RESEARCH OF TECHNOLOGICAL INDICATORS OF GRAIN QUALITY OF LEGUMES AS OBJECTS OF STORAGE AND PROCESSING

Olexander Tkachuk[1]
Myroslava Mordvaniuk[2]

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Abstract. One of the urgent needs of the agricultural sector is to ensure the growth of crop production, including legumes, and increase the competitiveness of domestic agricultural enterprises, which is impossible without government regulation and economic support for agriculture. Strategic development of agrotechnologies with a focus on global trends in approaches to growing and fertilizing crops necessitates the development of adapted varietal cultivation technologies, which will ultimately ensure the formation of a modern technological strategy for the development of Ukraine's agro-industrial complex and ensure its long-term food security. To date, many types of legumes have not lost their importance as important food crops and occupy a prominent place in the formation of food and protein resources in many countries. The unique properties of legumes open an extremely wide range in the solution of vegetable protein and can be used in many areas of the processing industry: a variety of products for daily, dietary and functional nutrition, feed production, drug production, cosmetics. Today, in the period of globalization of the world economy, the production of legumes requires a flexible approach to international competition, ensuring the solution of food and environmental security. Legumes play an important role in the grain and fodder balance of agricultural formations in Ukraine. Strategically, Ukraine should take a course to reduce the export of raw materials and create conditions for the organization of in-depth processing, which will contribute to: meeting the needs of intensive livestock with high-protein feed; creation of additional jobs; increase in tax revenues; ensuring food and environmental security of Ukraine.

[1] Doctor of Agricultural Sciences, Associate Professor,
Vinnytsia National Agrarian University, Ukraine
[2] Candidate of Agricultural Sciences, Senior Lecturer,
Vinnytsia National Agrarian University, Ukraine

1. Introduction

Among the resources of society, food is the most important. Ukraine is the world's leading food producer, even in terms of technological backwardness. However, the further development of the agricultural sector requires the state to develop and implement a well-thought-out strategy for the modernization of agricultural production. The agro-industrial complex, which produces agricultural raw materials and food, is the guarantor of the country's food security [7–8; 90–99].

One of the urgent needs of the agricultural sector is to ensure the growth of crop production, including legumes, and increase the competitiveness of domestic agricultural enterprises, which is impossible without government regulation and economic support for agriculture [1–3, 86–88].

The strategic development of agrotechnologies with a focus on global trends in approaches to growing and fertilizing crops necessitates the development of adapted varietal technologies, which will ultimately ensure the formation of a modern technological strategy for the development of Ukraine's agro-industrial complex and ensure its long -term food security. To date, many types of legumes have not lost their importance as important food crops and occupy a prominent place in the formation of food and protein resources in many countries [15–16; 20–22; 47–48].

The monograph is characterized by scientific novelty, which testifies to the authors' deep knowledge of theoretical and practical aspects of technological methods of growing legumes and is useful for agricultural professionals, as well as professionals who at the scientific and practical levels solve the problem of organic farming. The scientific and methodological value of the monograph lies in the presentation of the results of research conducted on the basis of the Research Farm «Agronomichne» of Vinnytsia National Agrarian University in the village of Agronomichne, Vinnytsia district, Vinnytsia region.

2. Analysis of recent research and publications

Intensification of grain production, including fodder, should become one of the strategic directions of accelerated development of all agro-industrial production of Ukraine by 2030 [4–5; 56–57]. For this purpose it is necessary to focus on creation of high-yielding varieties, innovative technologies for their cultivation, which will be based on the effective use of life factors (light, heat, moisture, nutrients), which will promote maximum synthesis of organic matter and protein. In addition, in the context of climate change, it will be necessary to form a unified agricultural policy for the production of legumes [6–7; 23–25; 81–85].

It should be noted that one of the main tasks of an agricultural producer is not only growing, but also bringing products to certain conditions and organizing its timely delivery to the points of the procurement system, as well as ensuring the quality of the part left by the producer [9–10; 17–19; 77–80]. First of all, the implementation of the global task of the agro-industrial complex to improve the quality of agricultural products, reduce its losses during post-harvest processing and storage depends on this. Industries involved in the storage and processing of agricultural products play a leading role in providing the population with food, as well as in the organization of grain exports of legumes, the traditional producer of which is Ukraine.

In Ukraine, the solution of theoretical, practical aspects of the formation and use of vegetable protein in crop production deals with a number of well-known domestic agricultural scientists, especially those representing the scientific school, in particular, Petrichenko V.F., Babych A.O., Mazur V.A., Bakhmat M.I., Kaminsky V.F., Pantsyreva H.V. and other [11–14; 26–30; 42–46; 57–61; 63–68].

Given the lack of organic fertilizers in the modern crop rotation of Ukrainian agriculture, when in 2019 the fertilized area of manure was only 503,600 ha, which is only 2.7% of arable land with an estimated application of organic fertilizers for the entire arable land of Ukraine 0.5 t/ha at scientifically based norm of 18.3 t/ha, which could partially stabilize the resilience of such agroecosystems, there is an important problem of finding alternative ways to replenish the stock of organic matter in the soil, which will not only improve the agro-ecological condition of soils, but also increase the resilience of such homogeneous agroecosystems. exposure to pests – pests, diseases and weeds, the number of which has increased sharply 61 [30–42].

The traditional legume crop of agricultural lands of Ukraine during the second half of the twentieth century was sown peas, which occupied in the structure of sown areas of each farm at least 10%. In those days, its straw was used for animal feed, so it was not scattered in the fields.

The removal of nutrients from the soil by cultivated crops was compensated by significant amounts of organic fertilizers. The agroecological significance of peas at that time was determined by its symbiotic nitrogen fixation and optimal characteristics of this crop as a steam precursor of winter wheat [49–50; 69–70].

However, it is not uncommon for straw in the fields to be simply burned after harvest. At the same time, about 1.5-2 tons of organic matter is irretrievably lost from one hectare, and the soil microflora is disturbed. This leads to a decrease in soil fertility, which affects the yield of crops. And although in Ukraine at the legislative level there is a ban on such incineration of crop residues, still from year to year it is neglected by many companies [71–76].

