (see Fig. 2).

For example, relevant state or public institutions are involved in the development and implementation of environmental strategies for any natural resources; therefore, it is appropriate to evaluate the results of their work and form their remuneration depending on the implementation of the corresponding strategies. The introduction of standards, limits, quotas, payments, and fines should take place in such a way that the persons for whom restrictions or payments are established are economically incentivised in sparing environmental security activities, that is, that the size of such economic levers of influence is economically tangible for them. Therewith, environmental control requires bringing to justice all violators of established environmental standards; moreover, to increase the probability of their detection and prosecution, regulatory authorities should receive sufficient remuneration so that they are not tempted, for example, to engage in any illegal corruption activities.

Thus, the mechanism of influence on environmental security is based on the economic interests of all stakeholders. As a matter of fact, this position requires a revision of the essence of the current and fairly common ecosystem approach to the study of natural resource management in the specialised literature.

Research and meaningful development of the category "ecosystem approach" with the inclusion of the human factor

The officially recognised interpretation of the term "ecosystem approach" was adopted and introduced in 2000 at the V Conference of the parties to the Convention on Biological Diversity [18]. Withing the framework of the development of this Concept, decision V/6 "Ecosystem Approach" was adopted in 2000, the annex to which

contains a description of the ecosystem approach (Section "A"): "ecosystem approach means an integrated management strategy for land, water and bioresources that ensures their conservation and sustainable use on an equitable basis. It is based on corresponding scientific methodologies covering all levels of biological organisation, including the main processes, functions, and relationships between organisms and the environment" [19].

As the above interpretation of the essence of the ecosystem approach suggests, there is no express and specific mention of the obligation to consider both the human factor (executors of functions) and their economic interest in the qualitative and effective performance of these functions. This, according to the authors, is somewhat erroneous and in practice can provoke failures in the functioning of the system under study. Notably, this aspect largely concerns the Ukrainian reality rather than the European or American one, since the underdevelopment of the functional content of the system under study and the lack of adequate performance of these functions in Ukraine is a generally recognised fact.

Therewith, considering economic issues relating to the green economy, Cameron Allen wrote: "It is important to conduct an informed analysis of policy measures, identify major trade-offs and synergies between economic, environmental, and social goals, and use this information to establish policy priorities. An important component of this is cost-benefit analysis, which requires adequate information about the costs associated with policy implementation" [3, p. 30]. In other words, the researcher emphasised the need to consider economic goals and interests, as well as to analyse costs and benefits upon implementing environmental policies.

As the analysis of specialised literature has shown, at present, apart from the ecosystem approach, such synonyms as "ecosystem management", "management based on the ecosystem approach", "ecosystem-oriented approach", "ecosystem management approach", "integrated approach" are also used. Furthermore, some researchers focus on highlighting, for example, an ecosystem approach to fisheries, integrated river basin management, or integrated marine and coastal management. According to the authors, the essence of the ecosystem approach lies not in the use of new terms or names of natural resources, but rather in the mechanism of management involving economic interests. Only a few authors dare to somehow include the human factor in the concept of an ecosystem approach (Table 2).

***Table 2**. Content analysis of ecosystem approach definitions with the inclusion of the human factor*

Author(s)	Definition
M.A. Deineha [20, p. 132-133]	The ecosystem approach is a tool that allows considering the relationships within ecosystems with other systems and **people for whom ecosystems are a place of residence and a means of subsistence**. The ecosystem approach relates to how the use of ecosystems by a person is affected by their functioning and productivity. Ecosystem approach **includes people... human needs** are associated with the biological capacity of ecosystems to **meet these needs**
N.M. Nechyporenko [12, p. 34]; I.B. Hobyr [21, p. 249]	The ecosystem approach is based on a new integrated approach, which involves a continuous comprehensive understanding of the essence of ecosystems, the products and services they provide, as well as support, **with the participation of people**, their productivity. The ecosystem approach recognises that people with their socio-cultural diversity **form an integral and active component of ecosystems**
N.V. Dehtiar [13]	Upon determining the state of an ecosystem, attention is often focused only on the biological components of ecosys-tems, while others include the functioning of the ecosystem or **aspects of physical, human, and economic dimen-sions**. The ecosystem approach constitutes a methodological framework for justification of management decisions made by **economic entities** in the process of designing development strategies and forming planning methods
Ye.P. Suietnov [19, p. 199]	The ecosystem approach is designed to guarantee a fair **distribution of all benefits** derived from the use of biodi-versity, **among all people** at the local, state, regional, and global levels
K.P. Smith, A.T.F. Bernard, A.T. Lombard, K.Y. Sink [22, p. 11]	The idea of a socio-ecological system stems from an ecosystem approach to management, which considers the social benefits of rendering ecosystem services, as well as **effects of human pressure** on the integrity of marine ecosystems

***Note**: The bold text highlights the proof that human participation and economic interests (benefits) are considered to form an integral and active component of ecosystems*
***Source**: developed by the author V.M. Antonenko*

It is the human factor, based on the economic interests and benefits of people (as consumers of ecosystem services, managers in the environmental sphere, or executors of environmental functions), that will contribute to the effective functioning and long-term development of environmental systems. In this sense, the ecosystem approach can have the following definition: it is an integrated system method of ensuring the effective functioning and long-term development of ecosystems, including natural resources and human factors (consumers of ecosystem services, managers in the environmental sphere, or executors of environmental functions), which is based on consideration of and attracting the economic interests of stakeholders as the main economic method of exerting influence by the managing system on the managed one.

Effective functioning and long-term development of ecosystems is possible only if economic growth is outperforming compared to the accumulation of environmental issues, which relates to decoupling – the gap between economic growth and reduction of the anthropogenic load on the environment [5, p. 31]. Ursula von der Leyen, President of the European Commission, quite aptly refers to the need for humankind to ensure this gap between economic growth and the anthropogenic load: "the European green course is our new growth strategy. It shows how to change our way of life and work, production and consumption so that we live healthier and make our business more innovative. We will help our economy become a global leader by moving quickly" [23]. Such a vector in the development of ecosystems should also be a reference point for Ukraine.

CONCLUSIONS

From the standpoint of a systematic approach, national security, has a structured hierarchy wherein all its components occupy a certain systemic place, among which environmental and related economic components are becoming increasingly more relevant. Their combination into a single ecosystem (meaning the integration of ecological and economic subsystems) is considered as an objective basis for the existence of effective factors for its efficient functioning and solving pressing environmental issues. Management of this integrated system is based on the fact that the economic subsystem acts as a managing subsystem, while the environmental subsystem acts as a managed subsystem.

In the ecological system, researchers quite frequently include exclusively natural resources that cannot directly respond to managerial actions stemming from the management subsystem, since management teams can only be perceived by people. Therefore, the environmental system should include both natural and human resources (consumers of ecosystem services, managers in the environmental sphere, or executors of environmental functions). Moreover, proceeding from the theory of management and the necessity of applying incentives, consumers of environmental services, managers in the environmental sphere, or executors of environmental functions should be economically interested in the effective functioning of the environmental system. It is the economic method of management that is based on the economic interests of stakeholders that is most effective. Thus, the authors corrected the definition of an ecosystem approach, which, in contrast to the generally accepted one, includes a managerial aspect, namely considering the economic interests of participants that ensure the functioning of ecosystems.

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Екосистемний підхід у контексті управління економічними інтересами

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Анотація. Актуальність теми статті зумовлена необхідністю пошуку шляхів вирішення проблеми екологічної безпеки та забезпечення ефективного управління нею. Метою дослідження було структурування системи національної безпеки з виділенням екологічної і економічної підсистем, конструктивний і критичний аналіз основних поглядів та позицій вчених щодо сутності та напрямів екосистемного підходу у вирішенні проблеми екологічної безпеки, подальший розвиток екосистемного підходу на основі економічних методів управління. Дослідження базується на використанні системного та матричного підходів, методів узагальнення, моделювання, аналізу та синтезу, контент-аналізу. Доведено, що система національної безпеки включає, зокрема, екологічну та економічну підсистеми та що між цими підсистемами об'єктивно існує внутрішній системний зв'язок, який при правильному використанні має забезпечити ефективне функціонування та розвиток обох підсистем. Окреслено функціонально-предметну матрицю системи екологічної безпеки, що сприятиме систематизації різних напрямів у її дослідженні. Встановлено, що з позицій теорії управління екологічна підсистема визначається як керована, а економічна – як керуюча; а управління забезпечується тим, що перша має у своєму складі не тільки природні, а й людські ресурси (споживачів екосистемних послуг, управлінців в екологічній сфері чи виконавців екологічних функцій). Обґрунтовано, що для ефективного вирішення екологічних проблем необхідно враховувати економічні інтереси таких людей, оскільки економічні інтереси є основою економічного (найефективнішого) методу управління. Практична цінність дослідження полягає у розробці економічного методу управління системою екологічної безпеки та обґрунтуванні ролі економічних інтересів, що сприятиме практичному вирішенню екологічних проблем в Україні

Ключові слова: національна безпека, екологічна проблема, економічна безпека, управління екологічною безпекою, природні ресурси

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State and Trends in the Banking System Development in the Context of Structural Reform of the National Economy of Ukraine

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Abstract. The relevance of the study was conditioned by the fact that the fulfillment of the banking system potential can ensure positive structural changes in the Ukrainian economy. The purpose of the study was to analyse the state and trends in the development of the banking system of Ukraine in terms of its impact on the structural reform of the national economy. In the course of this study, statistical analysis methods were used (to analyse the state and dynamics of the country's banking system development) and an analogue method (to identify the degree of influence of the banking system development on structural changes in the economy). It was proved that the effective functioning of the banking system is the key to successful economic development of the national economy, namely its reform. It was demonstrated that a mechanism for redistributing financial resources and funds operates through the banking system, so they are mobilised and attracted to economic circulation in those sectors of the economy that need it most. The study summarised the state and trends in the banking system development as prerequisites for fulfilling its potential in the structural reform of the national economy. As a result of analysing the state and trends in the banking system development, both positive and negative features were identified. It was proved that in Ukraine, at the current stage of the national economy development, the banking system has been cleared of low-liquid and conditionally fictitious banking structures, the volume of assets, namely highly liquid ones, is growing, as well as the loan portfolio of banks is improving along with their financial results, liquidity, and solvency, resistance to currency shocks are increasing, and bank lending to the economy is reviving. It was demonstrated that the Ukrainian banking system is described by certain systemic shortcomings, primarily a high level of concentration of bank capital and deposits in the largest banks, as well as state-owned banks in a number of segments of the banking sector in terms of the number of structural divisions, ATMs, terminals, active payment cards. There is a tendency to weaken the penetration of the banking sector into the economy, especially in terms of affordable lending to individuals and strategic sectors of the economy. The practical value of the study lies in the fact that the identified shortcomings in the development of the banking system and its impact on structural reforms allowed determining the strategic areas for improving state regulation in this area

Keywords: economic development, performance indicators of banks, volume of financial resources, lending to the economy, systemic shortcomings

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INTRODUCTION

The institutional elements of the banking system of Ukraine were developed and functioned as part of the financial system of the USSR, and in late 1991 – early 1992, Ukrainian commercial banks were re-registered, which, in fact, marked the beginning of the banking system development of the young state. At the present stage of development of independent Ukraine, the banking system has undergone numerous evolutionary changes, both qualitative and quantitative. It is natural that at each of these stages, the impact of the development of the banking system on the functioning and development of the national economy, its real sector, and the formation of changes in basic structural characteristics was different both in areas and nature. At first, it was to support business entities in the transition to a market-based management system by providing them with a set of banking services, capital placement and insurance, and business lending.

In accordance with the strengthening of the banking system, the supply of banking products and services, as well as its role in the national economy, has also evolved. The crises of 2008-2009 and 2014-2015 became pivotal for both banking and the Ukrainian economy. When both the financial and real sectors of the economy failed, which, among other things, confirmed the yet insufficient maturity, power, and development of the banking sector and its inability to perform functions relating to the stabilisation of the national economy, the development of its financial and economic stability, resistance to external and internal risks and threats, financial and economic shocks.

Thus, the National Bank of Ukraine introduced the policy of increasing transparency, activity of operations with derivatives, reducing the share of borrowed funds in the structure of bank capital and at the same time the introduction of a stimulating soft monetary policy of activation and dynamic development of lending by banks to enterprises and their innovation and investment projects, the development of microlending for small and medium-sized businesses as a necessary condition for structural reforms of sectors of the Ukrainian economy. These steps became critical for the development of the modern Ukrainian banking system.

In general, in recent years, more and more studies of Ukrainian researchers have appeared in the economic literature, using various standpoints to cover the issues of structural reform of the Ukrainian economy in general and the banking sector in particular. Thus, I. Ivashchuk and A. Ivashchuk noted the areas of transformation of the banking system in their research [1], ways to improve the efficiency and competitiveness of the banking sector became the subject of research by Ya.I. Tchaikovsky [2], G.T. Karcheva [3], promising vectors of development of banking credit activity and its impact on the real sector of the economy were investigated by O.V. Gasi and V.I. Klimenko [4], O.S. Irshak and I.Ya. Leshchuk [5]. Relevant issues of the banking system functioning and ensuring banking security of the state in the context of the information economy development, its digitalisation and development of non-cash payment infrastructure, the cryptocurrency market and electronic credit platforms were covered in the studies by S.A. Kuznietsova, T.M. Bolhar, Z.S. Pestovskaya [6], V.V. Glushchenko, D.M. Soloviov [7], M.I. Zveriakov, L.V. Zherdetska [8], A.I. Hulei [9], D.M. Hladkykh [10], V.A. Kornovska [11], O.I. Tkachenko [12], M.M. Bil, O.P. Mulska [13], T.H. Vasyltsiv, V.V. Boyko, S.S. Hrynkevych [14-15]. In general, these studies justified the role and place of the banking system of Ukraine in the implementation of national economic interests at a high scientific level, but the issue of evaluating the potential of the banking sector in the context of systemic reform of the Ukrainian economy remains understudied.

The purpose of this study was to generalise the state and trends in the development of the modern banking system of Ukraine as prerequisites for fulfilling its potential in the structural reform of the national economy.

MATERIALS AND METHODS

The theoretical and methodological framework of this study included fundamental and applied studies of Ukrainian researchers concerning the investigation of the state and trends in the development of the banking system of Ukraine, considering its elements, functions, and potential in ensuring economic growth. A set of general scientific and special methods and techniques was used to solve the analytical problems of this study, namely:

1) analysis, synthesis, comparison, structural analysis – upon identifying the main trends of generalising indicators of the banking system development in Ukraine regarding the quantitative and structural composition of the banking system; the network of banks, financial organisations and their institutions; internal, attracted funds of banks; participation of foreign capital in the bank's activities; financial results (income, expenses, and profit of banks; balance of credit resources and their use, etc.;

2) graphical and tabular – for compelling representation of the study results, evaluation and analysis of processes in the banking system of Ukraine;

3) generalisation and abstraction – upon forming conclusions about the positive and negative aspects of the current state of the banking system development and determining its possible impact on the structural reform of the economy.

