UDC: 633.36/37:631.54:633.63:631.527

STRATEGIC LINES TO BOOST GRAIN LEGUME PRODUCTION IN UKRAINE

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Our purpose was to rationalize the need for a significant increase in grain legume fields in Ukraine based on the analysis of food and feed indicators of their seeds, their impact on the soil quality and environment.

Significant nutritional value of legume seeds is determined by high contents of high quality protein, isoflavones, and essential trace elements. They have excellent palatability and pleasant aroma, swell and boil quickly. These crops are able to fix nitrogen from the air, satisfying their own needs and leaving significant amounts of nitrogen in the soil for subsequent crops in crop rotations. Grain legumes should be considered in the crop rotation system together with winter wheat as fallow crops. Their synergistic effect on subsequent crops in crop rotations is attributed to the peculiarity of the microflora of the rhisosphere, where symbiotic and free-living bacteria are concentrated. Surveys indicate the need to expand cultivation of pea, chickpea and lentil in Ukraine, as there are all the necessary conditions – cultivars adapted to water deficit, developed technologies for their cultivation, a positive experience of high yields.

Key words: *pea, chickpea, lentil, symbiotic nitrogen fixation, cultivar, export-import relations.*

Grain legumes play a crucial role in the food balance for mankind. Owing to them, millions of people are provided with a normal diet, especially in developing countries. In addition, for recent decades, increasing numbers of people have been consuming legume products, which reduces the dependence on today's diseases such as cancer, diabetes, dysbacteriosis, anemia, cardiovascular diseases, genitourinary, renal and liver diseases. Consumption of dishes from seeds of these crops helps to improve immunity, normalizes the gastrointestinal tract functioning, has a beneficial effect on the body weight, helping one to maintain a slender figure and prevent premature aging. Such a positive effect on the human body can be explained by biochemical characteristics of seeds. First, they contain high amounts of easily digestible protein, with elevated levels of some essential amino acids. Due to such composition, legume products can replace valuable meat and dairy products only for health benefits, as plant ingredients are free of cholesterol and contain little fat [1, 2]. It should be noted that the more new information about the functional characteristics of legume seeds comes to light, the wider they are used for food. Recently, it has been revealed that these plants accumulate negligible levels of nitrates, nitrites, radionuclides and other toxic substances in aerial parts. Seeds of legume cultivars contain 24–32% of protein, have excellent palatability and pleasant aroma, swell and boil quickly. Products from these crops are rich in isoflavones, which have a preventive effect on the cardiovascular system and anticancer activity, improve the elasticity of blood vessels, lower blood pressure and inhibit platelet aggregation [3, 4]. They are especially important for children and adolescents, who are gaining weight and have high energy expenditure [5, 6]. Legumes, especially lentil and chickpea, play significant roles in providing the population with such important trace elements as selenium, iron and zinc [7–10]. Several studies have clearly shown that diets based on meat-enriched legume-cereal mixtures are much healthier than pure meat or dairy diets [1, 11]. Depending on the crop, legume seeds contain 33.7–51.3% of available carbohydrates [1]. Their important feature is that they contain oligosaccharides, polyols and resistant starch, which are a nutrient medium for beneficial microorganisms in the large intestine performing bioregulatory functions in the gastrointestinal tract [12–15]. In addition to their nutritional value, legume seeds, especially peas, are an important protein component in the manufacture of feed for farm animals and poultry.

The second important feature of legumes is their ability to fix nitrogen from the air and, due to this, almost completely provide themselves with this element. During their vegetation periods, soybean, pea, chickpea, and lentil bind 80-120 kg/ha of nitrogen in active substances, which is equivalent to about 300 kg of nitrate added to the soil. Tubers and root residues are an important source of biological mass, due to which the humus content in the soil may increase. It should be noted that biological nitrogen, which is fixed from the air, is environmentally friendly, it gradually transits from organic compounds to mineral ones and thus fully absorbed. It is not washed away from the soil, does not pollute water reservoirs and the environment, and promotes organic farming, which is highly valued in many countries. Pre-sowing inoculation of seeds with highly effective strains of nodule bacteria, even in the arid steppe zone, ensures a significant gain in the yield [16].