In the 21st century, the sown area of peas in Ukraine has sharply decreased, and its agri-environmental significance has increased significantly. The decrease in the sown area of peas is due to economic and business factors and not very high intensification of the technology of its cultivation. At the same time, the sown areas of other, often uncommon legumes, including soybeans, began to grow [52–54].

Legume straw contains more organic matter than other organic fertilizers, and very valuable components to increase soil fertility: cellulose, pentose, hemicellulose and lignin, which are carbohydrate energy substrates for soil microorganisms. This is the main building material for soil humus.

3. Conditions, objective and methods of research

The scientific and methodological value of the monograph lies in the presentation of the results of research conducted on the basis of the Research Farm «Agronomichne» of Vinnytsia National Agrarian University in the village of Agronomichne, Vinnytsia district, Vinnytsia region. Scientific research was performed by conducting field and laboratory experiments. The research was conducted following generally accepted methods. The soil of the experimental field is leached black soil, low humus, on carbonate loam. The humus content in the soil layer is 0-30 cm (according to Tyurin is 3.86-4.11%; easily hydrolyzing nitrogen (according to Cornfield) – 111-121 mg/kg, mobile phosphorus and metabolic potassium (according to Chirikov) – 90 and 179 mg/kg of soil, respectively. The absorption capacity and the number of absorbed bases vary, respectively, between 33-36 and

30-33 mg-eq/100 g of soil. Hydrolytic acidity is 0.76-0.87 mg-eq/100 g soil, the degree of saturation of the basics – 94.7-99.0%.

The solid phase density is 2.58 g/cm^3, the density of the soil structure is 1.14-1.25 g/cm^3, the total porosity is 52-59%. The maximum soil hygroscopicity is 5.2%; the lowest moisture content is 23.4%, the total field capacity is 41.2%. The climate of the southwestern part of the Forest-Steppe of Ukraine is warm, with sufficient moisture. The average radiation balance in the region for the year is 43.3 kcal/cm^2, and for the growing season of sugar sorghum – 137.73 kJ/cm^2. Most of PAR come in June and July. From May to September, 3/4 of the annual amount of heat comes to the soil surface. Annual precipitation ranges from 550-700 mm, 3/4 of which falls during the warm season. The hydrothermal coefficient in the region is 1.4. The weather conditions of the sugar sorghum vegetation period in 2017–2019 years had the following features: with the average long-term rainfall and the sum of temperatures respectively 345 mm and 2903 °C, during the years these indicators fluctuated within such limits. During the research period, two experiments were conducted.

4. Research results

The revival of agro-industrial production, stabilization of economic conditions for the functioning of the food industry is the main goal of state agricultural policy in Ukraine. The agricultural sector, which grows crops, most of which are cereals, is a seasonal production.

In most farms, the main products stored are grains and seeds of various crops. Preservation and rational use of the harvest is an important task of every producer, every farm, regardless of its structure, production volume and other indicators.

A significant role in solving the problem of providing the population with wholesome food belongs to the agricultural processing industry. Along with powerful enterprises of the food industry, the number of agro-industrial enterprises of various forms of ownership, medium and small capacity for processing agricultural products has recently increased. In such enterprises, instead of «large» technologies, technologies with a reduced production cycle using a variety of equipment are used.

That is, depending on the characteristics of production, the quality of raw materials used in a particular technology, some technological parameters may change, but the principled approach to the processing of agricultural products.

Some attention is paid to the storage of agricultural raw materials, as well as products of its processing, because, as we know, the lack of a scientific approach to the problem of product preservation, violation of storage techniques leads not only to quantitative but also qualitative losses. Unwanted changes in the natural properties of raw materials require regulation of technological parameters of individual technological stages, as a result of which the stability of its initial parameters may decrease.

The value of legumes is very high, so they are grown in all countries. Legume seeds are rich in proteins, the content of which varies between 20-40% and on average twice the protein content of cereal grains.

The average chemical composition of the seeds of some legumes is given in table 1.

Table 1

Average chemical composition of grain (per 100 g of edible part of the product)

Culture	Water	Proteins	Fats	Mono- and disaccharides	Starch	Fiber	Ash	Energy value	
								kcal	kJ
Peas	14,0	20,5	2,0	4,6	44,0	5,7	2,8	298	1247
Bean	14,0	21,0	2,0	3,2	43,4	3,9	3,6	292	1222
Lentil	14,0	24,0	1,5	2,9	39,8	3,7	2,7	284	1188
Soybean	12,0	34,9	17,3	5,7	3,5	4,3	5,0	332	1389

* inedible part (in%) of peas, beans, lentils – 0.5; soybeans – 2.0.

Legume seeds are used for food, fodder and technical purposes. They give highly nutritious, protein-rich hay, good green fodder, silage, haylage.

When assessing the quality of legumes, special attention is paid to the appearance and color of seeds (Table 2).

The color determines the freshness, maturity of the seeds and belonging to a particular variety.

Table 2

Restrictive quality standards for leguminous crops

Indicator	Peas (classes)			Bean	Lentil		Chickpea	China	Soybean
	1-st	2-st	3-st		small-seeded	plate			
Humidity, %, no more	20	20	20	23	20	20	20	20	18
Garbage impurities, %, not more	3	6	8	8	8	8	8	8	5
including damaged seeds, %	0,4	2,5	*	-	-	-	-	-	-
Mineral impurities, %, not more	1,0	1,0	*	-	-	1,0	-	-	-
Grain impurities, %	7	15	15	15	15	15	15	15	10
including sprouted, %	1	3	5	5	5	3	5	5	-
Infection with pests	*not allowed except for tick infestation not higher than II degree*								

* within the total content of garbage

The best light-colored seeds, which usually have a thinner shell, grow well. The color of the seeds is the basis for the division of many legumes into types (beans, lentils, rank) or subtypes (peas, beans, chickpeas, beans). Seeds of food beans and lentils, depending on the color are divided into three types.

Of great importance in the evaluation of batches of legumes is the size of the seeds. The most valuable large seeds, which contain fewer shells and more nutrients than small ones. Seed quality is characterized by its uniformity. Aligned seeds are boiled at the same time in contrast to the heterogeneous size of the seeds, which increases the digestibility and taste of the finished product. When processing well-aligned seeds, a higher quality product is obtained.