The information basis of the study included statistical data of the National Bank of Ukraine, monographic and fundamental studies of Ukrainian researchers, as well as analytical calculations performed during the study.

In this study, the authors developed an original methodology for analysing the impact of the functioning and development of certain segments of the national economy on stimulating structural changes and reforms. In particular, the authors' methodology makes provision for the implementation of economic and analytical calculations, as a result of which, using the method of strategic management, a matrix is built, the left part of which is built in accordance with the method of SWOT analysis, but is based on positive and negative aspects of, on the one hand, the state of development, and, on the other hand, the trends in the country's banking system development. The right-hand part of the matrix projects the results obtained on the conclusions in the context of their impact on the structural reform of the national economy of the country. It is this approach that allows justifying the most accurate and balanced management decisions in the context of not only stimulating the growth and improving the efficiency of the banking system, but also the most complete use of the potential of these processes for structural reform of the country's national economy.

RESULTS AND DISCUSSION

Dynamics of institutional and organisational elements of the banking system of Ukraine

Researchers monitoring and analysing the state and trends in the development of the banking system of Ukraine tend to identify several stages in the evolution of the banking system of Ukraine (Fig. 1).

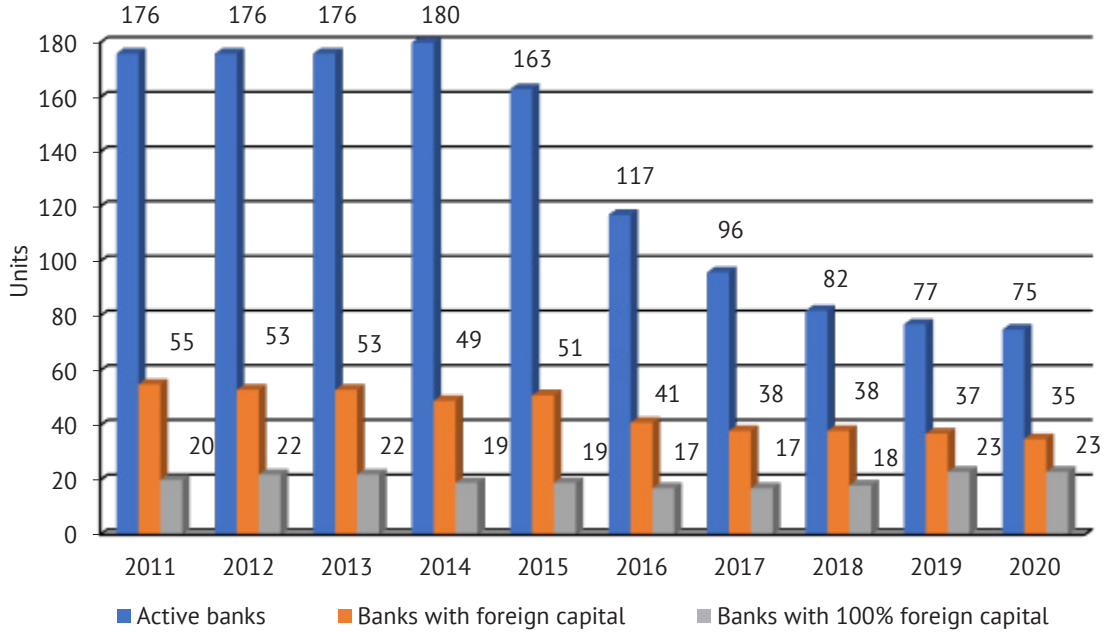

Figure 1. *Number of operating banks in Ukraine as of January 1, 2011–2020*

Source: *compiled by the authors based on [16]*

At first glance, a decrease in the total number of banks from 180 units as of January 1, 2014 up to 75 units as of January 1, 2020 appears to have weakened the potential of the banking system of Ukraine. Since the positive consequences of the so-called "great cleansing" are to strengthen the confidence of depositors in the preservation of their funds, the direction of financial resources by banks to lend to the real sector of the economy, in particular in the segment of small and medium-sized businesses, the growth of the volume of available credit resources, the localisation of capital in the internal market as opposed to its withdrawal abroad, increasing the level of stability of banks to financial and macroeconomic shocks, the growth of the overall effectiveness of monetary policy, which is implemented by the National Bank of Ukraine.

In 2020, there were 75 operating banks in Ukraine, including 35 banks with foreign capital, of which 23 units with one hundred percent foreign capital. If during 2011-2020 the total number of banks in Ukraine decreased by 2.3 times, the number of banks with foreign capital decreased by 36.4%, and with one hundred

percent foreign capital increased by 15.0%. Notably, between 2016 and 2020, the number and the share of banks with one hundred percent foreign capital in Ukraine increased (by 6 units and 35.3%, respectively). This, against the background of a certain stabilisation of the number of operating Ukrainian banks, is evidence of increased sustainability, as well as an increase in the transparency of capital and the banking system, which closely correlates with the further development of the potential of the country's banking sector.

This is also confirmed by decline in the rate of reduction in the number of solvent banks. For example, if in 2014 there were 16 insolvent banks in the country (10.9% of their total number), and in 2015-2014 the number of solvent banks decreased by 30 units or by 20.4%, then in 2020–2019 is decreased only by 1 unit. The number of state-owned banks – 5 units – has remained unchanged over the past four years, and their share in the total number of banking structures in 2014-2020 increased by 2%. At the same time, state-owned banks remain one of the largest on the market and, accordingly, have a fairly significant influence on the activities of enterprises and economic processes that take place in the country, in its production complex, and in the internal consumer market.

In 2014-2020, the structural ratios relative to the number of foreign and private banks changed to a certain extent. Thus, the share of foreign banks in 2014-2020 increased by 10.02%, while the share of private banks decreased by 12.01%. This indicates a higher sustainability and stability of foreign banks' activities against the background of relatively weak viability of Ukrainian private banks. Consequently, the growth in the number and share of more financially capable banking structures, on the one hand, can be considered a positive trend. However, on the other hand, an increase in the share of foreign capital in the banking system can threaten banking security, undermining the foundations of the country's financial and economic security.

In this regard, special attention and status are given to monitoring the level and structure of foreign capital in the country's banking system to ensure timely monitoring of the negative trends and processes associated with the dependence of the banking system on large non-resident banks, possible withdrawal of capital abroad, and monopolisation of certain segments of banking services.

The negative aspect of forming the potential of the banking sector in terms of structural reform of the national economy can be attributed to the reduction in the number of structural divisions of banks, which was typical for Ukraine during 2013-2020 and led to a deterioration in banking coverage of the country, its territories, population, and business entities. In addition, the rate of decline in the number of structural divisions of banks has become almost commensurate with the rate of decline in the total number of banks in the country, which is evidence of a deterioration in the institutional and economic capabilities of banks, because with a decrease in their total number, the number of structural divisions should grow and in place of banking structures that went bankrupt or left the market for other reasons, branches of existing solvent banks should "come", but this did not happen. Thus, stagnant trends in the deformation of the network of banking structures at the present stage of the country's development still take place and this objectively worsens the ability of the system to properly serve both the population and businesses in terms of capital allocation and obtaining proper credit resources.

Thus, if in 2013 there were 19.3 thousand units in Ukraine, by 2020, this indicator decreased to the level of 7.3 thousand units, which was 2.6 times less [16]. In 2019-2020 alone, the number of structural divisions of banks decreased by about 700 units (by 8.7%). Notably, the reduction in the number of structural divisions of banks has become typical for both state-owned banks, and PJSC CB PrivatBank, foreign, and private banks. However, this is mainly due to a particularly active reduction in the number of structural divisions directly in the segment of private banks. In particular, in 2013-2020, the indicator here decreased by 8.0 thousand units, and in relative terms – 5.4 times, which is substantial. Consequently, the share of structural divisions of private banks, which in 2013 exceeded 50.0%, by 2020 decreased to 24.7% (the reduction was 26.1%). This, on the one hand, is a consequence of the "cleansing" processes in the Ukrainian banking system, but at the same time indicates a deterioration in the capabilities of the private bank segment to provide full system service for the national economy.

Another notable aspect is the presence of an extensive network of structural divisions of state-owned banks, which, together with a considerable share of structural divisions of PJSC CB PrivatBank, indicates a certain hidden monopolisation of the network of banking structures. After all, 5 state-owned banks (6.8% of the total number) as of 2020 accounted for 56.2% of the total number of structural divisions of banks [16].

Unfortunately, the tendency to reduce the number of structural divisions of banks has become inherent in all regions of Ukraine without exception, which has further complicated the issue of fulfilling the potential of the banking system in structural reform of the economy

at the regional and subregional levels. In particular, the highest rates of decline in 2016-2020 were typical for such regions of the country as Zakarpatska Oblast (35.7%), Kyivska Oblast (36.6%), and Cherkaska Oblast (34.2%) [16]. The functioning of structural divisions of banks in Donetska, Zhytomyrska, Luhanska Oblasts and the city of Kyiv remained more stable. In these regions, the rate of decline did not exceed 20%. According to the largest number of structural divisions of banks per 100 thousand people, the authors can distinguish the cities of Kyiv, Odeska, Poltavska, Dnipropetrovska, Zaporizka, and Kharkivska Oblasts.

The presence of trends towards a certain monopolisation of the Ukrainian banking sector is also confirmed by data on the development of banking infrastructure, namely the number of ATMs and payment terminals. Thus, in 2013-2020, there was a clear tendency to increase the number of ATMs and terminals of state-owned banks (by 2.3 times) and the number of terminals of PJSC CB PrivatBank (by 70.9% in 2020-2016) [16].

As a result of these trends, as of 2020, a situation was formed when the share of PJSC CB PrivatBank in the total ATM network was 56.6%, and of state-owned banks – 21.8%; the corresponding indicators in the total network of terminals were 58.3% and 19.5% [16]. At the same time, the total share of foreign and private banks in the ATM system in 2020 dropped to 21.6%, and payment terminals – to 20.9%. On the other hand, the position of the private banking sector in the segment of active payment cards has also strengthened. Although the share of private banks in terms of the number of active payment cards issued in Ukraine in 2020 was only 13.0%, for 2016-2020 the indicator increased 2.4 times (from 2.1 million units to 5.0 million units) [16]. Therewith, the share of private banks increased by 6.5%.

The position of state-owned banks remains stable in this segment of banking services. Thus, despite the fact that the share of this group of banks in terms of the number of active payment cards in 2016-2020 slightly decreased (by 3.1%), the number of active payment cards did not change and amounted to 6.5 million units. The authors also noted the growth of the positions of PJSC CB PrivatBank against the background of their weakening in the group of foreign banks. Thus, in 2020, the share of PJSC CB PrivatBank in the total number of active payment cards increased to 57.3%, while the share of foreign banks decreased (by 6.4%); the number of active payment cards issued by foreign banks decreased from 6.2 million units up to 4.9 million units (the reduction was 21.0%). It can be summarised that, on the one hand, the high quality of payment card service, as well as the innovation of consumer banking services in the system of PJSC CB PrivatBank, contributes to improving the level of quality of public service. However, monopolisation of any sphere in the short or long term leads to negative consequences and does not contribute to competition as one of the important and integral features of the structural reform of the national economy of the country and its financial system.

Volumes, structure, and sources of formation of bank assets in Ukraine

The possibilities of the banking sector in terms of raising capital, as well as lending to the national economy, are largely evidenced by trends in changes in the volume and structure of assets and liabilities of banks (Table 1).

***Table 1**. Assets of commercial banks of Ukraine as of January 1, 2011-2020*

Indicators	Years							Growth rate, % / Absolute deviations (+/-)	
	2011	2013	2015	2017	2018	2019	2020*	2020/ 2011	2020/ 2019
Assets, billion UAH	942.1	1,127.2	1,316.7	1,256.3	1,336.4	1,360.8	1,494.5	158.6	109.8
Loans granted, billion UAH	755.0	815.3	1,006.4	1,005.9	1,042.8	1,118.6	1,033.5	136.9	92.4
Share of loans in assets, %	80.1	72.3	76.4	80.1	78.0	82.2	69.2	-10.9	-13.1
Loans granted to business entities, billion UAH	508.3	609.2	802.6	847.1	870.3	919.1	822.0	161.7	89.4
Share of loans granted to business entities, %	67.3	74.7	79.8	84.2	83.5	82.2	79.5	+12.2	-2.6
Loans granted to individuals, billion UAH	186.5	161.8	179.0	157.4	170.9	196.6	206.8	110.9	105.2

Table 1, Continued

Indicators	Years							Growth rate, % / Absolute deviations (+/-)	
	2011	2013	2015	2017	2018	2019	2020*	2020/ 2011	2020/ 2019
Share of loans granted to persons, %	24.7	19.9	17.8	15.7	16.4	17.6	20.5	-4.7	+2.4
Share of overdue loans in the total amount of loans, %	9.6	7.7	21.2	23.7	54.5	52.9	48.4	+38.8	-4.5
Reserves for active bank operations	148.8	141.3	204.9	484.3	516.9	555.9	492.1	3.3	88.5
Share of reserves in assets, %	15.79	12.54	15.56	38.55	38.68	40.85	32.93	+17.1	-7.9
Share of reserves in loans, %	19.71	17.33	20.36	48.15	49.57	49.70	47.61	+27.9	-2.1

***Note**: * – data as of September 2020*
***Source**: compiled by the authors according to the data from [17-18]*

In particular, the growth of assets objectively expands the ability of banks to lend to business entities and the population. In this regard, it is positive that in all years of the 2011-2020 period (except 2015), an increase in the volume of banks' assets was considerable. In 2011-2020, the indicator increased by more than UAH 0.5 trillion, or by 58.6%. Notably, the growth of bank assets in 2016-2020 is mainly typical for private banks (by 52.8%) and PJSC CB PrivatBank (by 52.3%). The volume of assets of state-owned banks also increased (by 25.1%). While the total amount of assets of foreign banks for the analysed period of time remained virtually unchanged (UAH 612 billion against UAH 604 billion).

If the situation with PJSC CB PrivatBank concerned its artificial recapitalisation, then the increase in total assets of private banks can be considered as a positive phenomenon, which will help expand their capabilities in terms of increasing the volume of activities and increasing the level of its financial and economic and commercial efficiency. The increase in net assets in this segment of the banking system (in 2017-2020) ensured the preservation of the corresponding share of net assets of private banks. Thus, at first, after the nationalisation of PJSC CB PrivatBank, the share of net assets of private banks in 2016 decreased to 29.7%, but as of 2020 it increased to 35.9%.

The structure of net assets of the banking sector of Ukraine by components is also described by certain disadvantages. In 2016-2020, the weight of such a source of net asset formation as internal governmental bonds (hereinafter referred to as "the IGB") considerably increased – from 19.3% in 2016 to 29.0% in 2020. This has its advantages and disadvantages. As for the shortcomings from the standpoint of the state's macroeconomic policy, these are one hundred percent guarantee obligations of the state to repay them, and, consequently, the need to divert an extensive financial resource to these purposes, in particular to cover financial risks, high maintenance costs (as compared with other sources of formation of net assets of banks), the lack of receipt of personal income tax to the budget, etc. Given the above, the tendency to reduce the share of loans of business entities in the structure of net assets of banks can be evaluated negatively. The indicator in 2016 was 38.0% and by 2020 it decreased to the level of 25.3%.