Considerable changes of the climate, which have been observed recently, cannot but affect agriculture. Constantly increasing temperature in spring and summer, long inter-rainy intervals during the growing periods of major crops, showers, thunderstorms and hail, frequent thawings in winter indicate that farmers have faced almost a new climate. This is especially felt in the steppe of Ukraine, where there is a clear upward tendency in soil and air droughts. Grain legumes, especially chickpea and lentil, are drought-resistant and usually grown in places, where other crops do not give economically reasonable yields.

Given the complex of positive features, sown areas and gross outputs of legumes in the world are constantly growing (Table 1).

Table 1

Sown areas and yields of legumes in the world

Year	Sown area, million ha	Yield, cwt/ha	Gross output, million tons
1961	64.01	6.4	40.78
1971	63.51	6.7	42.67
1981	62.56	6.6	41.63
1991	70.73	7.9	56.17
2001	67.64	8.3	56.34
2011	79.63	8.8	70.32
2014	83.46	9.4	78.86
2016	89.71	9.8	87.83
2018	94.75	9.7	92.32
2019	89.06	9.9	88.38

From the above data, it is clear that a significant increase in production of these crops only began at the beginning of the 21st century. In 2001, they occupied 67.64 million hectares in the world, while in 2011 their area exceeded 79 million hectares, i.e. increased by 17.7% within 10 years. The gross output increased by almost 14 million tons during this period. In the following decade, this trend maintained and only in 2019 there was a certain decline in production, due to changes in the export market. Thus, in the 21st century (2001–2019), the area under legumes increased by >21 million hectares, and the production of commercial seeds – by 32 million tons. In 2016–2019, the gross output doubled compared to 1981. In accordance with a FAO program, until 2029 the legume production will be on the fast track [17]. Thus, in 2029, the gross output will reach 102.64 million tons. 8.2 kg of seeds will be grown per capita in 2029 compared to 7.7 kg in 2017–2019. Accelerated growth of the production is predicted in Argentina, Peru, EU, India, Kazakhstan, Germany, and Thailand (Table 2).

Globally, the growth rates of areas under bean, chickpea and cowpea have been highest recently. However, in 2019, the production of chickpea and lentil fell sharply due to reduced areas in Australia, India and Russia. The main reason for this change in the production, from an upward trend to a downward one, is a significant drop in the world market prices. In 2017–2018, there was a "chickpea boom", and the price of top-quality commercial seeds reached $ 1,000 per ton. This situation has been caused by large-scale purchases by a number of countries, especially India, which is the largest importer of legumes in the world.

Table 2

Sown areas and yields of major grain legumes in the world

Cultivar	Sown area, million ha				Yield, cwt/ha				Gross output, million tons			
	2000	2014	2018	2019	2000	2014	2018	2019	2000	2014	2018	2019
Beans	23.8	30.3	34.5	33.1	0.75	0.89	0.88	0.87	17.8	26.8	30.4	28.9
Chickpea	10.2	13.9	17.8	13.7	0.79	0.96	0.96	1.04	8.0	13.4	17.2	14.2
Cowpea	8.9	12.6	12.5	14.4	0.37	0.45	0.58	0.62	3.3	5.6	7.2	8.9
Pea, seeds	6.0	6.8	7.9	7.2	17.8	1.72	1.72	1.98	10.7	11.7	13.5	14.2
Pea, vegetable	1.6	2.4	2.7	2.8	7.77	7.42	7.74	7.82	12.2	17.4	24.2	21.8
Lentil	3.9	4.0	6.1	4.8	0.87	1.17	1.04	1.19	3.4	4.7	6.4	5.7
Lupines	1.3	0.7	1.0	0.9	0.93	1.51	1.21	1.14	1.2	1.1	1.2	1.0
Vetch	0.9	0.5	0.4	0.4	1.10	1.70	1.71	1.83	1.0	0.9	0.7	0.7
Field beans	2.5	2.2	2.5	2.6	1.50	1.94	1.96	2.11	3.8	4.2	4.9	5.4

A significant reduction in purchases by several countries aimed at their self-sufficiency in 2018 led to a fall in the world market prices, and in 2019 – to a reduction in sown areas. In the coming years, an upward trend in the production of these crops is sure to be recommenced, as the population continues to grow, especially in African countries, which are consumers of a significant share of these products in the world market.

At the same time, the number of vegetarians and vegans, whose protein needs are satisfied mainly by legumes, is growing. In Ukraine, pea is the main legume, in addition to soybean. In the late 1980s, its fields amounted to nearly 1.5 million hectares, but then fell sharply. In the following period, the sown area changed, depending on the price and yield (Table 3).