Humidity for legumes is slightly higher than for cereals. This is due to the fact that very dry legume seeds are difficult to boil, when stored they crack and break down into cotyledons (such as beans), which dramatically reduces its safety and consumer properties. Soybean seeds have low humidity levels and are high in fat.

Peas are the most common legume, it is grown everywhere. In terms of chemical composition, it differs favorably from other cereals. Peas contain on average about 28% protein, 59 – carbohydrates, 1.7 – fat, 3.3 – ash and 8% fiber.

In the process of vegetation, the grains of the lower pods ripen earlier than the others, and last of all the grains of the upper ones. Thus, along with the ripe grains, the plant has a significant part of the grains in which the ripening process has not yet ended or is just beginning. Peas crack easily. To prevent losses, peas are harvested without waiting for full ripening, when the lower beans in most plants turn yellow. Naturally, the grains in different phases of ripening are characterized by different chemical composition and moisture. Biological processes in them also occur with varying intensity. In immature grains, the transformation of simpler chemicals into complex ones continues, which causes the respiratory process to intensify.

The presence of organic and mineral impurities in pea mounds reduces its stability during storage. Hygroscopic impurities, which are plant particles, as well as minerals contribute to the emergence and development of unwanted processes and also prevent aeration.

Characteristic of pea grain, especially dry, is the ability to easily split and break during threshing and other operations. The halves, as well as small particles of grain in places left without shells, are quickly affected by microorganisms, mold and spoilage. They are also more accessible to pests. Therefore, the presence of a significant number of halves and very fragmented particles is considered a serious drawback.

Features of the chemical composition of pea grains significantly affect its storage conditions. Due to the high protein content, peas quickly absorb moisture from the air and hold it with great force. Moisture of the grain and the presence of a large number of nutrients create conditions for enhancing the viability of peas and microorganisms that inhabit its surface, as well as pests.

Cleaning – one of the main measures that can improve the quality of peas. Cleaning of peas from plant residues, halves, very crushed grain particles, mineral impurities is carried out urgently, immediately after receipt of grain. Given the high flowability of pea grain, it is necessary, depending on the variety and size, to select sieves with holes of appropriate size and reduce their slope, placing under one side of the separator wooden bars.

Pea grain is well preserved with a humidity close to 14%. Methods and modes of drying are significantly different from grain grains. Peas are dried by air-solar method. In addition, it is good to pass the grain through the cleaning machines. Active ventilation with dry warm air also gives excellent results.

Thermal drying of peas is carried out very carefully. In the process of drying, the skin often bursts and the core breaks into halves, wrinkles are formed on the surface of the skin, which are clogged with dust. The presence of exposed particles and dust contribute to the development of fungal diseases and the appearance of grain pests. Heat drying modes are set depending on the humidity of the peas. When its humidity is above 18%, the maximum allowable grain heating temperature is 30 °C, and the allowable coolant temperature is 70 °C; at grain moisture not exceeding 18% – 40 and 80 °C, respectively. At high initial humidity peas are passed through the dryer twice or thrice.

When storing peas, keep in mind that it has high hygroscopicity. Conditions are created that prevent the penetration of groundwater, and appropriate ventilation modes are established. It is inadmissible to store peas in storages with clay and cement floors. It is necessary to control the humidity in the mounds, and to ventilate, ventilate and move the peas only if the humidity as a result of these operations will decrease or at least will not change, but the grain temperature will decrease.

As the grain of dry peas easily splits on impact, precautions are taken when shoveling, aerating, sorting and moving on conveyors. Impact machines should not be used. You can not throw peas very high, jerks when shoveling. In cleaning machines provide a uniform mode of their operation and continuous passage of grain layer of the same thickness. When moving on conveyors it is necessary to soften blows at falling of grain. To do this, in the middle of his path create obstacles in the form of inclined sieves of pieces of tarpaulin and sacking. The machines are moved on a clean swept floor. Ladders are placed on the surface of the grain embankment, on which workers are obliged to walk. The height of pea loading is up to 3 m, in the warm season it is reduced. grows strongly. That is why from time to time consignments of peas are sold. During storage, the most harmful pest is pea (bruchus).

It is important to note that weevils are not damaged by peas. This is of great importance for peas in storage. One of the main measures to control the grain at the embankment temperature exceeding 12 °C is aeration. Disinfection of peas is carried out only after 1.5-2 months from the date of harvest, because by this time aeration leads to a decrease in grain germination. The peas must have a moisture content of not more than 15.5%. Determination of germination is performed 15 days before and 15 days after disinfection. For seed peas, storage conditions and control of grain masses are stricter. Seed moisture should not exceed 14%, and in areas with high average annual temperature – 12-13%. The height of the stack in the cold season – eight bags, the embankment is not more than 2.5 m, and in the warm season, respectively, six bags and 2 m. The technique of cleaning and drying of pea seeds is the same as food.

Soybean grain has the following chemical composition: 36.5% protein, 26 carbohydrates, 17.5 fat, 5.5 ash and 4.5% fiber. In terms of protein and fat content, soybeans are significantly superior to grains of other legumes. It is used for making milk, cheese, confectionery, oil, flour, various fillers, to obtain protein concentrates.

Soybean harvest is carried out in September, when the weather becomes unstable and it often rains. This explains its high humidity. Biological properties and chemical composition of soybeans cause its instability during storage. The level of temperature and humidity of grain, as well as the degree of aeration of the grain mass has a decisive influence on storage conditions. With increasing humidity, the intensity of grain respiration increases sharply. The presence of decomposed grains and crushed grains has a significant effect on soybean storage. The respiration of decomposed wet grains increases six fold compared to whole grains. This is due to the development of mold fungi on the surface of grain particles that have been released from the shells.

The flow ability of soybeans is due to humidity. In wet grain, the duty cycle decreases. During storage, the grain volume decreases due to compaction. All batches of grain, regardless of moisture, should be thoroughly cleaned of impurities immediately upon receipt. This measure is of great importance for increasing the stability of soybean mounds, and is a consequence of the elimination of breeding grounds for mold fungi.