The positive trend is the growth of the share of funds of the NBU and other banks (from 14.2% in 2016 to 18.2% in 2020) and the share of loans to individuals (from 6.0% in 2016 to 8.4% in 2020). Raising funds from these and some other sources is more reliable and economical for the subjects of the country's banking system, and, consequently, allows forming a less cost-intensive and more competitive banking product for both businesses and the population, implement a number of programmes and projects concerning the support of the structural reform of the country's national economy. The authors summarised that the banking system of Ukraine generally operates with sufficient amounts of financial resources to provide financial and credit support to the economy, because considerable amounts of funds are in correspondent accounts of banks with the NBU and other banks, invested in interbank loans, IGB, NBU certificates of deposit. The lion's share of these funds could be used for long-term lending to investment and innovation projects of subjects of the real sector of the national economy, qualitative development of consumer lending, and expanding the capacity of the internal market.

The banking sector of Ukraine is monopolised at a fairly high level. This conclusion is confirmed by the considerable shares of the largest banks in the net assets of the country's banking sector. Thus, in 2020, the share of the largest bank was 20.6% and by 2016 this indicator increased by 3.0%. Evidently, this situation not only discourages proper competition, hinders the

complete fulfilment of the banking system's potential for economic growth, but the banking system itself requires structural reforms. The segments of deposits of individuals remained quite concentrated both as of 2020 and especially during 2017-2019 (with the value of the Herfindal-Hirschmann index up to 1,000, which corresponds to a weakly concentrated environment, the indicator value of total assets ranged from 1,581 to 1,738 in 2016-2020. At the same time, the value of the concentration indicator in the net asset segment is also approaching 1,000.

Trends and problematic aspects of Ukrainian bank lending

To a certain degree, the growth of bank assets has become one of the factors and prerequisites for increasing the volume of bank lending. However, its growth rate has not become equal and comparably stable. Thus, in 2011-2020, the volume of loans granted increased by 36.9%, and in certain years (2013, 2017, and 2020) was lower than in the previous year [16]. This led to a decrease in the level of lending (to the amount of bank assets) (by 10.9%) in 2020, when the indicator was 69.2%, compared to 2011 (81%).

Notably, the reduction in absolute values and growth rates of lending volumes was more typical for the individual segment. Thus, with the overall growth in the volume of loans granted to individuals (by 10.9% in 2020-2011), the share of such loans decreased (by 4.7%) [16]. While the share of loans granted to business entities for the same time period increased (by 12.2%). As of 2020, the ratio between the shares of lending to legal entities and individuals was 79.5% to 20.5%. Consequently, there are grounds to conclude on the deterioration of the banking system's contribution to structural changes relating to stimulating internal consumer demand, increasing the level of purchasing power of the population and improving its accessibility to goods and services, especially for investment purposes, and improving the quality of life.

Another negative aspect is related to the low volume of lending to the national economy, which was largely conditioned by the limited assets of banks, since the share of loans in assets remained quite high. Therewith, as of January 1, 2019, the assets of Ukrainian banks in foreign currency (USD) amounted to 36.4%, and as of January 1, 2020 – to 32.9% [16]. Thus, despite the reduction in the share of banks' assets in foreign currency, the level of this indicator is still quite high.

It is worth paying attention to the increase in the level of overdue debt on loans in the total amount of loans, which is evidence of insufficient solvency of borrowers, on the one hand, and a certain discrepancy between the credit conditions and the capabilities of business entities regarding timely repayment of the loan body and servicing interest on loans, on the other hand. Thus, as of January 1, 2019, the share of overdue loan debt in the total amount of loans increased to more than half – 52.9%. In 2020, the indicator, although it decreased to 48.9%, further signalled the preservation of a critically high level of overdue credit debt [16]. State-owned banks continued to predominate in terms of problem loans (49.3%), while private banks continued to have a moderate level of problem loans (18.6%). The share of overdue debt on loans from foreign banks was considerably higher – 32.5%.

The deterioration of the quality structure of bank lending is also evidenced by an increase in the level of reserves in both assets (by 17.1 percentage points in 2011-2020) and loans (by 27.9 percentage points) of banks. Thus, starting from 2020, there has been a definite tendency towards an improvement in the situation and a gradual decrease in the level of provisioning of credit operations by banks. Thus, the share of problem loans in the banking system of Ukraine remains substantial, but does not generate critical risks and threats, since the level of coverage of such loans by reserves exceeds 95%.

State and structure of bank liabilities in Ukraine

As for a factor of weakening the potential of the banking system in ensuring economic growth and structural reforms, the authors considered it to be the structure of liabilities, namely with an emphasis on the financial stability of banks in Ukraine. As of 2020, the structure of banks' liabilities continued to occupy a fairly high share of such a source of financial resource formation as funds of individuals – 36.9% or UAH 552.6 billion. At the same time, in recent years, banks' attraction of funds from business entities has also been actively increasing. If the share of this source of liability formation in 2011 was 15.3%, then in 2020 it was 33.3%; the total amount of capital raised by banks from business entities for the analysed time period increased 3.5 times.

In general, this trend is positive, but it should be supplemented and developed towards improving the structure of funds of the population and business entities attracted by banks, because today there is a meagre share of funds that are distributed for a long time, for example, more than 2 years. Accordingly, this makes it impossible for banks to fully develop long-term lending programmes for enterprises in the real sector of the national economy. Thus, the most important task for the Ukrainian authorities is to restore the deposit market, especially in terms of attracting long-term financial resources in the national currency.

The structure of liabilities in the banking system of Ukraine is dominated by the share of state-owned banks, which, on the one hand, indicates a high level of ability of these structures to attract financial resources, and, on the other hand, can serve as a factor of a lower level of their financial stability, growing dependence on debt obligations, increasing potential threat of a general destabilising impact on the country's financial system. In 2013-2020, the share of state-owned banks in the liabilities of banks in Ukraine increased from 16.96% to 34.33%, and in absolute terms, the amount of liabilities increased 2.8 times (Table 2).

***Table 2**. Volumes and structure of liabilities by bank groups in Ukraine in 2013-2020*

Indicators	Years								Growth rate, % / Absolute deviations (+/-)	
	2013	2014	2015	2016	2017	2018	2019	2020*	2020/ 2013	2020/ 2019
Total, billion UAH	1,085	1,130	1,151	1,133	1,173	1,205	1,293	1,500	138.3	116.01
State-owned banks, UAH billion	184	243	338	399	423	430	474	515	2.8	108.7
Share of state-owned banks, %	16.96	21.50	29.37	35.22	36.06	35.68	36.66	34.33	+17.4	-2.3
PrivatBank, UAH billion	n/a	n/a	n/a	206	234	171	188	240	116.5	127.7
PrivatBank's share, %	n/a	n/a	n/a	18.18	19.95	14.19	14.54	16.00	-2.2	+1.5
Foreign banks, UAH billion	231	357	406	376	357	353	372	442	191.3	118.8
Share of foreign banks, %	21.29	31.59	35.27	33.19	30.43	29.29	28.77	29.47	+8.2	0.7
Private banks, UAH billion	670	530	407	149	150	251	260	302	45.1	116.2
Share of private banks, %	61.75	46.90	35.36	13.15	12.79	20.83	20.11	20.13	-41.6	+0.03

***Note**: * – data as of September 2020*
***Note**: * * – until 2016*
***Source**: compiled by the authors according to the data from [17-18]*

At the same time, against the background of growing obligations of state-owned banks, they do not perform their inherent functions and tasks regarding financial support for the implementation of structural reforms that are strategically important for the national economy (in particular, in terms of public-private partnership projects, strategically important industries, modernisation of the public sector, etc.). Notably, the volume of liabilities of foreign banks increased quite significantly (by 91.3% in 2020-2013). Due to this, their share in the structure of liabilities increased by 8.2%. A certain increase was also inherent in the obligations of PJSC CB PrivatBank, which in 2016-2020 increased by 16.5%, but at the same time the share of PJSC CB PrivatBank even decreased by 2.2%.

Thus, there was an evident decrease in the participation of private banks in the formation of obligations of the Ukrainian banking system, when the volume of such banks in 2013-2020 more than halved, and their share decreased by 41.6%. Again, this trend has both positive (a decrease in the level of financial dependence of private banks) and negative (a shortage of financial resources for resuming long-term lending projects to the economy) aspects.

Deposits in the banking system: Trends and causes of instability

It has already been noted that both the volume and growth rate of deposits of individuals in the banking system of Ukraine are insufficient and constitute of the main factors in the development of a shortage of financial resources of banks, which could be used to expand and increase the quality of bank lending programmes for the population and the real sector of the national economy.

Therewith, the structure of deposits of individuals by bank groups in Ukraine did not change much during 2013-2020. If at the beginning of the analysed period 64.5% of individual deposits were attracted by private banks, then in 2020 the total share of private banks and PJSC CB PrivatBank was 49.0% (Fig. 2). If the indicator for PJSC CB PrivatBank remained mostly constant during 2016-2020, then, accordingly, the share of private banks for the analysed period decreased by about 15%.

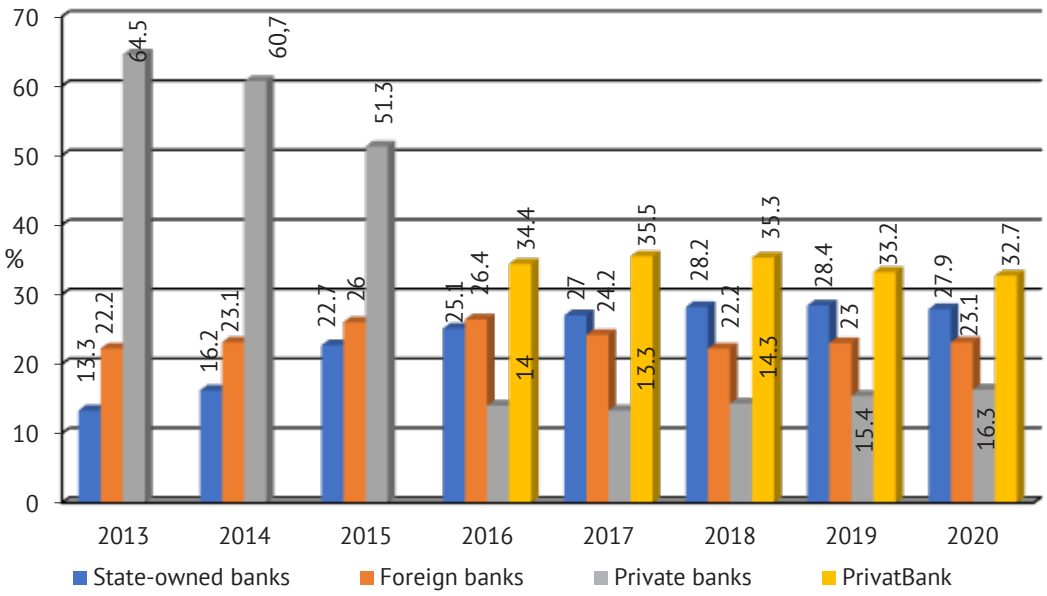

***Figure 2**. Structure of individual deposits by bank groups in Ukraine as of December 31, 2013-2020**
***Note**: * – data as of September 2020*
***Source**: compiled by the authors based on [17-18]*

From 2013 to 2020, the share of state-owned banks in the structure of deposits of individuals considerably increased, namely by 24.6% (from 3.3% to 27.9%). The share of foreign banks in the structure of deposits of individuals changed insignificantly, which fluctuated at the level of 22-26% on average. Thus, among the guidelines of national policy, it is important to single out the incentivisation of the restoration of household confidence in making deposits in the country's banking system, especially in terms of developing deposit programmes of private and foreign banks.

The role of bank lending in the Ukrainian economy

Despite the presence of numerous critically negative aspects of functioning and crisis phenomena in the Ukrainian banking system, which hinder the fulfilment of its potential in restoring economic growth and improving certain basic structural features of the national economy, the key parameters of the state of banking security in Ukraine are threatening, but still not critical, which indicates the available opportunities to improve the situation in the area under study. But in recent years, the situation has substantially worsened according to the indicator "share of gross loans to business entities in GDP". This indicator is a stimulant and is considered acceptable when its limit value is at least 30%. Until 2016, the indicator value was in an acceptable range and, starting from 2017, the level of bank lending coverage of the corporate sector of the economy began to decline rapidly, reaching 20.5% in 2020, which is negative and indicates the extremely low role of bank lending in the formation of financial support for the functioning and, more importantly, the development of the national economy.

The conclusions drawn absolutely correlate with data and trends concerning the level of penetration of the banking sector in the national economy of Ukraine. Notably, the values of all of the indicators presented in Table 3, in 2013-2020 worsened, and the role of bank capital in the economy, respectively, weakened. For example, the level of net loans of business entities in the country's GDP decreased to 11.0% in 2020, when in 2013 the figure was 42.6% (Table 3).

***Table 3**. Indicators of the level of penetration of the banking sector in the national economy in Ukraine in 2013-2020*

Indicators	Years								Absolute deviations (+/-)	
	2013	2014	2015	2016	2017	2018	2019	2020*	2020/ 2013	2020/ 2019
Gross loans to business entities / GDP, %	47.7	51.7	41.8	35.5	29.0	25.8	20.7	20.5	-27.2	-0.2

Table 3, Continued

Indicators	Years								Absolute deviations (+/-)	
	2013	2014	2015	2016	2017	2018	2019	2020*	2020/ 2013	2020/ 2019
Net loans to business entities / GDP, %	42.6	44.7	30.9	20.0	15.1	13.3	10.4	11.0	-31.6	+0.6
Gross loans to individuals / GDP, %	12.4	13.1	8.8	6.6	5.7	5.5	5.2	5.5	-6.9	+0.3
Net loans to individuals / GDP, %	9.5	9.1	4.8	3.2	3.1	3.2	3.6	3.7	-5.8	+0.1
Funds of business entities / GDP, %	17.0	17.8	17.6	17.3	14.3	12.1	13.2	16.0	-1.0	+2.8
Funds of individuals / GDP, %	29.1	25.4	20.2	18.3	16.0	14.3	13.9	16.6	-12.5	+2.7

Note: * – data as of September 2020
Source: *compiled by the authors based on [18]*

The level of penetration of the Ukrainian banking sector in lending to individuals has decreased even more. Thus, in 2013-2020, the level of gross loans to individuals to GDP decreased by 6.9%, falling to 5.5%. Similar indicators for the level of net loans to individuals to GDP were 5.8% and 3.7%. That is why it is not necessary to assert a sufficient contribution of banks to financial support for both the population and businesses, and this should be considered an obstacle to fulfilling the potential of the banking system in ensuring structural changes and shifts in the national economy. As a result, banks did not provide an increase in the capital used by Ukrainian business entities. If in 2013 the share of business entities' funds to GDP was 17.0%, then by 2020 it has not considerably changed, having decreased by 1.0% – to 16.0%. But the level (to GDP) of individual funds experienced a substantial reduction: from 2013 to 2019, there was an annual decrease in this indicator as a whole by more than half (from 29.1% in 2013 to 13.9% in 2019). In 2020, there was an increase in the level of funds of individuals to the country's GDP. However, the value of the indicator was 12.5% less than at the beginning of the analysed period.