Table 3

Pea seed production in Ukraine

Year	Sown area, thousand ha	Yield, cwt/ha	Gross output, thousand tons
1987	1437.0	2.41	3471.7
2000	258.2	1.75	499.4
2001	298.0	2.07	619.0
2002	324.3	1.89	613.2
2003	337.6	1.10	371.2
2004	258.2	2.46	636.3
2005	311.1	1.98	616.0
2006	236.7	2.00	652.7
2007	246.8	1.09	238.1
2008	201.1	2.26	454.9
2009	237.0	1.81	493.6
2010	278.5	1.62	452.4
2011	245.0	1.49	364.3
2012	216.8	1.58	342.5
2013	185.2	1.14	211.2
2014	144.3	2.49	359.3
2015	182.2	2.14	390.0
2016	238.0	3.16	752.1
2017	405.0	2.67	1081.4
2018	431.5	1.86	802.6
2019	257.0	2.27	583.4
2020	235.0	2.17	509.9

This situation has led to disruption of crop rotations; in some regions – to soil degradation and a sharp decrease in organic matter, shortage of products made from other crops due to inappropriate predecessors. It should be noted that during this period the pea areas in countries-major importers of cereals increased significantly. Thus, in 2000 in Canada it amounted to 1,220,000 hectares, and in 2018 – to 1,711,000 hectares; in the Russian Federation – to 535,800 and 1,210,000 hectares, respectively; in the US – to 71,200 and 425,700 hectares, respectively. It should be noted that the pea yields our country are comparable to those in these countries. For example, the average yield for 2017–2019 in the United States was 2.03 t/ha, in Canada – 2.53 t/ha, in Russia – 2.05 t/ha, and in Ukraine – 2.24 t/ha. The main driver for increasing pea fields is its value as the best forecrop for cereals, especially for high quality grain wheat. Recently, this has been intensively practiced in the US and Canada. Nowadays, fallow predecessors are replaced with legumes, mainly pea, chickpea and lentil on a large scale in these countries. This transition does not reduce the yields of subsequent crops in crop rotations, increases the gross outputs due to the elimination of fallow fields, improves the soil quality, and stabilizes yields over time. It is important to note that this process takes place in regions, where climatic conditions are very similar to those in the steppe of Ukraine. In Canada, these provinces are Saskatchewan and Alberta, where the precipitation amount is 350–400 mm. In the US, complete fallow is being increasingly replaced by pea over the past decade in the arid region, the so-called wheat belt (Great Plains), with the precipitation amount of 320–400 mm. These states are Kansas, Oklahoma, Nebraska, Colorado and others.

As we mentioned above, the climatic conditions in Ukraine are favorable for obtaining economically viable pea yields. In addition, one should take into account a potential gain in the yield of a subsequent crop in crop rotation owing to this excellent forecrop. American scientists' multi-year studies have shown that the yield from winter wheat sown after pea increases by 12% compared to other forecrops, including soybean. This combination of crops gives a synergistic effect, which arises from the more efficient use of water, improved microbiota in the soil and its products stimulating plant growth. It is important to note that this response is more discernible on drought. Thus, the "pea – winter wheat" sequence can be a basis of effective crop rotation in arid regions.

Ukraine has all pre-requisites for pea expansion. The State Register of Plant Varieties Suitable for Dissemination in Ukraine has 52 cultivars; 29 of them have been bred by domestic research institutions. Results of variety trials at stations and farms indicate that under optimal conditions of cultivation the yields from new cultivars amount to 5.0 t/ha. They are highly resistance to lodging and diseases, suitable for direct combining. The Plant Production Institute named after V.Ya. Yuriev of NAAS, Institute of Bioenergy Crops and Sugar Beet of NAAS and Plant breeding and genetics institute – National center of seed and Cultivar Investigation have made the greatest contributions to the creation of such cultivars. Since large area under pea are located in the steppe, our institution have bred drought-resistant medium-sized cultivars for this zone, with a plant height of 80–85 cm [18]. A number of resistant to lodging and diseases cultivars were created at the Plant Production Institute named after V.Ya. Yuriev of NAAS [19]. Recently, a new innovative direction in pea cultivation has been launched – pre-winter sowing. Our four-year studies in the central zone of Odesa Oblast show that expansion of such plantings is quite promising [20].