Soybean storage is possible at a humidity of 10-12%. When drying soybeans use air-solar method and active ventilation with dry warm air. Typical drying is carried out very carefully. During accelerated drying, moisture evaporates from the surface of the grains and their inner layers at different rates. The husks dry so quickly that the moisture present in the inner layers does not have time to redistribute and moves to the grain surface. While the former retain almost the same volume, the size of the drying shells decreases rapidly. This leads to their rupture and disintegration of the grains into halves. At the accelerated modes of drying steaming and considerable decrease in germination is also observed. Therefore, drying of soybeans is carried out in 2-3 steps. The temperature of the drying agent should be 25 °C; 30… 35; 50 ... 60 °C. The increase in temperature during each process should be less, the greater the initial humidity of soybeans.

Under such drying modes, the grain dries fairly evenly. During drying, the temperature and condition of the grain are closely monitored. If there is an increase in the number of grains with cracked shells and a change in their color, the temperature is reduced and at the same time increase ventilation. It is not necessary to raise temperature of drying agent above 50 ... 60 °C. It is better to store soybeans in well-ventilated dry storages with wooden or asphalt floors. The height of the dry grain embankment should not exceed 2 m, with short-term storage of wet grain – 0.5 m.

In the process of storage of soybean seeds should be careful care to ensure the preservation of its sowing properties. The height of the embankment of seeds in the winter is 1.5 m or a stack of eight bags, and in the warm season it is reduced by a third, respectively, 0.5 m and two bags. A 0.5-0.75 m wide passage is left between the stacks. Seed germination decreases rapidly during storage under adverse conditions. After 3-4 years, as a rule, the seeds lose viability and germinate poorly. Therefore, seed grain must be stored in dry ventilated storage. The seeds should be immediately cleaned of impurities, thin and broken grains and dried at the mildest temperatures to a humidity of 10%.

5. Conclusions

The obtained research results give grounds to believe that the use of high-yielding varieties in intensive cultivation technology is recommended for obtaining highly productive yields of legumes with appropriate grain quality indicators by agro-formation of the Right-Bank Forest-Steppe in intensive cultivation technology. The introduction of high-yielding varieties into production practice with the improvement of technological methods of cultivation will reduce the deficit of vegetable protein, as well as improve the physicochemical and phytosanitary conditions of the soil.

Some attention is paid to the storage of agricultural raw materials, as well as products of its processing, because, as we know, the lack of a scientific approach to the problem of product preservation, violation of storage techniques leads not only to quantitative but also qualitative losses. Unwanted changes in the natural properties of raw materials require regulation of the technological parameters of individual technological stages, as a result of which the stability of its initial parameters may decrease.

In Ukraine and the world promising competitive adaptive technologies for growing legumes based on determining the characteristics of growth, development and yield formation with a comprehensive study and differentiated combination in the technological process of basic elements: varieties, fertilizers, tillage, crop protection from weeds , pests and diseases, as well as studies their biologized models, involving the introduction of low doses of mineral fertilizers in combination with by-products (non-commercial) products of predecessors. These technologies make it possible to obtain a yield of peas – 3.5-4.0, white lupine – 3.2-3.5, yellow lupine – 2.0-2.2, narrow-leaved lupine – 3.0-3.2, beans – 2.5-2.8 t/ha. However, the weak point of such technologies is the binding to specific types of soils, unidirectional application of classical mineral fertilizers, focus on the standard format of microfertilizers, lack of tactics of concomitant control over changes in soil fertility, conflicting data on the effectiveness of such technologies for tillage and the impact of stressors. As a result, the efficiency of the real realization of the yield potential of the outlined range of legumes by 30-55%, and for a number of promising valuable legumes chickpeas, lentils – up to 60-68%. Such aspects confirm the relevance, innovation and production significance of research and its national research and production relevance for the agro-industrial complex of Ukraine and world agricultural practice.

References:

1. Albinus M. (2008) Effects of land use practices on livelihoods in the transboundary sub-catchments of the Lake Victoria Basin. *African Journal of Environmental Science and Technology*, vol. 2, no. 10, pp. 309–317.

2. Albinus M. (2008) Effects of land use practices on livelihoods in the transboundary sub-catchments of the Lake Victoria Basin. *African Journal of Environmental Science and Technology*, vol. 2, no. 10, pp. 309–317.

3. Bakhmat O.M. (2010) Influence of agrotechnical measures on soybean productivity in the conditions of the western region of Ukraine. Feed and feed production: interdepartmental. topic. science. zb. / [editor: V.F. Petrichenko (ed.) and others]. Vinnytsia: Marushchak A.I., issue 66, pp. 103–108.

4. Bakhmat O.M. (2010) Influence of agrotechnical measures on soybean productivity in the conditions of the western region of Ukraine. Feed and feed production: interdepartmental. topic. science. zb. / [editor: V.F. Petrichenko (ed.) And others]. Vinnytsia: Marushchak A.I., issue 66, pp. 103–108.

5. Bandura V., Mazur V., Yaroshenko L., Rubanenko O. (2019) Research on sunflower seeds drying process in a monolayer tray vibration dryer based on infrared radiation. INMATEN – Agricultural Engineering, vol. 57, no. 1, pp. 233–242.

6. Begey S. V., Shuvar I. A. (2007). Ecological Agriculture: Textbook. Lviv: Novyi Svit-2000, 429 p.

7. Bransby D. I. Compatibility of switchgrass as an energy crop in farming systems of the southeastern USA. D. I. Bransby, R. Rodriguez-Kabana.

8. Bulgakov V., Adamchuk V., Kaletnik G., Arak M., Olt J. (2014) Mathematical model of vibration digging up of root crops from soil. *Agronomy Research*, no. 12(1), pp. 41–58.

9. Bulgakov V., Adamchuk V., Kaletnik G., Arak M., Olt J. (2014) Mathematical model of vibration digging up of root crops from soil. *Agronomy Research*, no. 12(1), pp. 41–58.

10. Bulgakov V., Kaletnik H., Goncharuk I., Ivanovs S., Usenko M. (2019) Results of experimental investigations of a flexible active harrow with loosening teeth. *Agronomy Research*, no. 17(5), pp. 1839–1845.

11. Chinchyk O.S. (2012) Influence of fertilizer on yield of legumes in the conditions of the Western Forest-Steppe. Feed and feed production: interdepartmental. topic. Science. zb. NAAS; [editor: V.F. Petrichenko (ed.) And others]. Vinnytsia, vol. 72, pp. 64–67.