Notably, these trends were to a large extent due to the high cost of servicing bank lending, which led to a decrease in the demand of both the population and businesses for bank loans. Conversely, the result of the active policy of the NBU, focused on reducing the discount rate, was a revival in demand for bank loans and a return to the trend towards increasing the volume of bank lending to the national economy. Thus, the weighted average annual rate on NBU refinancing operations in 2011-2019 (with some exceptions typical for 2012-2013) was mostly unstable and excessively high, for example, in 2015 it amounted to 25.22%, while in 2020 it dropped to 6.21%.

Changes in the NBU discount rate were described by almost similar trends: with relative stability in 2011-2013, in 2014-2015, it increased mainly due to the need to contain the negative consequences of the political and economic crisis of 2014-2015, in particular, to curb the growing inflation. Starting in 2019, after a certain stabilisation of the political and economic situation, the NBU launched a policy focused on reducing the discount rate to revive economic development, which the authors of this study regarded positively in the context of stimulating structural changes in the national economy of Ukraine. Accordingly, in 2019 alone the NBU reduced the discount rate five times, which allowed lowering its level from 18.0% to 13.5%, and in 2020 there were four further stages of rate reduction, while as of June 12, 2020 it was fixed at 6.0%.

Further effective reduction of the NBU discount rate is impossible without systemic reforms primarily in the areas of the judicial system and proper protection of creditors' rights, shadowing, and de-offshoring of the economy, increasing the level of capital transparency and solvency of the corporate sector, the development of the mortgage and real estate market, which would considerably minimise the financial risks of bank lending and the financial system of the country in general. In 2011-2020 there was a fairly close correlation between the direction and dynamics of changes in the NBU discount rate and the average monthly interest rate on loans and deposits. As a result, the average rates on loans of business entities (in national currency) as of October 2020 decreased to 9.6% per annum (for foreign currency loans – to about 5.0% per annum), and for loans to individuals – to 30.9% per annum. Thus, the cost of bank credit resources, especially for the population, remains excessively high. But it is also high for businesses, when, for example, in the EU countries, subjects of the real sector of the economy can receive long-term investment loans at 1.5-1.6% per annum.

The transition from the crisis to gradual financial and economic development, as well as building up the

potential of the banking system of Ukraine, gives grounds to assert an improvement in the financial results of banks, typical for 2018-2020, which became especially relevant after the crisis of 2014-2015, the consequences of which were especially noticeable in 2015, when the total loss of banks was estimated at UAH 159.4 billion. In the same year, a critically negative decline in the quality of the banks' loan portfolio led to almost the largest deductions to reserves in the recent history of Ukraine (UAH 198.3 billion).

In fact, 2015 was also described by the lowest value of net interest income of banks – UAH 39.1 billion. In the following years, the difference between total interest income from credit operations, operations with securities and derivatives and the total amount of expenses for paying interest on deposits and borrowed funds of banks began to grow, reaching UAH 78.9 billion in 2019, which was 60.7% more than in 2013 and 8.1% more than in 2018. Notably, the situation with net commission income of banks in Ukraine during the analysed period was more stable and the difference between the commissions and fees received by banks, as well as the commissions and fees paid by them for services received, improved in almost all years of the period under study. From 2013 to 2019, the indicator increased from UAH 21.0 billion to UAH 44.0 billion (by UAH 23.0 billion or 2.1 times).

By 2019, banks' contributions to reserves substantially decreased, which is evidence of a gradual increase in the quality of the banks' loan portfolio and an increase in the financial and economic efficiency of the country's banking sector in general. As a result, the growth of banks' net profit was natural, which was typical for 2018 and 2019 and continued in 2020, although with a lower growth rate compared to 2019. In particular, the profit of banks in the third quarter of 2020 exceeded the same indicator in the second quarter of this year, but was about 20% less than in the corresponding quarter of the previous year. Thus, the recovery and growth of the revenue-generating capacity and profitability indicators of the banking sector of Ukraine is a direct evidence of the strengthening of its potential in ensuring both structural changes and economic growth in general. But this requires the implementation of a balanced incentivising national policy that would coordinate the economic interests of banks regarding their further development and the state in terms of the positive impact of the functioning of the banking sector on structural changes.

Thus, it is necessary to address the fact that there are certain structural flaws directly in the processes of growth of financial and economic efficiency in the analysed sector of the economy, which also require their elimination or settlement. This refers, for example, to the fact that in 2020, more than half (52.2%) of banks' profits were received by only one bank – PJSC CB PrivatBank. The value of the indicator was UAH 7.2 billion, while the total profit of all other banks was only UAH 6.6 billion. The positive aspect can be attributed to the increase in the bank adequacy ratio during 2016-2020. If the standard value of this indicator was not lower than 10% in 2020, its actual value in the banking system of Ukraine was 21.9%. This is evidence of the high level of ability of banks to fully and timely perform their obligations and assume the main part of the risk specifically by banks, and not by their creditors or depositors.

Impact of banking system development on structural reform of the national economy of Ukraine: Conclusions for national policy

Thus, at the current stage of socio-economic development of Ukraine, the banking system is described by both positive and negative aspects of the state and development trends, which can be regarded as both positive and negative prerequisites for fulfilling its potential in the structural reform of the national economy (Table 4).

***Table 4**. Summary results for the state and trends in the banking system development as prerequisites for fulfilling its potential in the structural reform of the national economy*

Aspects of the development ***state***		Conclusions in the context of ***impact on structural reform*** of economy
Positive	**Negative**	
▪ Retention of a group of relatively financially stable, liquid, and solvent banks with a transparent capital structure; ▪ availability of potential reserves of financial resources for lending to the economy and the population; ▪ small proportion of banks at risk; ▪ high quality of banking supervision in the country; ▪ sufficiency of banking sector reserves; ▪ stability of banking infrastructure functioning, activation of digital interaction and online services;	▪ high level of concentration of bank capital and deposits in the largest banks; ▪ concentration of certain banking sector segments according to the number of structural divisions, ATMs, terminals, and active payment cards; ▪ high level of IGB and insufficiently rational structure of the banking system's net assets; ▪ predominance of state-owned banks' liabilities in the structure; ▪ high maintenance costs and the level of problem bank loans; ▪ low return on capital, limited net assets of the banking system;	➢ Development of financial potential for the implementation of investment projects for technological modernisation of production as a result of stabilisation and strengthening of the banking system; ➢ limiting the possibilities of financial support for economic diversification programmes, especially in the areas of small and medium enterprises, research and development, innovation, smart technologies, high-tech exports, etc.; ➢ deformation of the structure of social capital and conditions of its reproduction; ➢ incentivisation of shadow forms of capital formation

Table 4, Continued

Aspects of the development ***trends***		**Conclusions in the context of *impact on structural reform* of economy**
Positive	**Negative**	
▪ Cleansing of the banking system from low-liquid and conditionally fictitious banking structures; ▪ growth of banks' assets and loan portfolio, improvement of its quality; ▪ growth in the volume and share in the structure of liabilities of banks of equity and funds raised from enterprises and individuals; ▪ increase in highly liquid assets of banks; ▪ improvement of financial results and improving banks' liquidity and solvency; ▪ strengthening the banking system's resilience to currency shocks; ▪ reduction of the NBU discount rate and interest rates on loans, revival of bank lending to the economy	▪ Reduction of private and foreign-capital banks, their infrastructure elements, reduction of structural divisions of banks, which weakens competition and the ability to service remote territories; ▪ growth of the share of IGB in the structure of formation of net assets of banks; ▪ reduction of the share of loans of business entities in the structure of net assets of banks; ▪ growth in the level of overdue loans; ▪ strengthening differentiations in interest and commission income, profitability between large and other banks; ▪ weakening of banking sector penetration in the national economy; ▪ deterioration of basic indicators of national banking security	➢ Partial de-shadowing of the country's financial and economic system as a result of the withdrawal of quasi-legitimate, affiliated, insolvent banks from the market; ➢ limiting the impact on the sectoral structure of the economy due to the weakening of specialised banks' capabilities; ➢ deterioration of the ratio in the "domestic production – import" system due to a decrease in the level of lending to local producers; ➢ growth of the share of unprofitable enterprises, activation of fictitious mutual settlements and bankruptcies; ➢ growing imbalances in the balance sheet: intellectual and human resources resource of the economy-external migration of the population due to restrictions on lending programmes to individuals, especially young people, intellectual, and specialised personnel

***Source**: compiled by the authors*

CONCLUSIONS

Thus, the evolution of the Ukrainian banking system has had both a positive and negative impact on the development of some critical structural correlations in the national economy of Ukraine. On the positive side, it is the stabilisation and development of banks, improvement of their performance indicators, withdrawal of "dishonest" banks from the market, which resulted in lending to important investment projects of business structures, as well as the de-shadowing of the country's financial and economic system.

At the same time, until now, there still have been more manifestations of negative influence (or at least "non-interference" of the NBU and commercial banks in changing the situation in numerous structural correlations). This refers to the limited supply practices (due to the weakening of positions in the market of specialised banks) of high-quality affordable bank lending programmes and support for business projects in the areas of strategic development (which can act as growth drivers, focused on the production of products with a high content of added value, are new to the global environment) of economic activities, the creation, attraction, and implementation of modern advanced technologies, activating and improving the efficiency of research and technical work, innovative activity of enterprises, etc.

This also refers to the active use of the government bonds instrument, which violates the proportions in the system of capital placement and its further redistribution, demotivates the growth of deposits and the development of other segments of the stock market. The high cost-intensity of bank lending encourages businesses to search for and apply shadow capital raising schemes, transition from a production form of entrepreneurship to a trade one, which further complicates the problems of import substitution of the internal market. The weakening of the banking sector's penetration into the economy, especially in terms of affordable lending to individuals, is one of the factors complicating the self-fulfilment of the young and intellectual part of the population in Ukraine, the growth of foreign educational, labour, and even stationary migration abroad.

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Стан і тенденції розвитку банківської системи в контексті структурного реформування національної економіки України

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Анотація. Актуальність теми дослідження полягає в тому, що реалізація потенціалу банківської системи спроможна забезпечити позитивні структурні зрушення в економіці України. Метою дослідження є аналіз стану і тенденцій розвитку банківської системи України у фокусі його впливу на структурне реформування національного господарства. У процесі дослідження використано методи статистичного аналізу (для аналізу стану та динаміки розвитку банківської системи країни) та аналоговий метод (для ідентифікації міри впливу розвитку банківської системи на структурні зміни в економіці). Обґрунтовано, що ефективне функціонування банківської системи – запорука успішного економічного розвитку національної економіки, зокрема її реформування. Показано, що через банківську систему діє механізм перерозподілу фінансових ресурсів і грошових коштів, відтак відбувається їх мобілізація та залучення в економічний обіг у тих галузях економіки, які найбільше цього потребують. Узагальнено стан і тенденції розвитку банківської системи як передумови реалізації її потенціалу в структурному реформуванні національної економіки. У підсумку аналізування стану і тенденцій розвитку банківської системи виявлено їх як позитивні, так і негативні характеристики. Доведено, що в Україні на сучасному етапі розвитку національної економіки відбулося очищення банківської системи від низьколіквідних та умовно фіктивних банківських структур, зростають обсяги активів, зокрема високоліквідних, а також покращується кредитний портфель банків, підвищуються їх фінансові результати, ліквідність і платоспроможність, стійкість до валютних шоків, пожвавлюється банківське кредитування економіки. Показано, що для банківської системи країни характерними залишаються низка системних недоліків передусім високого рівня концентрації банківського капіталу та депозитів у найбільших банках, а також державних банків у низці сегментах банківського сектора за чисельністю структурних підрозділів, банкоматів, терміналів, активних платіжних карток. Виявлено тенденцію до послаблення проникнення банківського сектора в економіку, особливо в частині доступного кредитування фізичних осіб і стратегічних галузей економіки. Практична цінність дослідження полягає в тому, що на основі виявлених недоліків розвитку банківської системи і її впливу на структурні реформи визначені стратегічні напрями удосконалення державного регулювання у цій сфері

Ключові слова: економічний розвиток, показники діяльності банків, обсяги фінансових ресурсів, кредитування економіки, системні недоліки

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Features of International Economic Integration in Latin America

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Abstract. The importance and number of integration blocs continue to grow, with agreements being concluded by countries on all continents. This affects not only the development of their member countries but also third countries, in particular trade with them. A considerable number of trade and economic associations are established by Latin American countries, and although researchers study mainly Mercosur, it is advisable to consider other blocs, wherein the integration of developing countries originates in Latin America. The purpose of the study was to examine the development of integration in Latin America and external trade peculiarities of individual trade and economic associations. To achieve this purpose, the authors used foreign and Ukrainian studies, statistical data of international organisations, as well as analysis and synthesis, comparative, historical, graphic, and other methods. The study considered the integration in Latin America, caused by internal issues of countries, its individual stages. In particular, the researchers outlined the features of each stage and identified the advantages of integration, which has become a driving force for trade development. It is advisable to consider the factors that contributed to integration when concluding future regional trade agreements, as well as the level of development of individual integrating countries, their participation in other trade and economic associations, international organisations, and other factors. Calculations for trade areas demonstrated that in 2018, compared with 1995, the total and intraregional exports of the studied integration blocs grew, and the share of the latter did not fall below 10.5%, with the exception of the Andean Community, some blocs reached 20%, although during the specified period for most trade and economic associations it decreased. Considering the results obtained, there are reasons to predict the development of integration in Latin America, yet it is worth considering the influence of internal and external economic factors, as well as methods of regulation and adaptation

Keywords: regional trade agreements, integration blocs, trade, exports, intraregional exports

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INTRODUCTION

In recent years, the importance of international economic integration has continued to grow, as evidenced by the increase in the number of integration blocs, as well as their appearance in developing countries and countries with different economic development levels, etc. It is advisable to consider the specific features of combining Latin American countries, given that these are primarily developing countries, as well as the fact that some of them belong to the Largest Exporters on the world market, in particular agricultural products, for example, Brazil and Argentina. Notably, the Southern Common Market countries (Mercosur) have reached the highest economic development compared to other integration blocs of the continent, as well as high level on the world stage, so a considerable part of the research focuses on this association, in particular, K. Caltentler and F.O. Mora, upon studying Latin American economic integration, analyse Mercosur [1].

The researchers analyse individual stages of integration, as well as the development of external trade and changes in trade policy, etc., while the authors of this study consider and determine the features of integration activities of blocs on the entire continent, analyse the position of individual associations on the world market, and highlight the integration issues. The integration of Mercosur and the EU is quite important, especially given Ukraine's European integration aspirations. Thus, Y. Oleynik called them "two powerful integration associations", and believes that the establishment of a free-trade zone (FTZ) will lead to a reduction in Mercosur's dependence on the North American Free Trade Zone and trade advantages, for the EU there will be an opportunity to develop another centre of a multi-polar world [2, p. 134]. Notably, K. Caltentler and F.O. Mora examine the possibility of establishing supranational bodies in Mercosur, which is typical of the EU, considering the motives for integration [1]. Hem Ts. Besnet and D. Pradhan in their research drew conclusion regarding the prospects for deeper economic integration of the Mercosur countries [3, p. 107].