The last decade was characterized by significant instability of yields from almost all crops, including pea, over the years. Thus, during the past five years, the average yield of the crop in our country ranged 18.2 to 31.3 cwt/ha. Such variability is attributed to two main factors: water in the soil and air temperature during the growing period. In the steppe, the yield variability is determined by even harsher parameters.

It is possible to improve water and thermal modes via autumn sowing, which allows plants to efficiently use winter and spring water reserves and give higher yields. Our field studies on the Serbian cultivar of Moroz and the French cultivars of Enduro and Balltrap demonstrated that this technology had a number of advantages [20]. First, plants make better use of winter and spring water reserves. Secondly, they avoid the negative effects of high temperatures in May – early June. As a result, their yields are more stable over the years. In addition, early spring seedlings protect the soil from wind and water erosion.

It is important to note that the global warming, which is especially evident in the steppe of Ukraine, promotes the implementation of this pea growing technology. The winters have become milder over the last decade, and the spring comes earlier. This trend is predicted to persist; therefore, the new method of pea cultivation looks rather promising. It is beneficial that winter plantings ripen 15–20 days earlier than spring ones, allowing one to accumulate more water for the subsequent crop in the rotation, which is usually winter wheat. We recommend sowing on October 15–20, i.e. after winter cereal sowing. Figure 1 illustrates plants of different pea cultivars on the eve of winter (November 7, 2017) and in the middle of winter (January 9, 2018). It is important to note that most operations of the new autumn sowing technology do not differ significantly from those of the traditional one. Winter and spring cereals as well as corn and millet are good forecrops.

a b

Fig. 1. a – pea plants one month after sowing (November 7, 2017), b – two months after sowing (January 9, 2018). Cultivars: A – Svit, Б – Enduro, В – Darunok Stepu, Г – NS Moroz.

It was proven that a good yield could be also obtained with the No-till or Strip-till technologies. On the sowing day, seeds should be treated with an inoculant made from a highly effective *Rhizobium leguminosarum* strain. This eliminates the need for significant amounts of mineral nitrogen fertilizers. Prior to inoculation, seeds are dressed. The period between dressing and inoculation should be 12–14 days. Generally, phosphorus-potassium fertilizers are applied concurrently with sowing.

Autumn sowing in October is better than spring sowing in wet soil. Particularly significant advantages of this technology are seen when seeds are sown directly in the stubble after harvesting spiked cereals. Even at present in the subtropical zone of China, pea cultivars are mainly sown on the eve of winter. AS Moroz (a Serbian cultivar) has been entered in the State Register of Plant Varieties Suitable for Dissemination in Ukraine for cultivation by the new technology. Our research shows that good results can also be obtained with Enduro and Balltrap (French cultivars). Autumn-sown cultivars are capable of basal branching (Fig. 2).

Fig. 2. Three-branched and two-branched plants of the Enduro pea cultivar

If the main stem is damaged for some reason (low temperature, pests, mechanical injury), the plant is able to form an additional one or two full-fledged lateral branches. This is especially important for thinned plantings. In a large-scale study conducted by Chinese scientists, 672 collection accessions were examined in three zones during three growing periods [21]. As a result, 16 genotypes, which turned out to be the most adapted to the study site conditions in 2015–2016 and resistant to -18^{o}C, were identified. Their genetic analysis using 267 polymorphic markers showed significant levels of variability. This made it possible to categorize the accessions into two groups within the studied gene pool. As to the geographical origin, one group included mainly accessions from China. The English winter-hardy PI 269818 line was found to have been singled out due to this feature in the US much earlier [22]. Seven molecular markers that are closely related to high frost tolerance were described.

Surveys showed that the following temperature mode was the best for the selection of cold-tolerant forms: 4-week adaptation at 4^{o}C with subsequent freezing of seedlings at -7^{o}C to -9^{o}C [23, 24]. Based on the obtained results, it was concluded that cold tolerance depended on 3–4 genes. This trait is significantly influenced by genes that determine the hilum pigmentation (chromosome VI) and the seed coat color (chromosome I).

For breeding purposes, a fairly simple method of screening cold-tolerant pea genotypes based on seedling stem growth rate and chlorophyll fluorescence has been developed [25]. Using this method, one can test 16 plants per hour.