12. Cholovskyi Yu.M. (2010) Osoblyvosti vodospozhyvannia posivamy liupynu vuzkolystoho zalezhno vid zastosuvannia mineralnykh dobryv. Kormy i kormovyrobnytstvo – Forage and feed production, vol. 66, pp. 146–147.

13. Cholovskyi Yu.M. (2010) Osoblyvosti vodospozhyvannia posivamy liupynu vuzkolystoho zalezhno vid zastosuvannia mineralnykh dobryv [Features of water consumption of crops of lupine branched depending on the application of mineral fertilizers]. *Kormy i kormovyrobnytstvo – Forage and feed production*, vol. 66, pp. 146–147.

14. Cultural Pasture: Patent No 40618 / V. L. Puyu, M. I. Bakhmat, S. A. Tsvigun; Podillya State Agrarian Engineering University, UA. Application dated 01.07.2008; published 27.04.2009. *Industrial Property*. Kyiv, 2009. Bulletin No 8.

15. Datta, A., Hossain, A., Roy, S. (2019) An Overview on Biofuels and Their Advantages and Disadvantages. Asian Journal of Chemistry, 31(8), 1851–1858. DOI: https://doi.org/10.14233/ajchem.2019.22098

16. Didur I., Bakhmat M., Chynchyk O., Pantsyreva H., Telekalo N., Tkachuk O. (2020) Substantiation of agroecological factors on soybean agrophytocenoses by analysis of variance of the Right-Bank ForestSteppe in Ukraine. *Ukrainian Journal of Ecology*, no. 10(5), pp. 54–61.

17. Didur I., Bakhmat M., Chynchyk O., Pantsyreva H., Telekalo N., Tkachuk O. (2020) Substantiation of agroecological factors on soybean agrophytocenoses by analysis of variance of the Right-Bank ForestSteppe in Ukraine. *Ukrainian Journal of Ecology*, no. 10(5), pp. 54–61.

18. Didur I., Bakhmat M., Chynchyk O., Pantsyreva H., Telekalo N., Tkachuk O. (2020) Substantiation of agroecological factors on soybean agrophytocenoses by analysis of variance of the Right-Bank Forest-Steppe in Ukraine. *Ukrainian Journal of Ecology*, no. 10(5), pp. 54–61.

19. Didur I., Chynchyk O., Pantsyreva H., Olifirovych S., Olifirovych V., Tkachuk O. (2021) Effect of fertilizers for Phaseolus vulgaris L. productivity in Western Forest-Steppe of Ukraine. *Ukrainian Journal of Ecology*, no. 11(1), pp. 419–424.

20. Didur I., Pantsyreva H., Telekalo N. (2020) Agroecological rationale of technological methods of growing legumes. The scientific heritage, 52, pp. 3–14.

21. Didur I., Pantsyreva H., Telekalo N. (2020) Agroecological rationale of technological methods of growing legumes. The scientific heritage, 52, pp. 3–14.

22. Didur I.M., Prokopchuk V.M., Pantsyreva H.V. (2019) Investigation of biomorphological and decorative characteristics of ornamental species of the genus *Lupinus* L. *Ukrainian Journal of Ecology*, vol. 9(3), pp. 287–290.

23. Didur I.M., ProkopchukV.M., Pantsyreva H.V. (2019) Investigation of biomorphological and decorative characteristics of ornamental species of the genus Lupinus L. Ukrainian Journal of Ecology, vol. 9(3), pp. 287–290.

24. Dospekhov B.A. (1985) Metodyka polevoho opyta (s osnovamy statystycheskoi obrabotky rezultatov yssledovanyi). Yzd. 5-e dop. y pererab. Moscow: Ahropromyzdat, p. 351.

25. Egli D. B. (1999) Variation in leaf starch and sink limitations during seed filling in soybean. Crop Science, 39, pp. 1361–1368.

26. Environmental Issues of Agriculture (2010) / I. D. Prymak, Y. P. Manko, N. M. Ridey et al.; Ed. I. D. Primak. Kyiv: Center of Educational Literature, 456 p.

27. Honcharuk I., Kovalchuk S. (2020) Agricultural Production Greening Management in the Eastern Partnershipcountries with the EU. Theoretical and practical aspects of the development of the European Research Area. Publishing House «Baltija Publishing», Riga, Latvia, pp. 42–68.

28. Honcharuk I., Kovalchuk S. (2020) Agricultural Production Greening Management in the Eastern Partnershipcountries with the EU. Theoretical and practical aspects of the development of the European Research Area. Publishing House «Baltija Publishing», Riga, Latvia, pp. 42–68.

29. Honcharuk I., Pantsyreva H., Mazur V., Didur I., Tkachuk O., Telekalo N. (2020) Integration of traditional and innovation processes of development of modern science; Tkachuk O., Telekalo N. Agroecological potential of legumes in conditions of intensive agriculture of Ukraine, pp. 91–104. Collective monograph. Publishing House «Baltija publishing». Riga. Latvia, pp. 42–108.

30. Honcharuk I.V., Branitsky Yu.Yu., Tomashuk I.V. (2017) The main aspects of effective formation and use of resource potential in agricultural enterprises (on the example of Vladovo-Lyulinetska DSS IBK and the Central Bank of NAAS of

Ukraine). Economy. Finances. Management: current issues of science and practice, no. 10(26), pp. 54–68.

31. Honcharuk I.V., Branitsky Yu.Yu., Tomashuk I.V. (2017) The main aspects of effective formation and use of resource potential in agricultural enterprises (on the example of Vladovo-Lyulinetska DSS IBK and the Central Bank of NAAS of Ukraine). Economy. Finances. Management: current issues of science and practice, no. 10(26), pp. 54–68.

32. Kaletnik G. (2018) Diversification of production of biofuel – as the basis of maintenance of food, power, economic and environmental safety of Ukraine. [Diversification of production of biofuel – as the basis of maintenance of food, power, economic and environmental safety of Ukraine]. *Visnyk ahrarnoi nauky – Bulletin of agrarian science*, 11, 169–176. Retrieved from: http://agrovisnyk.com/pdf/en_2018_11_21.pdf

33. Kaletnik G. Honcharuk, I. (2013) Innovatsiine zabezpechennia rozvytku biopalyvnoi haluzi: svitovyi ta vitchyznianyi dosvid [Innovative support for the development of the biofuel industry: world and national experience]. In *Biznes Inform – Business Inform*, no. 9, pp. 155–160.