S.R. Keichilo analysed the compliance of Mercosur with regional integration, considering its features, characteristics of member states, etc., compared the bloc with the EU, and thus concluded that fully clarifying the regional integration in Mercosur is not possible [4, p. 117]. The researcher also noted that countries for many years have not developed harmonised trade rules that could promote integration [4, p. 132]. H.K. Besnet and S.K. Sharma, upon exploring the possibilities of integration in Latin America, analysed the indicators of the seven largest economies in Latin America: Argentina, Brazil, Chile, Colombia, Mexico, Peru, and Venezuela – and came to positive conclusions [5, p. 551]. J.S. Lima, upon analysing Latin American regionalism, noted that after the collapse of the Free Trade Area of the Americas (FTAA), integration has become more heterogeneous [6, p. 339].

Considering the above, the authors can state that the Latin American integration is quite relevant, important, and multifaceted, and the importance of the given subject is also confirmed by attempts to establish an FTZ by individual blocs and countries with the largest integration associations.

METHODOLOGY

The theoretical basis of this paper included studies of Ukrainian and foreign researchers, as well as statistical data of international organisations. The study applied the historical, analysis and synthesis, comparative, graphical, economic, and mathematical methods. Amid the growing importance of international economic integration and Latin American countries on the world stage, the study included the historical aspect of integration development, as well as the features of individual integration blocs. Moreover, the fact that developing countries began to unite in Latin America led to examining the features of their integration, identifying the individual stages, the number of member countries in blocs, etc. and, accordingly, determining the results. The fact that the economic development level of member countries is considerable for international integration necessitated an analysis of individual countries and studying the causes for integration in Latin America, in particular, considering the consequences of increased production, as well as the causes for its acceleration in this region.

Noting the development and considerable export potential of individual integration blocs in Latin America, the authors determined the share the blocs occupy in World Trade and compare them. The study analysed the dynamics of total and intraregional exports and determines the share of the latter for the purpose of studying the integration development, using UNCTAD statistics. The authors compared the commodity structure of exports of integration blocs based on statistical data from the international trade centre – the World Trade Organisation and the United Nations.

RESULTS AND DISCUSSION

Evolution and features of integration in Latin America

In Latin America, there are numerous integration blocs: the Central American Common Market – CACM, the Andean Community – CAN, the Caribbean Commonwealth – CARICOM, the Latin American Integration Association – LAIA,

the Southern Common Market – Mercosur, etc. – which is typical for other parts of the world, in particular Europe: the EU, the European Free Trade Association (EFTA), etc., as well as Africa: the Economic Community of West African States (ECOWAS), Central African Customs and Economic Union (UDEAC), etc. – although the integration level of their associations is quite different.

Regional integration in Latin America began in 1960, when the Latin American Free Trade Association (LAFTA) was established, the purpose of which was to create a common market in Latin America, and this was perceived as the first step towards the economic integration of this territory [5, p. 552]. Thus, since the 1960s, integration blocs have been established in Latin America, as in other regions of developing countries [7, p. 52], in fact, of developing countries, the countries of Latin America were the first to unite [8, p. 89]. Thus, dozens of blocs were established, the number of their participants varies from 2 to 15; bilateral regional trade agreements predominate (77.4%), as in the world, most agreements were developed on the "South-South" model [7, p. 54]. Notably, the economic integration in the Latin American economic and legal literature is identified with its specific forms [9].

D.O. Labzova, upon considering the economic causes for the integration of Latin American countries, notes that industrialisation, which took place before the 1960s, was largely hindered by economic disunity. Thus, the internal markets of most countries could not meet the demand for the products of their enterprises, in addition, export conditions in conventional external markets worsened, which became an incentive to expand intraregional exports [10]. Furthermore, it is noteworthy that these causes may contribute to the integration of other countries and should be considered upon concluding regional trade agreements.

Taking into account the peculiarities of Latin American integration and the increase in the number of integration blocs over the decades, it is worth considering its individual stages (Table 1).

Table 1. *Features of Latin American integration according to individual stages*

Stage number	Period	Features
Stage 1	1960-1980	In 1960, the first agreement was signed – the Latin American FTZ. There was no real integra-tion, and industrial cooperation was developing. By 1990, the blocs of this region, as well as other integration associations whose members are developing countries, did not reach the FTZ level due to: low level of economic development; the one-sided structure of the economy and exports; low level of infrastructure development; low economic interdependence level. As a result, the focus was on industrial cooperation within the region (as a tool for improving the economic development level of member countries), rather than trade liberalisation
Stage 2	1990-2000	Covers the period of the 1990s within the framework of the new regionalism, when the CAN, CARICOM, CACM blocs held consultations based on new FTZ agree-ments to activate integration; Mercosur is being formed; until 2000, there were 4 blocs in the form of FTZ or IPU
Stage 3	mid-2000s – till date	The shift of emphasis in integration from trade to politics was reflected in ALBA (Bolivarian Alliance for the Peoples of Our America), UNASUL (Union of South American Nations), which were created for political purposes, and this was one of the causes for the stagnation of most integration projects in the region. A special feature is the dynamic development of new blocs, approximately 90% of those that are currently operating, in particular the Pacific Alliance

Source: compiled based on [7, p. 52-53]

Thus, for the successful integration, the economic development of countries, a high infrastructure development level, the structure of the economy and exports, etc. are of great importance, although an increase in the economic development of countries is one of the expected consequences of integration. G.M. Kostyunin and O.A. Kozlova noted that, as in other regions of developing countries, integration in Latin America has stimulated trade growth, although the magnitude of this effect is not as considerable as in blocs that consist of developed countries [7, p. 64].

Latin American economic development and its significance in the context of international economic integration

In 2003-2012, Argentina was ahead of most countries in terms of average annual GDP growth (7.1%), which has not been observed for almost 100 years, since 1914 [11, p. 69]. Furthermore, according to P. Yakovlev, modern processes in Latin America confirm that the 21st century is a period of historical rise of developing countries [12, p. 55]. The researcher also believes that the region has entered the second decade as a constant value of the concentric system of international relations, as evidenced

by: Brazil's participation in the BRICS (this grouping includes Brazil, Russia, India, China, South Africa), as well as Brazil, Argentina, and Mexico in the G-20 (countries account for the vast majority of trade and the world's population), the integration increase in the region in new forms, the reset of Latin European relations, the trade and economic orientation of numerous leading countries towards Pacific Asia, joining APEC (Asia-Pacific Economic Cooperation).

Notably, in the last decade of the twentieth century in Latin America, there were considerable market reforms of the monetary area, which had ambiguous financial and macroeconomic consequences. Although the results of neoliberal theory and practice seemed rather disappointing, considerable changes were observed at the turn of the millennium. Thus, the crisis, the largest sovereign debt default in the world's history in Argentina, and unsettled phenomena in other countries of the region have led to a re-establishment of models and content of economic and socio-political development. This contributed to the development of economic growth, which provided for: increasing the role of the state in the reproduction; expanding the domestic consumer market through a fight against poverty, increasing the living standard of the majority of the population; intensive geographical and sectoral diversification of external economic relations and more active participation in the system of World Economic Relations, integration into the global production chains of Latin American economies; a considerable increase in the size and number of Latin American private and state multinational companies, the so-called "trans-latinos" or "multi-latinos" [12, p. 55-56].

Notably, the application of the new model by leading Latin American countries has led to an acceleration of economic growth, which has also become more sustainable. To a large extent, the dynamics of economic growth was enhanced by the environment on world markets, which provided growing demand and high prices for raw materials and food products, prices for which doubled on average in 2000-2012. Thus, due to a combination of external factors and internal efforts, in 2000-2012, regional GDP grew 2.7 times, while commodity exports increased more than 3 times, foreign exchange reserves increased 5.3 times, and accumulated foreign direct investment increased 4.5 times. Moreover, Latin American countries have become considerable capital exporters in these years. Thus, the foreign direct investment level of multi-latinos in 2011 exceeded 1 trillion USD, which is 5 times higher than in 2000. In addition, there was a reduction of the debt burden, in particular, a considerable reduction in public debt to GDP. Moreover, the increase in the importance of Latin America was also confirmed by solving relevant global issues, primarily global and energy, because countries can considerably increase agricultural production and contribute to ensuring world food security. The reason for this is, for example, that in Latin America in 1990-2011, wheat production increased by 60%, corn – almost 3 times, rice – twice, soybeans – more than 4 times, meat – by 144%, cane sugar – by 2.5 times. With the growth of production, it became possible not only to fill the internal market more, but also to increase exports, so in 2000-2012, agricultural exports of Latin American countries increased almost 4 times (from 5 57.7 billion to. 220.4 billion USD). Therewith, the positive experience of individual countries in the region, in particular Brazil, in solving the food issue deserves attention [12, p. 56-57].

Although foreign investors do not show a desire to establish divisions in Latin America that are engaged in research and development (R&D), the opposite case can be noted in relation to Brazil, where a number of Western European companies have established enterprises for the development of new technologies (in particular VolksWagen, Fiat, Ericsson, Siemens), yet compared to Singapore, India, China, and some other Asian countries, this form of foreign capital application is quite limited in Latin America [13, p. 52]. Thus, Brazil stands out notably from other countries in the region, and the development of R&D in the country can help it maintain a leading position in the future, both within Mercosur and Latin America, as well as diversify exports, and finished products.

Latin American countries were not affected by considerable interstate conflicts as much as European and Asian ones, since they remained on the "periphery" of big world politics for a long time [14, p. 182]. That is, when countries are not at the centre of world politics, they get fewer benefits, but they are also insured against significant costs, although commodity and geographical diversification of trade, diversification of investment are one of the prerequisites for stability and development. Therewith, all attention should not be focused only on the largest importing countries, it is necessary to develop external economic activity with countries that are located on the "periphery", since this leads to a number of positive consequences, and they are less affected by the consequences of global changes.

Although there is an increase in the importance of Latin American countries on the world stage and the establishment of integration blocs by them, the regional associations are characterised by difficulties in integration. D.V. Romanov notes that there are three blocs: the Andean Community (which was established

as one of the first in 1969 Ecuador, Peru, Colombia, Chile and Venezuela), the Central American Common Market and CARICOM failed to regulate customs and tax policies, establish close economic ties, while Bolivia, Venezuela, and Colombia sought to join Mercosur [15, p. 455].

The researchers identify the causes for the acceleration of integration in South America: 1) the creation of more open and larger markets was caused by the revenue growth from the use of new technologies and investments, as well as increased competition in trade (it was obvious that the closed market would lead to a slowdown in development in all areas); 2) the liberalisation of external trade in the late 1980s (the introduction of single tariffs and the elimination of non-tariff restrictions created conditions for concluding bilateral and multilateral agreements on trade liberalisation, which was impossible in a closed economy. In addition, the introduction of preferential tariffs and their elimination in certain sectors of the economy stimulated trade in the region); 3) a radical revision of integration mechanisms in the region [16, p. 387]. Therefore, it is also advisable to consider these causes and measures upon concluding regional trade agreements, developing relevant regulatory documents, but it is also necessary to consider the specific features of each member country, its participation in other integration blocs, international organisations, and other factors.

"Open regionalism": The UN statement

The considerable importance of Latin American countries and their integration is also confirmed by the fact that the UN Economic Commission in 1994 (at the 25th session) introduced the "open regionalism", which was based on 9 provisions:

1. Sectoral liberalisation of the markets of goods and services, differentiated for different countries in time;
2. Large-scale market liberalisation involving as many countries as possible, especially those that are conventional partners;
3. To ensure, in accordance with the rules of the World Trade Organisation, the stability and transparency of liberalisation;
4. To increase the role of regional institutions in macroeconomic stabilisation of countries to minimise the risk of new crises;
5. To protect the national economy, remain out of moderate protectionist measures against third countries and gradually switch to joint external tariffs (if necessary);
6. To reduce transaction costs between and within each country, ensure the convertibility of national currencies, and sign payment agreements;
7. To promote technology transfer through the signing of industry agreements;
8. To develop special measures to adapt economically less developed countries and regions, in particular by reducing protectionism and providing fiscal incentives to attract investment;
9. To develop flexible institutional structures to attract the bulk of the population [17, p. 266-267]. The issue of technology transfer is particularly important, as it is one of the main prerequisites for economic development, especially in modern conditions, as well as the application of moderate protectionist measures.

External trade trends of individual integration blocs

It is advisable to consider the position of individual integration blocs on the world market, the development of their general and intra-regional exports, etc. Notably, the share of individual Latin American blocs in world exports is quite low and changed slightly (Table 2), in particular in 1995-2018 CACM in the range of 0.2-0.3%, CAN – 0.4-0.8%, CARICOM – 0.1-0.2%, LAIA – 4.1-5.7%, Mercosur – 1.7-2.4%.

***Table 2**. Share of individual integration blocs of Latin America in world exports of all goods, %*

Integration associations	Years																
	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
CACM	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
CAN	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.7	0.7	0.6	0.6	0.6	0.6	0.6
CARICOM	0.1	0.1	0.1	0.2	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
LAIA	4.1	5.2	5.1	5.3	5.2	5.2	5.2	5.5	5.6	5.7	5.5	5.3	5.2	5.1	5.2	5.2	5.3
Mercosur	1.8	1.8	2.1	2.1	2.1	2.3	2.2	2.3	2.4	2.3	2.2	2.0	1.8	1.8	1.8	1.8	1.7

***Source**: calculated by the author based on UNCTAD data [18]*

Indeed, Mercosur's share in the global market is one of the largest compared to other associations, and it is worth considering the desire to create a free trade zone with the EU, which is one of the world's largest importers. Therewith, the exports of all these blocs increased considerably, in particular, in 2018, compared with 1995, CACM increased 4.5 times, CAN – 5.7, CARICOM – 3.1, LAIA – 4.8, Mercosur – 3.9 times. Although during this period, in some years, export volumes were considerably higher than in 2018, as can be seen from the example of Mercosur (Fig. 1).

The share of intraregional exports of all blocs except CAN was not less than 10.5% (CARICOM), and the maximum values were 21.8% (CACM) and 19.1% (Mercosur). In 2018, compared to 1995, the total and intraregional exports of each specified integration grouping increased (Table 3), however, the share of the latter as a whole increased only in the CACM.

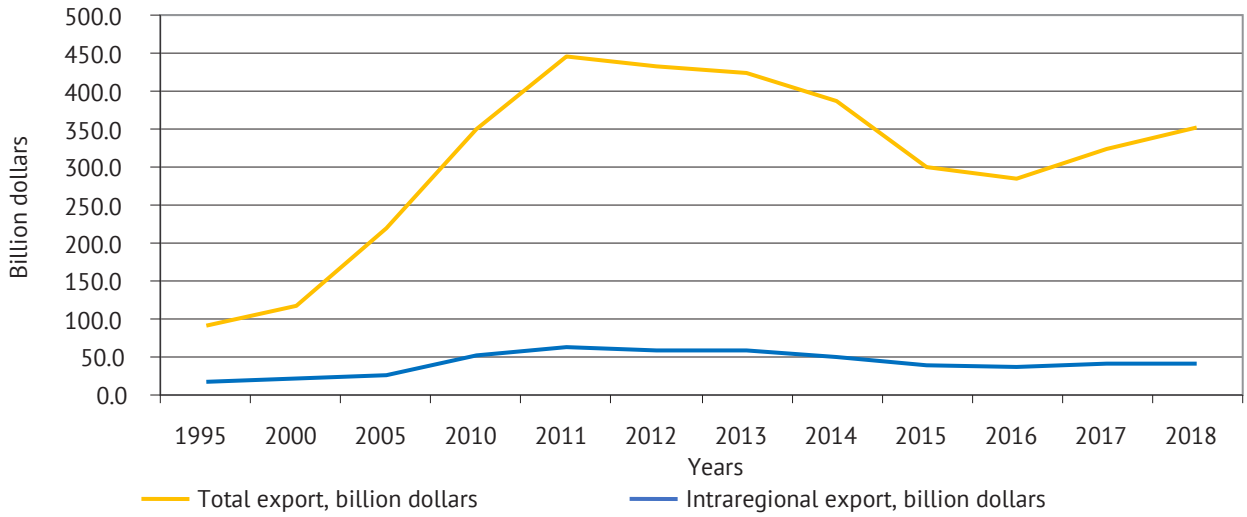

Figure 1. Dynamics of total and intra-regional exports of all Mercosur goods, 1995-2019
Source: complied by the author based on UNCTAD data [18]

Table 3. *Dynamics of domestic and non-regional exports (USD billion), as well as the regional share in the export of individual integration blocs, %*

Integration associations	1995	2000	2005	2010	2011	2012	2014	2015	2016	2017	2018
						General export					
CACM	9.3	15.4	22.7	31.5	37.8	39.6	40.5	38.7	38.5	41.6	41.6
CAN	21.2	25.5	51.0	100.2	134.9	142.5	132.2	96.6	91.4	109.4	120.5
CARICOM	5.8	8.1	14.7	17.8	23.2	21.4	22.4	17.8	14.5	16.3	18.3
LAIA	209.5	329.4	537.1	835.5	1032.1	1046.4	1008.1	854.6	824.5	925.4	1012.5
Mercosur	90.7	116.9	220.6	350.3	445.8	433.6	386.4	300.9	285.0	324.4	352.1
						Intraregional exports					
CACM	1.5	2.5	3.9	5.8	6.8	6.9	7.4	8.0	8.2	8.7	9.1
CAN	1.8	2.0	4.6	7.9	9.3	10.2	9.9	7.7	7.2	7.9	9.0
CARICOM	0.8	1.3	2.1	2.3	2.7	2.4	2.6	2.1	1.7	1.9	1.9
LAIA	37.5	46.9	79.7	139.9	171.8	172.3	152.9	118.4	107.4	122.4	129.4
Mercosur	17.3	21.1	25.6	51.6	62.5	57.7	51.0	40.1	37.3	40.9	42.3
						Share of intraregional exports in total exports, %					
CACM	15.6	16.0	17.2	18.3	17.9	17.4	18.2	20.8	21.4	20.9	21.8
CAN	8.5	7.9	8.9	7.9	6.9	7.2	7.5	8.0	7.9	7.2	7.4
CARICOM	14.4	15.7	14.4	12.8	11.8	11.2	11.7	12.0	12.0	11.4	10.5
LAIA	17.9	14.2	14.8	16.7	16.6	16.5	15.2	13.9	13.0	13.2	12.8
Mercosur	19.1	18.1	11.6	14.7	14.0	13.3	13.2	13.3	13.1	12.6	12.0

Source: *complied by the author based on UNCTAD data [18]*

Thus, there was an increase in both total and intraregional exports, mostly in total, for all trade and economic associations, except for the CACM. Blocs export products of different groups (Table 4) and the main ones are given for CACM, CARICOM, Mercosur, whereas agri-food products are among the ten most exported goods of CACM (edible fruits and nuts, sugar and confectionery, various food products, fats and oils of animal or vegetable origin), as well as MERCOSUR (seeds and fruits of oilseeds, meat and edible offal, cereals).

***Table 4**. Main export goods of the CACM, CARICOM, Mercosur integration blocs*

CACM	CARICOM	Mercosur
08 edible fruits and nuts	27 mineral fuels; oil and its distillation products	27 mineral fuels; oil and its distillation products
90 optical and photographic devices and apparatuses	89 vessels	12 seeds and fruits of oilseeds
61 clothing and accessories for clothing, knitwear	28 inorganic chemical products	26 ores, slag, and ash
17 sugar and sugar confectionery products	71 natural or cultured pearls, pre-cious or semiprecious stones	02 meat and edible offal
85 electric machines	29 organic chemical compounds	10 cereals
39 plastics, polymer materials	61 clothing and accessories for clothing, knitwear	23 food industry residues and waste
21 different food products	84 nuclear reactors, boilers, ma-chinery	87 means of land transport, except rail transport
III. 15 fats and oils of animal or vegetable origin	72 ferrous metals	84 nuclear reactors, boilers, machinery
48 paper and cardboard	86 railway locomotives	72 ferrous metals
61 clothing and accessories for clothing, knitwear	26 ores, slag, and ash	47 wood mass

***Source**: compiled by the author based on data from [19]*

Therewith, a considerable share is accounted for by the export of non-agri-food products, as can be seen from the above data. Notably, the economic integration development of Latin American countries is characterised by two opposing trends, namely: the penetration of foreign monopolies into blocs is increasing, and on the other hand, the struggle for economic independence in the region is worsening [9, p. 2]. V.Ya. Krasilchuk notes: "integration is one of the key processes of economic development in Latin America and the Caribbean". Therewith, the most essential characteristic features of internationalisation of economic relations in this region are: the duration, complexity, and inconsistency of Latin American integration [20, p. 129]. Although there are many difficulties, there are positive consequences of the integration of Latin American countries, and integration is considered as one of the prerequisites for a country's economic development.

CONCLUSIONS

Thus, in Latin America, a considerable number of integration blocs are being created, and for the first time the developing countries have begun to unite. Mercosur has achieved the highest development among numerous integration blocs, but the study suggests that there are prospects for the development of integration processes in the region. In addition, the expansion of intraregional trade became essential for countries, which required the conclusion of regional trade agreements. It is worth considering the features of integration in certain periods, which made it possible to identify its individual stages. It is advisable to consider the causes for the acceleration of integration (the use of new technologies, trade liberalisation, etc.), since this can also be applied to other blocs.

The analysis demonstrated that the share of integration blocs in world exports is relatively low, yet one of the highest is observed in Mercosur, whereas associations increase the volume of total and intraregional exports, although the share of the latter in 2018 compared to 1995 mainly decreased, with the exception of CAN, none of these blocs fell below 10.5% (CARICOM) and reached up to 20% in some blocs. As for the commodity structure of exports, in CACM and Mercosur, a considerable part is accounted for by agri-food products. Trade policies, development concepts of individual

countries, and a number of other factors are important for integration development. The development of integration in Latin America is essential for the countries of the region and third countries, especially given the availability of natural resources, the number of people, the participation of countries in international organisations, the desire to deepen integration and conclude a Mercosur FTZ with the EU, and a number of other factors.

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Особливості міжнародної економічної інтеграції в Латинській Америці

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Анотація. Зростання значення та кількості інтеграційних угрупувань продовжується, причому угоди укладаються країнами усіх континентів. Це впливає не лише на розвиток їх країн-членів, але й на треті країни, зокрема торгівлю з ними. Значна кількість торговельно-економічних об'єднань сформована країнами Латинської Америки, і хоча вчені досліджують переважно МЕРКОСУР, проте доцільно розглянути й інші угрупування, причому інтеграція країн, які розвиваються, розпочинається саме в Латинській Америці. Метою статті є дослідження розвитку інтеграційних процесів у Латинській Америці та особливостей зовнішньої торгівлі окремих торговельно-економічних об'єднань. Для її досягнення було використано праці закордонних та українських вчених, статистичні дані міжнародних організацій, а також методи аналізу та синтезу, порівняльний, історичний, графічний та ін. Розглянуто причини інтеграції в Латинській Америці, що було зумовлено внутрішніми проблемами країн, окремі її етапи, зокрема наведено особливості кожного з них, а також виявлено переваги інтеграції, що стало рушійної силою розвитку торгівлі. Доцільно враховувати фактори, які сприяли інтеграції при укладанні майбутніх регіональних торговельних угод, а також рівень розвитку окремих країн, що інтегруються, участь їх у інших торговельно-економічних об'єднаннях, міжнародних організаціях та інші фактори. Розрахунки щодо напрямів торгівлі показали, що у 2018 році, порівнюючи з 1995 роком, загальний і внутрішньорегіональний експорт досліджуваних інтеграційних угрупувань зростав, причому частка останнього не опускалась нижче 10,5 %, за виключенням лише Андського співтовариства, а по окремих угрупуваннях досягала й 20 %, хоча протягом зазначеного періоду для більшості торговельно-економічних об'єднань вона зменшилась. Враховуючи отримані результати, існують підстави прогнозувати розвиток інтеграційних процесів країн Латинської Америки, проте варто врахувати вплив внутрішніх та зовнішніх економічних факторів, а також методи регулювання та адаптації

Ключові слова: регіональні торговельні угоди, інтеграційні угрупування, торгівля, експорт, внутрішньорегіональний експорт

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Economy Offshoring in the National Economic Security

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Abstract. This study considers the modern development features of economic systems – intensification of economy offshoring, which determines the relevance of the subject matter. The purpose of the study was to analyse offshoring, establish its impact on the national economic security, and develop means to de-offshorise the economy. The methodological basis of the study included general scientific and special cognition methods, in particular dialectical cognition, theoretical generalisation and abstraction, methods of economic and statistical analysis, induction, deduction, and synthesis. The study analysed the volume of offshore capital withdrawals, the tax asymmetry level, and the economy offshoring level in different countries, including Ukraine. Based on the analysis data, the study indicated the threatening level of modern economy offshoring. The study included the theoretical analysis of offshoring in the system of national economic security, the main causes, advantages, and disadvantages of this process for the national economy. The authors highlighted the main threats posed by offshoring to the economy and economic security. The terms "offshoring" and "de-offshoring" were defined, considering their security significance. The study identified that a considerable share of the withdrawn capital is returned to the national economy in the form of so-called "round-trip" investments. As a result, it is necessary to consider the safety indicators of "round-trip" investments for the economy upon implementing measures to reduce their volumes. The study analysed the ratio of withdrawn capital and external debt of different countries and determined that Ukraine is one of the leading countries according to this indicator. The authors developed the main means of Ukrainian economy de-offshoring and ensuring economic security

Keywords: offshore jurisdiction, international financial markets, de-offshoring, capital, investments

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INTRODUCTION

A characteristic feature of the global economy of the 20th-21st century is a noticeable transformation of financial and economic relations, which are associated not only with economy globalisation and digitalisation but also with the emergence of so-called offshores or offshore jurisdictions. Since the middle of the last century, there has been a gradual movement of capital and financial-economic operations to offshore companies, which caused economy offshoring. The global economic community representatives attempt to reduce the tax burden, which leads to the movement of a substantial capital share to offshore jurisdictions, where the tax burden is considerably less or absent. As a result, the tax payments in the overall structure of the country's GDP, and consequently budget revenues, decrease, and there is a considerable increase in the amount of capital withdrawn from countries to offshore companies. In other words, the growth of the economy offshoring level leads to an increase in tax asymmetry, capital outflows, and creates numerous threats to the economic security of both individual states and the global economy. Offshoring has become a real phenomenon of the modern economy.

The main cause for withdrawing capital and financial transactions outside of national jurisdictions is the high tax burden compared to offshore jurisdictions. Globalisation played an important role in the world economy offshoring, as well as the liberalisation of economic policies, and especially the foreign economic policies of many states, the development of free and open markets, the free movement of capital and investment contributed to the intensification of offshoring of national economies and the global economy. Technological advances, in particular the development of information and communication systems, and the economy digitalisation in general, also made a considerable contribution to this process. Therewith, offshore jurisdictions are developed for various reasons, mainly states with low indicators of socio-economic development or depressed territories that require an influx of investment and capital. Thus, offshoring as an actively developing process substantially affects the economies of many countries and the world economy, international financial and capital markets, accordingly, affects the financial and economic security of all states of the world.

Since the beginning of the 90s, an active offshoring of the Ukrainian economy has begun. Considerable amounts of capital are being withdrawn from the state, the foreign economic activity with counterparties from offshore jurisdictions is constantly growing, and a significant amount of investment in the Ukrainian economy comes from offshore companies. Accordingly, there is a great impact of offshoring on the Ukrainian economy, in particular on the national economic security. The above determined the relevance of the chosen research subject since there is a need to cover the theoretical content of offshoring, identify its impact on the national economy and the means to minimise the negative impact on the economy to ensure the national economic security.

The purpose of the study is to conduct a theoretical analysis of offshoring and its impact on ensuring national economic security. To achieve this purpose, the authors outlined the main tasks of the study, namely to analyse offshoring in the system of national economic security; to establish the positive and negative consequences of offshoring for the economy; to develop means to minimise the negative impact of offshoring on the national economy.

LITERATURE REVIEW

The studies of Ukrainian and foreign scientists cover the main issues of economy offshoring, shadowing, and their impact on the national economic security. In Particular, R. Cabral, A.V. Mollick, E. Sausedo [1] investigated the relationship and impact of illegal and criminal transactions on the inflow or outflow of foreign direct investment. R. Gupta, P. Makena [2], who investigated the essence and main causes of tax evasion, developed an alternative theoretical justification for the relationship between tax evasion and inflation. R.K. Goel, J.V. Sanoris [3] considered the impact of economy offshoring and the shadow economy on the economic growth and development of the state in the long term, and also identified the main areas for legalising the economy. R. Hendricks, R. Fernandez [4] analysed the impact of offshore jurisdictions on the global economy, studied the scale and consequences of capital outflows to offshore companies, and predicted the main development areas of the global economy. P. Fev, A. Moura, O. Pierrar [5] investigated the economy offshoring, in particular the offshoring of the banking sector and the offshoring impact on financial stability and security. O. Apostle and A. Pop [6] investigated the impact of corruption and bureaucracy in post-communist countries on the spread of neoliberalism, analysed the impact of ethical motives and tax consulting on the mentality of taxpayers and on the volume of tax payments. P. Sikka and H. Wilmott [7] investigated the use of transfer pricing and its impact on the volume of tax payments, capital outflows, and financial stratification of the population. H.M. Argyle-Bosch, D. Ravenda and H. Garcia-Blando [8] investigated the relationship between e-commerce and

corporate social responsibility and, in particular, the impact of e-commerce on employee payroll taxation. A. Breezy, M. Giacomantonio, B.M. Shumpe and L. Manetti [9] analysed the factors influencing the volume of tax payments and established a considerable influence on this process of entrepreneur's moral and ethical norms, the level of their social responsibility, and the level of trust in the government.