34. Kaletnik G. (2018) Production and use of biofuels: Second edition, supplemented: textbook. Vinnytsia: LLC «Nilan-Ltd», 336 p.

35. Kaletnik G., Honcharuk I., Okhota Yu. (2020) The Waste-Free Production Development for the Energy Autonomy Formation of Ukrainian Agricultural Enterprises. Journal of Environmental Management and Tourism, vol. XI, Summer, 3(43): 513–522. DOI: https://doi.org/10.14505/jemt.v11.3(43).02

36. Kaletnik G., Honcharuk I., Yemchyk T., Okhota Yu. (2020) The World Experience in the Regulation of the Land Circulation. *European Journal of Sustainable Development*, no. 9(2), pp. 557–568.

37. Kaletnik G.M., Yanovych V.P. (2017) Substantiation of operating and design parameters of a gyration mill for the production of highly active premixes, Vibrations in engineering and technology, 84, no. 1, pp. 15–21.

38. Kaletnik G.M., Zabolotnyi, G.M. Kozlovskyi S.V. (2011) «Innovative models of strategic management economic potential within contemporary economic systems». Actual Problems of Economics, vol. 4(118), pp. 11.

39. Kaletnik, G., & Lutkovska, S. (2020) Innovative Environmental Strategy for Sustainable Development. *European Journal of Sustainable Development*, 9(2), 89. DOI: https://doi.org/10.14207/ejsd.2020.v9n2p89

40. Kaletnik, G., Shubravska, O., Ibatullin, M., Krysanov, D., Starychenko, Y., Tkachenko, K., Varchenko, O. (2019) Features of Food Security of the Country in Conditions of Economic Instability. Int. J. Manag. Bus. Res, 9(4): 176–186.

41. Kantolic A. G. (2007) Development and seed number in indeterminate soybean as affected by timing and duration of exposure to long photoperiods after flovering. Annals of Botany, 99, pp. 925–933.

42. Kolesnik, S. (2012) Bacterial fertilizer to optimize nitrogen and phosphorus nutrition soybeans, chickpeas, peas, lentils and commit. Feed and fodder. 73:145–151.

43. Kosse, V. Mathew, J. (2017) Design of hammer mills for optimum performance. Proceeding of the Institution of Mechanical Engineers, no. 215, pp. 87–94.

44. Kukharchuk V.V., Kazyv S.S., Bykovsky S.A. (2017) Discrete wavelet transformation in spectral analysis of vibration processes at hydropower units, Przeglad Elektrotechniczny, 93, no. 5, 65–68.

45. Kukharchuk V.V., Kazyv S.S., Bykovsky S.A. (2017) Discrete wavelet transformation in spectral analysis of vibration processes at hydropower units, Przeglad Elektrotechniczny, 93, no. 5, 65–68.

46. Kupchuk I.M., Solona O.V., Derevenko I.A., Tverdokhlib I.V. (2018) Verification of the mathematical model of the energy consumption drive for vibrating disc crusher, Inmateh – Agricultural Engineering, 55, no. 2, 111–118.

47. Kupchuk I.M., Solona O.V., Derevenko I.A., Tverdokhlib I.V. (2018) Verification of the mathematical model of the energy consumption drive for vibrating disc crusher, Inmateh – Agricultural Engineering, 55, no. 2, 111–118.

48. Li J., Wang E., Chen W., Chen X. (2008) "Genetic diversity and potential for promotion of plant growth detected in nodule endophytic bacteria of soybean grown in Heilongjiang province of China. Soil Biology & Biochemistry, vol. 40, pp. 238–246.

49. Li J., Wang E., Chen W., Chen X. (2008) "Genetic diversity and potential for promotion of plant growth detected in nodule endophytic bacteria of soybean grown in Heilongjiang province of China. Soil Biology & Biochemistry, vol. 40, pp. 238–246.

50. Ma Z. (2001) Impact of row spacing, nitrogen rate, and time on carbon partitioning of switchgrass Z. Ma, C. W. Wood, D. I. Bransby. Biomass Bioenergy, no. 20, pp. 413–419.

51. Malchevskaya, E., Mylenkaya, G. (1981) The comments and Animal Husbandry quality forage analysis. Minsk: Harvest, p. 143.

52. Mazur O.V. (2019) Otsinka sortozrazkivsoi za kompleksom tsinnykh hospodarskykh oznak [Estimation of varieties for a set of valuable economic characteristics]. *Zbirnyk naukovykh prats VNAU. Silske hospodarstvo ta lisivnytstvo – Collection of scientific works of VNAU. Agriculture and Forestry,* 12, 98–115.

53. Mazur V., Didur I., Myalkovsky R., Pantsyreva H., Telekalo N., Tkach O. (2020) The productivity of intensive pea varieties depending on the seeds treatment and foliar fertilizing under conditions of right-bank forest-steppe Ukraine. *Ukrainian Journal of Ecology*, no. 10(1), pp. 101–105.

54. Mazur V.A., Didur I.M., Pantsyreva H.V., Telekalo N.V. (2018) Energy-economic efficiency of growth of grain-crop cultures in conditions of Right-Bank Forest-Steppe of Ukraine. Ukrainian Journal of Ecology, no. 8(4), pp. 26–33.

55. Mazur V.A., Mazur K.V., Pantsyreva H.V. (2019) Influence of the technological aspects growing on quality composition of seed white lupine (Lupinus albus L.) in the Forest Steppe of Ukraine. *Ukrainian Journal of Ecology*, vol. 9, pp. 50–55. URL: https://www.ujecology.com/archive.html

56. Mazur V.A., Mazur K.V., Pantsyreva H.V., Alekseev O.O. (2018) Ecological and economic evaluation of varietal resources Lupinus albus L. in Ukraine. *Ukrainian Journal of Ecology*, vol. 8, pp. 148–153.

57. Mazur V.A., Pantsyreva H.V., Mazur K.V., Didur I.M. (2019) Influence of the assimilation apparatus and productivity of white lupine plants. Agronomy Research, 17(X), 206–209. DOI: https://doi.org/10.15159/AR.19.024

58. Mazur V.A., Pantsyreva H.V., Mazur K.V., Myalkovsky R.O., Alekseev O.O. (2020) Agroecological prospects of using corn hybrids for biogas production. Agronomy Research, 18(1), 177–182.

59. Mazur V.A., Prokopchuk V.M., Pantsyreva H.V. (2018) Pervynne introduktsiine otsiniuvannia dekoratyvnykh vydiv rodu Lupinus v umovakh Podillia. *Naukovyi visnyk NLTU Ukrainy*, t. 28, no. 7, pp. 40–43.

60. Mazur, V. A., & Pantsyreva, H. V. (2017) Vplyv tekhnolohichnykh pryiomiv vyroshchuvannia na urozhainist i yakist zerna liupynu biloho v umovakh Pravoberezhnoho Lisostepu. *Silske hospodarstvo i lisivnytstvo*, 7, 27–36.

61. Mazur, V. A., Myalkovsky, R.O., Mazur, K. V., Pantsyreva, H. V., Alekseev, O.O. (2019). Influence of the Photosynthetic Productivity and Seed Productivity of White Lupine Plants. *Ukrainian Journal of Ecology*, 9(4), 665–670.

62. Mazur, V. A., Myalkovsky, R.O., Mazur, K. V., Pantsyreva, H. V., Alekseev, O.O. (2019) Influence of the Photosynthetic Productivity and Seed Productivity of White Lupine Plants. *Ukrainian Journal of Ecology*, 9(4), 665–670.

63. Mazur, V. A., Myalkovsky, R.O., Mazur, K. V., Pantsyreva, H. V., Alekseev, O.O. (2019) Influence of the Photosynthetic Productivity and Seed Productivity of White Lupine Plants. *Ukrainian Journal of Ecology*, 9(4), 665–670.

64. Mazur, V.A., Branitskyi, Y.Y., Pantsyreva, H.V. (2020) Bioenergy and economic efficiency technological methods growing of switchgrass. *Ukrainian Journal of Ecology*, 10(2), 8–15.

65. Mazur, V.A., Didur, I.M., Pantsyreva, H.V., & Telekalo, N.V. (2018) Energy-economic efficiency of grain-crop cultures in the conditions of the right-bank Forest-Steppe of Ukraine. *Ukrainian J Ecol*, 8(4), 26–33.

66. Mazur, V.A., Didur, I.M., Pantsyreva, H.V., Telekalo, N.V. (2018) Energy-economic efficiency of growth of grain-crop cultures in the conditions of right-bank Forest-Steppe zone of Ukraine. *Ukrainian Journal of Ecology*, vol. 8, no. 4, pp. 26–33.

67. Mazur, V.A., Mazur, K.V., Pantsyreva, H.V., Alekseev, O.O. (2018) Ecological and economic evaluation of varietal resources Lupinus albus L. in Ukraine. *Ukrainian Journal of Ecology*, 8(4), 148–153.

68. Melnychuk, T., Patyka, V. (2011) Microbial preparations bioorganic farming system. Collected articles "Third All-Ukrainian Congress of Ecologists with international participation". Vinnytsya, tom 2: 423–426.

69. Metodologiya i praktyka vykorystannya mikrobnyx preparativ u texnologiyax vyroshhuvannya silskogospodarskyx kultur (2011) [Methodology and practice of microbial drugs use in crop growing technologies] / V. V. Volkogon, A. S. Zaryshnyak, I. V. Grynyk ta in. Kyiv: Agrarna nauka, 153 p.

70. Mohamed Z., El-Sayed S., Radwan T., El-Wahab G. (2009) "Potency evaluation of Serratiamarcescens and Pseudomonas fluorescens as biocontrol agents for root-knot nematodes in Egypt". *Journal of Applied Sciences Research*, vol. 4, no. 1, pp. 93–102.

71. Monarkh Veronika Valentynivna, Pantsyreva Hanna Vitaliivna (2019) Stages of the Environmental Risk Assessment. *Ukrainian Journal of Ecology*, 9(4), 484–492. DOI: https://doi.org/10.15421/2019_779

72. Muir J. P. (2001) Biomass production of Alamo switchgrass in response to nitrogen, phosphorus, and row spacing. J. P. Muir, M. A. Sanderson, W. R. Ocumpaugh at all. Agron J., no. 93, pp. 896–901.

73. Naum Raichesberg (2000) Adolphe Quetelet, His Life and Research Activities. Moscow: Elibron Classics, 98 p.

74. Osoro N., Kawaka F., Naluyange V. (2014) "Effects of water hyacinth (Eichhornia crassipes [mart.] solms) compost on growth and yield of common beans (Phaseolus vulgaris) in Lake Victoria Basin". *European International Journal of Science and Technology*, vol. 3, no. 7, pp. 173–186.

75. Ovcharuk V.I., Mulyarchuk O.I., Myalkovsky R.O., Bezvikonnyi P.V., Kravchenko V.S., Klymoych N.M. (2019) Parameters of beet plants. *Bulletin of the Uman National University of Horticulture*, no. 1, pp. 70–75.

76. Palamarchuk V., Honcharuk I., Honcharuk T., Telekalo N. (2018) Effect of the elements of corn cultivation the technology on bioethanol production under conditions of the rightbank forest-steppe of Ukraine. *Ukrainian Journal of Ecology*, vol. 8(3), pp. 47–53.

77. Pantsyreva H. V. (2019) Perspektyvnist vykorystannia Asteracea L. v ozelenenni zony Podillia. *Naukovyi visnyk NLTU Ukrainy*, 29(8), 55–59. DOI: https://doi.org/10.36930/40290808

78. Pantsyreva H.V. (2018) Doslidzhennia sortovykh resursiv travianykh vydiv Paeonia L. v Ukraini. *Naukovyi visnyk NLTU Ukrainy*, 28(8), 74–78. DOI: https://doi.org/10.15421/40280815

79. Pantsyreva H.V., Myalkovsky R.O., Yasinetska I.A., Prokopchuk V.M. (2020) Productivity and economical appraisal of growing raspberry according to substrate for mulching under the conditions of podilia area in Ukraine. *Ukrainian Journal of Ecology*, vol. 10(1), pp. 210–214.