Z.S. Varnali [10] considered offshoring from the standpoint of security studies and its impact on the economy. The researcher defined offshoring as an institutional threat to the national economic security, investigated means of de-offshorising the Ukrainian economy as a priority area of security activities. M.I. Karlin, A.V. Borisyuk [11] studied the main jurisdictions within Europe, Asia, America, and Africa that are considered offshore, revealed the specific features of the functioning of offshore companies, as well as characterised the features of the functioning territories and jurisdictions that are offshore according to the legislation of Ukraine. A.V. Lebed, V.A. Garkusha [12] analysed the positive and negative consequences of offshore activities using the SWOT analysis methodology, considered the consequences of non-interference of the state in the activities of economic entities using offshore companies, assessed the impact of offshore operations on the Ukrainian economy and justified the existence of the main threats caused by the active use of offshore jurisdictions by Ukrainian businesses. I.S. Lutsenko [13] investigated methodological approaches to assessing the level of state tax security and proposed indicators for assessing the level of tax security, as well as their limit values. Z. Lutsishin, N. Yuzhanina, and T. Frolova [14] studied the economic content and essence of offshoring, the scale and consequences of capital outflow from the Ukrainian economy to offshore companies, studied the main schemes for withdrawing capital and money laundering, considered the state and main issues of the Ukrainian economy offshoring. E.V. Redziuk [15] studied the role and scale of offshoring, its impact on the Ukrainian economy, developed a number of measures to encourage the return of previously exported capital to Ukraine. P.A. Chernomaz and I.S. Subacheva [16] investigated offshoring as a separate economic category, analysed the effectiveness of the methodology for calculating the economy offshoring coefficient and its impact on the national economic security.

METHODOLOGICAL REASONING

The methodology for studying the theoretical content of offshoring and developing recommendations for minimising its negative impact on the economy is based on foreign and Ukrainian papers on theoretical and applied aspects of economy offshoring. The study was based on a combination of general scientific and special methods of cognition used to clarify the essence and features of offshoring in modern globalised economic systems. The methods of dialectical cognition, theoretical generalisation, and abstraction allowed studying and clarifying the essence of the term "offshoring", especially its perception within security studies. The historical and theoretical analysis allowed identifying the causes of the origin and development of offshoring. The system analysis method allowed clarifying the essence of the terms "offshoring" and "de-offshoring".

The methods of economic and statistical analysis enabled the assessment of the scale of financial and economic operations using offshore jurisdictions, identifying the amount of capital withdrawn to offshore jurisdictions of different countries. The induction method allowed the authors to identify the advantages and disadvantages of offshoring for businesses. The study identified the threats that can lead to a high level of offshoring for the Ukrainian economy by applying the deduction method. The synthesis method was used to determine the interrelation between the volume of foreign direct investment and "*round-trip*" investment.

Statistical analysis methods and a graphical method were used to identify the main states-investors in the Ukrainian economy, regions-recipients of international direct investment, and the coefficients of economy offshoring of various countries. The use of hypothetical and formalisation methods allowed devloping recommendations for de-offshoring the Ukrainian economy. The research conclusions were based on the use of the generalisation method.

The information base of the study comprised scientific papers and other publications of Ukrainian and foreign researchers, data from the State Statistics Service of Ukraine, and other statistical organisations.

RESULTS AND DISCUSSION

Genesis of offshoring as a socio-economic phenomenon

There are numerous terms for territories where the tax burden is very low, compared to other countries, or absent. Such jurisdictions attract many economic entities, especially representatives of international business, to place capital and conduct financial transactions. In particular, the terms "tax oasis", "tax paradise", or "tax haven" are employed. However, the term "offshore" is most common. It comes from the English collocation "*offshore*", which means – off the shore, off the limits. Therefore, an offshore company is a territory outside of national jurisdiction, where considerably lower taxes are established

or are completely absent, an area with a rather simplified form of control and reporting. Accordingly, an offshore jurisdiction is a territory (country) that is subject to preferential tax and business conditions in accordance with the current legislation. Offshore companies are essentially very similar to free economic zones, but they differ from the latter in that preferential tax conditions are usually set for non-resident companies. In free economic zones, benefits are enjoyed by resident companies that engage in economic activities on the territory of the free economic zone, and in offshore companies, benefits are enjoyed by non-resident companies that engage in economic activities outside the offshore zone. However, according to many researchers, offshore companies constitute types of free economic zones that have their distinctive features.

Despite the fact that the rapid development of offshore business occurred in the 1960s and 1970s, the presence of territories with a preferential tax regime dates back to the beginning of the Common Era. Many Greek islands around Athens set lower import and export duty rates than Athens, accordingly, most of the cargo was unloaded at their ports, and then illegally transported to Athens, where customs tariffs were too high. Thus, the desire to optimise tax and customs payments has been inherent in entrepreneurs for a long time. Subsequently, preferential tax regimes were introduced in Flanders, which almost devastated English wool merchants, as well as the ones from the US in the 16th-18th centuries. Many prototypes of offshore companies were created in the "porto franco" form – free ports. That is, ports where preferential tax conditions were established. In particular, the "porto franco" status was granted to such Black Sea ports as Odesa, Feodosia, and Batumi. Subsequently, in some territories of the British Empire, especially in the Caribbean, preferential tax regimes were introduced, accordingly, this list was substantially expanded and amounted to about 100 territories with a preferential tax regime.

The current level of capital flows through offshore companies is impressive. In particular, about 10% of the world's capital is concentrated in offshore companies, more than 50% of world trade passes through offshore companies [14], according to rough estimates, the total amount of assets placed in offshore companies ranges from 21 to 32 USD trillion. According to the Organisation for Economic Co-operation and Development (OECD), approximately one-third of the capital in the form of deposits is located offshore, which is about 11.5 USD trillion [15]. The volume of capital withdrawal from countries to offshore companies is also impressive, in Figure 1 data for the period 1970-2016 are presented.

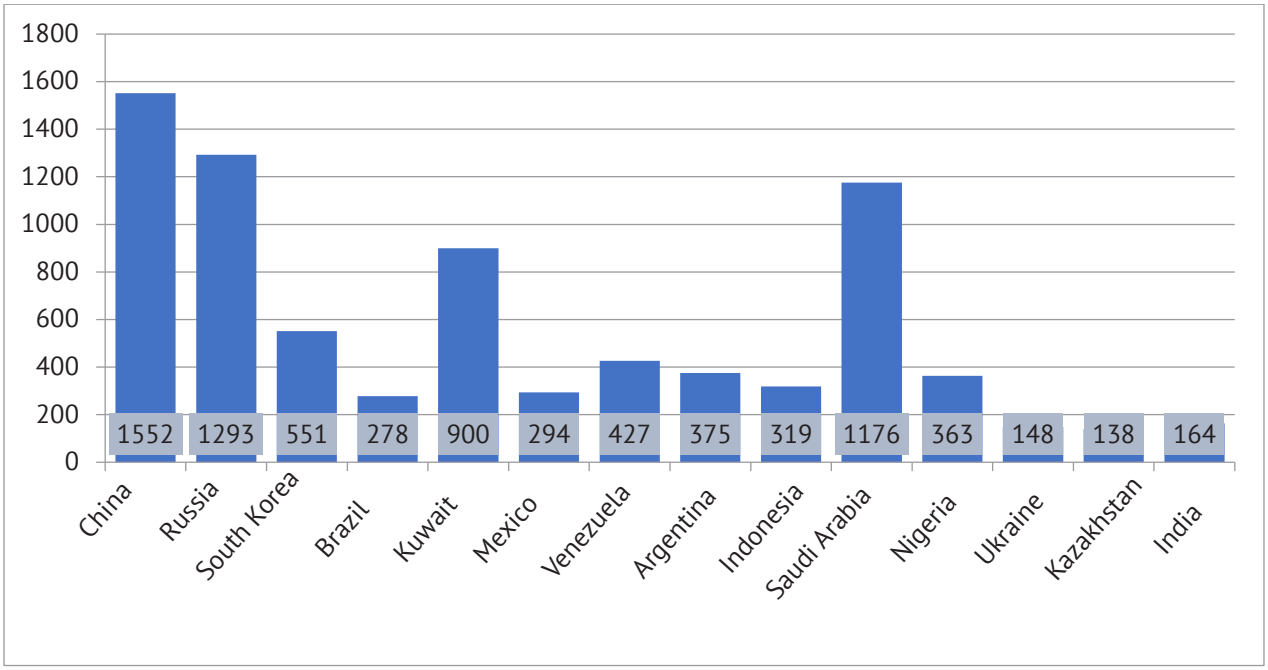

Figure 1. The amount of capital withdrawn to offshore jurisdictions in 1970-2016, USD billion
Source: developed by the author based on data from [17]

It is estimated [18] that 89% of the leading American corporations and 99% of the leading EU corporations place their structural divisions in offshore jurisdictions. As for the post-Soviet countries and Ukraine, a large share of capital is returned to the country in the form of investments in various economy sectors, but the amount of capital accumulated in offshore companies is also substantial. Business representatives of Russia,

Kazakhstan, and Ukraine store approximately 40% of their capital offshore. Notably, the same indicator in the United States and Japan is only 2%, and in the EU – 10% [19]. Ukrainian businesses actively use Cyprus to reduce the tax burden and withdraw capital. According to experts, the amount of capital placed in Cyprus reaches about 30 USD billion. Since the beginning of the Russian aggression, more than 500 UAH billion worth of assets has been withdrawn to Cyprus [15; 21].

Given the growing popularity of offshore companies, the term "offshoring" is frequently used along with the term "offshore" in scientific publications and in the media. However, there is no common approach to defining this term. A number of researchers consider offshoring as a process that takes place at three levels: at the micro-level (enterprises), at the macro-level (national economy), and at the mega-level (global economy) – and is a set of processes for expanding the list of economic entities that use offshore jurisdictions to optimise the economic environment, cooperation, and achieve favourable socio-economic and political business conditions, as well as strengthening their influence on the development of the global economy by shadow capital movement across state borders. Such movement is usually carried out due to transfer pricing, which allows distributing funds between structural divisions. However, in practice, such activity is just a legal way to move the capital to offshore companies to reduce taxation [7].

According to Z.S. Varnali, offshoring is a process of the negative impact of offshore activities on the national economy, which manifests itself in the unproductive capital withdrawal to offshore jurisdictions to optimise investment conditions, minimise or evade taxation, and launder money. The researcher considers it as a betrayal of national interests and a threat to the statehood of Ukraine [10]. P.A. Chernomaz and I.S. Subacheva interpret "offshoring" as the influence of offshore activities on the economy, namely the capital withdrawal through the creation and use of offshore firms to avoid or minimise taxation. Researchers propose to calculate the coefficient of economy offshoring, the growth of which indicates a substantial impact on the economy of offshore jurisdictions and, accordingly, an increase in threats to the national economy [16]. In general, the authors of this study agree with the researchers' definition of "offshoring", and suggest considering it through the lens of national economic security and economy legalisation.

Offshoring and national economic security: A mechanism of interaction

The main causes for the offshoring of the national economy and a number of post-Soviet economies include the ability to protect property and intellectual rights, property rights that are violated and cannot be fully secured by state authorities. In the former Soviet Union, there is a high level of regulatory and political influence on business, a high corruption level, numerous raider seizures, and other violations of rights and freedoms. That is why offshore companies have become a legal and affordable way to protect your business from such threats [20].

Therefore, the authors determined offshoring as the process of moving capital and financial transactions from national to offshore jurisdictions. The reasons for this phenomenon may differ, although from the standpoint of security, the result remains the same – the movement of capital and financial transactions, which reduces the tax base in national jurisdictions and reduces tax liabilities, poses a threat to the national economic security. The reverse process is de-offshoring. Accordingly, the authors interpret the term "de-offshoring" as the process of moving capital and financial transactions from offshore to national jurisdictions.

Thus, offshoring contributes to the development of numerous advantages and contains a number of threats to the business. The advantages of offshoring include:

– low tax burden and simplified reporting system;

– simplified access to international financial markets;

– protection of property and other rights, international legal protection against corruption and raiding, judicial protection in accordance with the provisions of international law;

– confidentiality of information about business owners and the volume of financial and economic activities, as well as the protection of such information.

Despite a considerable number of advantages, offshoring poses certain threats to business, which include:

– increased attention of fiscal and law enforcement agencies to enterprises registered in offshore companies;

– state restrictions on the acquisition of assets by non-residents, the need to obtain licenses for activities;

– state barriers to activities in the field of ensuring national security and the military-industrial complex;

– deterioration of business reputation due to the use of an offshore company, the need to prove that the capital owned by the company was not acquired by criminal means.

Offshoring contributes to the development of numerous threats not only to business but also to the state economy, namely:

– reduction of tax revenues and budget revenues;

– capital outflow abroad;

– withdrawal of illegally obtained funds and their legalisation;

– economy shadowing.

The advantages of offshoring for the state economy

are the availability of flexible and effective mechanisms for reinvesting funds in the national economy through access to the global financial system, as well as the ability to avoid legal conflicts and protect business structures in accordance with the provisions of international law.

It is advisable to pay attention to another cause for the popularity and spread of offshore companies – favourable conditions for investment and business development. Part of the capital withdrawn from the country is subsequently returned in the form of foreign investment. Such investments in the modern economy are called "*round-trip*" which to a word means "*travelling back and forth*". This term is used in telecommunications to refer to the time required to transmit a signal from the transmitter to the recipient. Accordingly, "*round-trip*" are Ukrainian investments that were previously withdrawn to offshore jurisdictions, and then returned as foreign investments. Figure 2 demonstrates the ratio of Foreign Direct Investment (FDI) and "*round-trip*" investments in Ukraine.

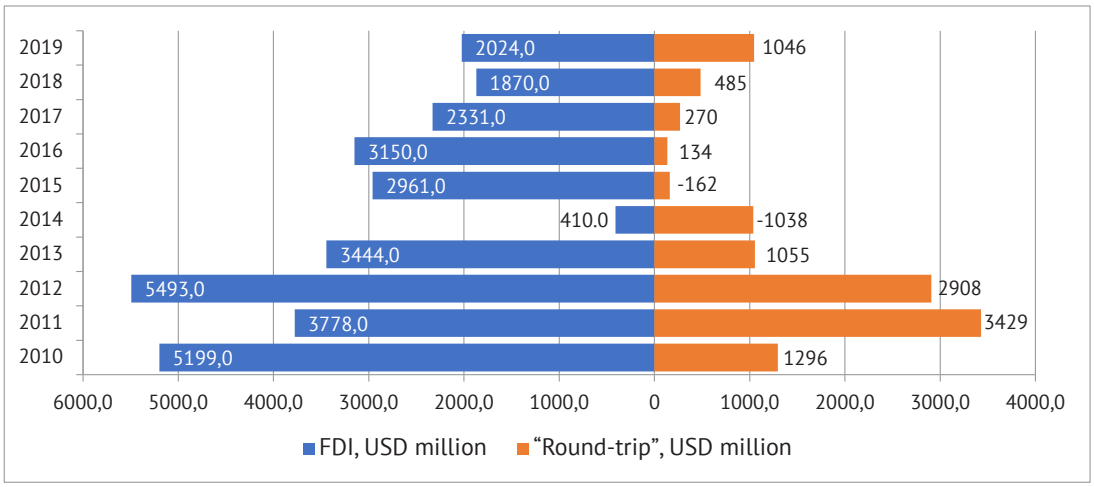

Figure 2. *The ratio of foreign direct investment and "round-trip" investments for 2010-2019, million dollars*
Source: *developed by the author based on data from [24]*

In general, reinvestment is an important process for the Ukrainian economy, since in recent decades such schemes have become not only common but also the main source of financing the Ukrainian economy and ensuring economic development. Figure 3 presents the main investor countries in the Ukrainian economy.