80. Pantsyreva, H. V., Mykoliuk, O. O., & Semchuk, V. V. (2019) Suchasnyi stan kolektsii pivonii na bazi botanichnoho sadu «Podillia» Vinnytskoho natsionalnoho ahrarnoho universytetu. *Naukovyi visnyk NLTU Ukrainy*, 29(8), 46–50. DOI: https://doi.org/10.36930/40290806

81. Pantsyreva, H. V., Mykoliuk, O. O., & Semchuk, V. V. (2019) Suchasnyi stan kolektsii pivonii na bazi botanichnoho sadu "Podillia" Vinnytskoho natsionalnoho ahrarnoho universytetu. *Scientific Bulletin of UNFU*, 29(8), 46–50. DOI: https://doi.org/10.36930/40290806

82. Pantsyreva, H. V., Mykoliuk, O. O., & Semchuk, V. V. (2019) Suchasnyi stan kolektsii pivonii na bazi botanichnoho sadu «Podillia» Vinnytskoho natsionalnoho ahrarnoho universytetu. *Naukovyi visnyk NLTU Ukrainy*, 29(8), 46–50. DOI: https://doi.org/10.36930/40290806

83. Pantsyreva, H.V. (2019) Morphological and ecological-biological evaluation of the decorative species of the genus Lupinus L. *Ukrainian Journal of Ecology,* 9(3), 74–77.

84. Pantsyreva, H.V. (2019) Technological aspects of biogas production from organic raw materials. *Bulletin of KhNTUSG them. P. Vasilenko*. Kharkiv, pp. 276–290.

85. Prokopchuk V. M. (2017) Pervynna introduktsiina otsinka sortiv Antirrhinum Majus v umovakh biostatsionaru Vinnytskoho natsionalnoho ahrar-

noho universytetu. *Zbirnyk naukovykh prats VNAU. Silske hospodarstvo ta lisivnytstvo*, vol. 7, tom 1, pp. 113–120.

86. Rai R. K., Tripathi N., Gautam D., & Singh P. (2017) Exogenous application of ethrel and gibberellic acid stimulates physiological growth of late planted sugarcane with short growth period in subtropical India. *Journal of Plant Growth Regulation*, 36(2), 472–486.

87. Razanov S.F. Tkachuk O.P., Mazur V.A., Didur I.M. (2018) Effect of bean perennial plants growing on soil heavy metal concentrations. *Ukrainian Journal of Ecology*, 8(2). 294–300. DOI: https://doi.org/10.15421/2018_341

88. Razanov S.F., Tkachuk O.P., Bakhmat O.M., Razanova A.M. (2020) Reducing danger of heavy metals accumulation in winter wheat grain which is grown after leguminous perennial precursor. *Ukrainian Journal of Ecology*, no. 10(1), pp. 254–260. DOI: https://doi.org/10.15421/2020_40

89. Razanov S.F., Tkachuk O.P., Mazur V.A., Didur I.M. (2018) Effect of bean perennial plants growing on soil heavy metal concentrations. *Ukrainian Journal of Ecology,* no. 8(2), pp. 294–300. DOI: https://doi.org/10.15421/2018_341

90. Razanov S.F., Tkachuk O.P., Razanova A.M., Bakhmat M.I., Bakhmat O.M. (2020) Intensity of heavy metal accumulation in plants of Silybum marianum L. in conditions of field rotation. *Ukrainian Journal of Ecology*, no. 10(2), pp. 131–136. DOI: https://doi.org/10.15421/2020_75

91. Rohach V.V., Rohach T.I., Kylivnyk A.M., Polyvanyi S.V., Bayurko N.V., Nikitchenko L.O., Tkachuk O.O, Shevchuk O.A., Hudzevych L.S., Levchuk N.V. (2020) The influence of synthetic growth promoters on morphophysiological characteristics and biological productivity of potato culture. *Modern Phytomorphology*, 14, 111–114.

92. Varchenko O., Krysanov D., Shubravska O., Khakhula L., Gavryk O., Byba V., Honcharuk I. (2020) Supply Chain Strategy in Modernization of State Support Instruments for Small Farms in Ukraine. *International Journal of Supply Chain Management*, vol. 9, no. 1, pp. 536–543.

93. Vdovenko S.A., Prokopchuk V.M., Palamarchuk I.I., Pantsyreva H.V. (2018) Effectiveness of the application of soil milling in the growing of the squash (Cucurbita pepo var. giraumontia) in the right-benk forest stepp of Ukraine. *Ukrainian Journal of Ecology*, 8(4), 1–8.

94. Vdovenko, S.A., Pantsyreva, G.V., Palamarchuk, I.I., & Lytvyniuk, H.V. (2018) Symbiotic potential of snap beans (Phaseolus vulgaris L.) depending on biological products in agrocoenosis of the right-bank forest-steppe of Ukraine. *Ukrainian J Ecol*, 8(3), 270–274.

95. Vdovenko, S.A., Prokopchuk, V.M., Palamarchuk, I.I., & Pantsyreva, H.V. (2018) Effectiveness of the application of soil milling in the growing of the squash (Cucurbita pepo var. giraumontia) in the right-benk forest stepp of Ukraine. *Ukrainian J Ecol*, 8(4), 1–5.

96. Wolters D., Beste A. (2000) Biomasse – umweltfreundlicher Energieträger? Ökologie und Landbau, 116, 4, pp. 12–14.

97. Yanovych, V., Honcharuk, T., Honcharuk, I. & Kovalova, K. (2018) Engineering management of vibrating machines for targeted mechanical activation of premix components. INMATEH – Agricultural Engineering, 54(1), 25–32.

98. Yhurber J.A. (1958) Inhibitory effect of gibberellins on nodulation in dwarf beans, Phaseolus vulgaris. *Nature*, vol. 181, pp. 1082–1083.

99. Yowling W.A., Buirchell B.J., Tarta M.E. Lupin. Lupinus L. (1998) Promoting the conservation and use of underutilized and neglected crops 23. Institute of Plant lyenetis and crop Plant Research, yatersleben. International Plant lyenetic Resources Institute. Rome, pp. 112–114.

100. Zhao, H., Cao, H., Ming-Zhen, P., Sun, Y., & Liu, T. (2017) The role of plant growth regulators in a plant aphid parasitoid tritrophic system. *Journal of Plant Growth Regulation*, 36(4), 868–876.