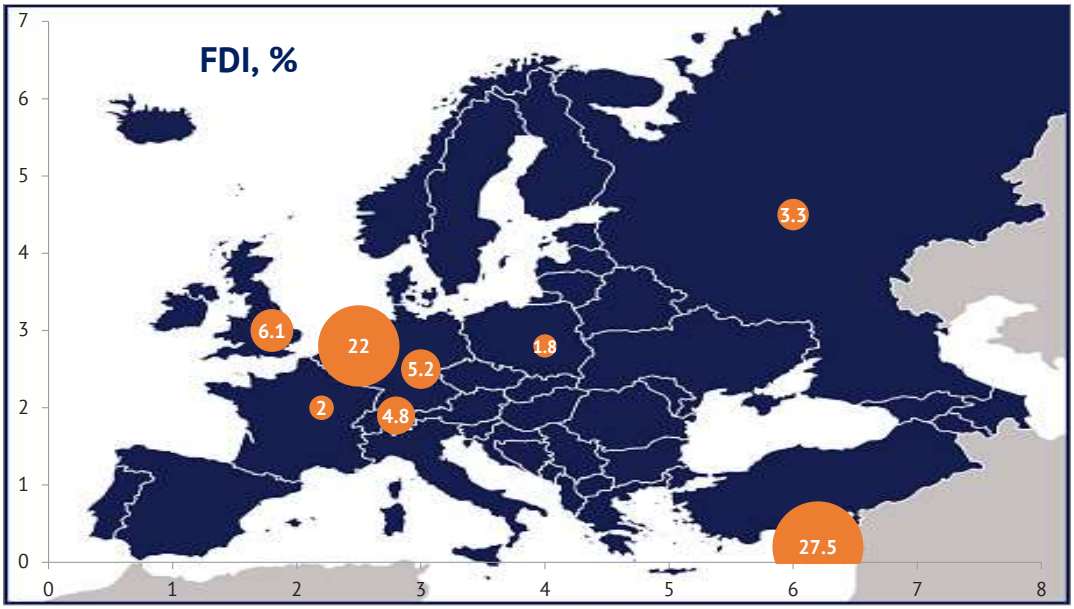

Figure 3. *Cartographic representation of the countries that invest in the Ukrainian economy, in %*
Source: *developed by the author based on [22]*

Based on the analysis, the authors conclude that the main investor in the Ukrainian economy is economic entities located in Cyprus and the Netherlands – two of the most famous and popular offshore jurisdictions in Europe. Accordingly, the objects of investment are Kyiv, Kyiv and Dnipropetrovsk regions – administrative-territorial units, on the territory of which a considerable share of Ukrainian industrial potential is concentrated.

Upon analysing the dynamics of foreign direct investment and the dynamics of "*round-trip*" investments (Fig. 4). The authors can conclude that there is a high level of their co-dependence. Solely in 2016 there was a relatively weak correlation, in all other years analysed, the relationship is quite substantial. Thereby, the dynamics and, to a certain extent, the volume of foreign direct investment depends on "*round-trip*" investments. Thus, the reduction of the "*round-trip*" investment volume can lead to a considerable decrease in the total volume of foreign direct investment, which will substantially affect the national economic security. Therefore, upon developing measures to reduce the volume of the round-trip investment, it is necessary to consider its security importance at this development stage of the Ukrainian economy.

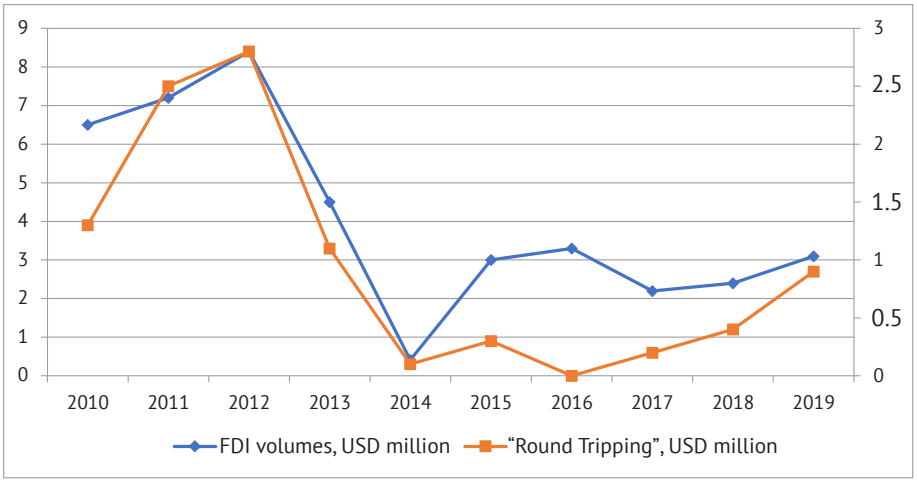

Figure 4. *Dynamics of foreign direct investment volumes and "round trip" investments, billion dollars*
Source: *developed by the author based on [23]*

Notably, return on investment and reinvestment is important to ensure the national economic security and economy legalisation. In particular, the authors noted that in some countries the volume of withdrawn capital considerably exceeds the volume of their external debt (Fig. 5). In particular, in Ukraine, this ratio (withdrawn capital / external debt) is 1.29. That is, the volume of capital withdrawn is 29% higher than the volume of external public debt. Accordingly, an equally important area is the return of withdrawn capital to Ukraine, which makes provision for the introduction of mechanisms for asset recovery and capital amnesty. Such measures would contribute to the capital return, economy de-offshoring, and ensuring the national economic security.

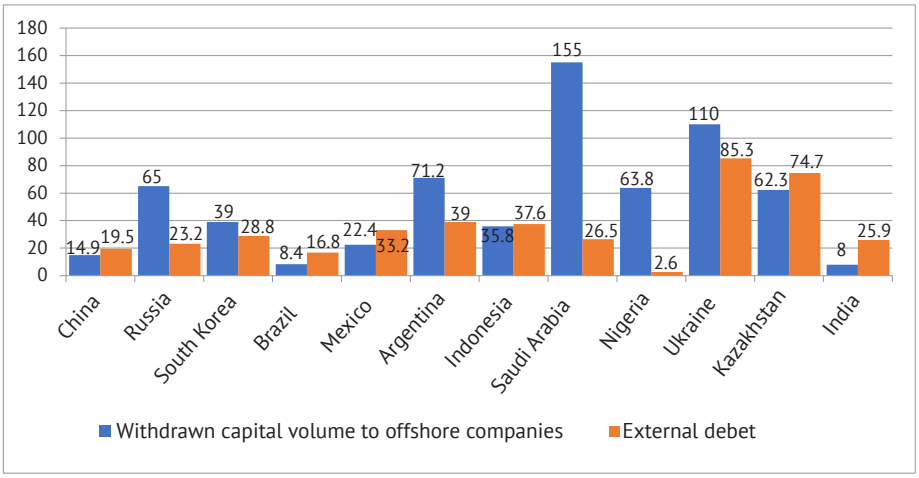

Figure 5. *The ratio of withdrawn capital volume to offshore companies and the country's external debt, billion dollars*
Source: *developed by the author based on [22]*

Therefore, considering historical aspects and current trends, offshoring should be regarded not only as a tax evasion, but also as optimisation of economic activity, which to a certain extent contributes to business and economic development. Notably, according to researchers' studies [9], the tax payment level and the level of tax asymmetry are influenced not only by tax rates, penalties for non-payment, and tariffs for auditors' services, but also by moral and ethical values, the level of social responsibility of an entrepreneur, and the level trust in the government, the confidence that tax revenues are used to improve public welfare [9]. Therefore, a high social responsibility level and trust in the government contribute to the development of entrepreneurs' tax culture, accordingly, the volume of tax revenues increases, and tax asymmetry decreases. Thereby, the low level of trust in the government and social responsibility contributes to the economy offshoring. That is why most international companies and other representatives of the international business environment use offshore companies in their financial activities.

Given the development of modern information and communication technologies, as well as globalisation, offshoring should also be considered as a consequence of economic globalisation. Some researchers [8] have established that globalisation and the digital economy can have a negative impact on national economic security. In particular, e-commerce is a convenient tool for tax evasion, especially payroll taxation. That is, within liberalisation of economic systems, capital movement liberalisation and integration of national economies into the world economic system, it is very difficult to prevent capital withdrawal and reduce tax asymmetry, and offshoring can be considered as a logical follow-up to globalisation and the development of the world financial system. Preventing and decelerating offshoring will be possible only when the difference in the amount of tax burden in different countries is substantially reduced.

Generally, the economy offshoring is a negative phenomenon for the national economy, since it greatly affects and increases the volume of the shadow economy, yet its spread is caused by other reasons, in addition to reducing or avoiding taxation. In particular, this refers to the possibility of the legal protection of Ukrainian businesses, especially from raiding, avoiding excessive administrative pressure from fiscal services, and reducing political pressure on businesses. The deficiency of the tax system and legislation, a considerable criminalisation level, and corruption of society and government led to the rapid national economy offshoring in the late 1990s and early 2000s. Accordingly, in the authors' opinion, these causes for the offshoring growth of the Ukrainian economy should not be ignored, since without their solution it is impossible to reduce the level of economy offshoring, and therefore to legalise the economy.

Economy de-offshoring as a tool for strengthening Ukraine's economic security

Upon summarising the results of the theoretical analysis, the authors noted that it is currently essential to de-offshorise the economy to legalise it and ensure national economic security. Notably, offshoring has become a threat not only to the Ukrainian economy but also to the economy of many states and to the global economy. Therefore, in 2013 the OECD developed a plan to blur the tax base and remove profits from taxation (plan *BEPS*), the main task of which is to prevent the flow of capital to offshore jurisdictions. More than 100 countries have joined the plan, including Ukraine. It is worth focusing on four points of this agreement, which are binding on all participating countries:

– joint counteraction to unfair tax practices;

– prevention of abusing certain provisions of double taxation treaties;

– harmonisation and optimisation of transfer pricing documentation requirements;

– development and improving the effectiveness of mechanisms for resolving disputes between states related to tax issues.

In general, recognising the importance of compliance with these provisions, the authors will focus on the main proposals that, in their opinion, will contribute to the de-offshoring of the economy and its legalisation. First of all, it is necessary to solve the issues that encourage business entities to choose offshore jurisdictions, in addition to the desire to reduce the tax burden – protection of property, Intellectual, and other rights violated in Ukraine, protection of businesses from raiding, access to effective and reliable financial instruments on the international market. Thus, recommendations for de-offshoring the economy and ensuring the economic security of Ukraine include:

1. Improvement of Ukrainian legislation on countering raiding, protecting property, Intellectual, and other rights and freedoms of citizens.

2. Improving the market environment of doing business, improving the investment level – such measures should be systematic and include an increase in the transparency of the judicial authorities, financial infrastructure development, restoring the status of the authorities and government institutions, increasing investment attractiveness through economic and political stabilisation in the state.

3. Implementation of regulatory procedures for controlled foreign corporations. These measures will make it possible to include the income of resident individuals who own non-resident companies in gross tax liabilities. Such measures will also counteract the migration of capital between companies that are in fact owned by the same individual.

4. Introduction of a mandatory reporting system for residents who own businesses outside of national jurisdictions.

5. Tightening transfer pricing rules, which will limit the price manipulation for goods and services in financial settlements made between related parties residents of different countries.

6. Conclusion of cooperation agreements and agreements on the exchange of tax information regarding a violation of tax legislation.

7. Countering the money laundering obtained illegally.

8. Development of effective mechanisms for asset recovery and introduction of capital amnesty, optimisation of tax rates for capital withdrawal.

9. Strengthening responsibility for violations of tax legislation and ensuring a fair tax environment for all economic entities and economy sectors.

CONCLUSIONS

To summarise the results of the study, it is worth noting that the offshoring issues are inherent not only in the Ukrainian economy but also in the global one. The volume of foreign direct investment largely depends on the reinvestment of capital previously withdrawn to offshore companies – "*round-trip*" investments. Accordingly, when developing measures to reduce the volume of "*round-trip*" investments it is necessary to consider their security importance for the economy.

In recent years, the international community has been providing all conditions for de-offshoring of the economy, which allows assuming that in the future this issue will be solved both for the global and Ukrainian economies. To achieve this purpose the conditions stipulated in the plan *BEPS* must be met and a number of proposed measures on economy de-offshoring which provide for improving domestic legislation to increase the investment level and raiding counteracting must be taken. Therewith, it is necessary to slightly strengthen reporting systems, liability for violations of tax legislation, control over transfer pricing, etc. Considering the volume of withdrawal and capital in offshore companies, it is necessary to liberalise the provisions of Ukrainian legislation on capital return and amnesty.

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Офшоризація економіки в конструкті економічної безпеки держави

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Анотація. Розглянуто особливості сучасного розвитку економічних систем – інтенсифікація процесів офшоризації економіки, що обумовлює актуальність тематики дослідження. Мета дослідження полягає у здійсненні теоретичного аналізу офшоризації, встановленні її впливу на економічну безпеку держави та розробці шляхів деофшоризації економіки. Методологічною основою дослідження стали загальнонаукові і спеціальні методи пізнання, зокрема методи діалектичного пізнання, теоретичного узагальнення та абстракції, методи економічного та статистичного аналізу, індукції, дедукції та синтезу. У дослідженні проаналізовано обсяги виведення капіталів у офшори, обсягів податкової асиметрії та обсягів офшоризації економік різних держав, зокрема й України. Ґрунтуючись на даних аналізу, вказано на загрозливі обсяги офшоризації сучасної економіки. Здійснено теоретичний аналіз процесу офшоризації в системі економічної безпеки держави, встановлено основні причини, переваги та недоліки цього процесу для економіки держави. Виокремлено основні загрози, що становить офшоризація для економіки та економічної безпеки держави. Сформовано визначення понять офшоризація та деофшоризація із врахуванням їхнього безпекового значення. З'ясовано, що значна частка виведених капіталів повертається в економіку держави у вигляді так званих «round-trip» інвестицій. Зроблено висновок про необхідність врахування їхнього безпекового значення для економіки при запровадженні заходів щодо зменшення їх обсягів. Здійснено аналіз співвідношення виведених капіталів і зовнішнього боргу різних держав та встановлено, що Україна належить до країн-лідерів за цим показником. Розроблено основні шляхи деофшоризації економіки України та забезпечення економічної безпеки держави

Ключові слова: офшорна юрисдикція, міжнародні фінансові ринки, деофшоризація, капітал, інвестиції

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