A study of hybrid populations in Michigan (USA) showed an advantage of anthocyanin-synthesizing plants, i.e. field pea, in terms of winter hardiness. In addition, the presence of red eyes on seeds had a positive effect on overwintering [26]. Similar results were obtained in Bulgaria at the Institute of Forage Crops (Pleven) [27]. Field studies showed that some pea cultivars were able to tolerate frosts of -8 to -12^{o}C [22, 28].

Molecular genetics identified six QTLs affecting cold tolerance in pea [29]. Of these, the effects of three QTLs were detected in all test sites. They are located on chromosomes 3, 5 and 6. There were significant genetic studies of inheritance of cold tolerance in pea in Turkey [30]. There, four female components were crossed with three testers. F_1 and F_2 hybrids were grown in the field and at rather low temperatures. It was found that young plants survived -16.8^{o}C without much damage. Several hybrid populations, which were more cold tolerant than their parents, were singled out. The maximum tolerance to low temperature was observed in hybrid populations, where the female component was the Sprinter cultivar. It was found that the general and specific combining abilities for this trait in the parents varied significantly and Sprinter had the highest positive GCA. The estimate of broad-sense heritability was high for winter hardiness in pea.

Studies in France showed that increased tolerance to low temperatures was due to genes associated with photosynthetic activity, as well as with those involved in cysteine and methionine biosynthesis [31]. Thus, cysteine and methionine molecules are cryoprotectants under cold stress. In another study, French scientists investigated a large set of recombinant inbred pea lines and composed a genetic map including 679 markers of seven linkage groups [32]. Two QTL clusters belonged to linkage group III, and one cluster – to group VI. Their results demonstrated that independent breeding for tolerance to low temperatures and performance/product quality was expedient.

Last decade, Serbian breeders made significant progress in the breeding of pea cultivars for autumn sowing. Their cultivars are distinguished by good winter hardiness, longer growing periods and high yields. In this country, pea is sown in the first 10 days of October and harvested in mid-July. Moroz is a quite common cultivar in production; it was derived from crossing French and Serbian frost-tolerant accessions. Lately, this cultivar has been added to the National Register of Ukraine.

It should be noted that in the last few years winter pea sowing spread rapidly on farms in Ukraine, especially in the steppe. The farm *Shestirnia* (Dnepropetrovska Oblast, Shirokivskyi Raion) can be an example. In 2020, pea was grown here on 530 hectares there. Moroz and Enduro were grown. The average yield in this dry year was 34.7 cwt/ha. The area has been increased to 550 hectares this year. On Oleksander Volodymyrovych Maslianyi's farm (Mykolayivska Oblast, Kazanskyi Raion), 27 cwt/ha of winter pea grown by No-till technologies was harvested last year. In Odeska and Mykolayivska Oblasts, dozens of farmers have mastered this innovative way of sowing and get quite high yields of pea.

In 2018–2020, our station together with breeders of the Plant Production Institute named after V.Ya. Yuriev performed a significant number of crossings in order to create cultivars for this technology. To date, stable recombinant lines of this type have been identified, and next year a cold-tolerant cultivar for autumn sowing will be submitted for qualification examination.

Commercial pea seeds are an important segment of the international trade. This was especially clearly demonstrated in 2016–2017 and became the main reason for the expansion of the crop plantings. Large batches of pea were exported mainly to India and Pakistan. The peak of this trend was 2017, when Ukraine harvested more than 1 million tons of pea, of which 872,000 tons, i.e. 80%, were exported. A great portion was sold to India in July–October 2017. Unfortunately, this year (in November), India has raised the import duty by 50%, which significantly reduced exports not only from Ukraine but also from Canada, Russia, the US and France. This action has led to a sharp drop in the world market prices, as India, being the largest importer of legumes, is a trendsetter. The current policy of this country is to provide themselves with these products in order to save currency. The country has introduced price regulation at a minimum level, launched a national program to support farmers in order to significantly expand plantings of these crops. It is important to note that exports from Canada fell by 42% during this period. Due to these changes, Ukrainian pea was later exported to Myanmar, Somalia, Bangladesh, Egypt and Nepal. Pea export to EU countries (Italy, Spain, Germany, the Netherlands, France and Belgium) has also increased significantly. For the market year of 2019/2020, our country has sent 41% of total pea exports to the EU. Thus, nowadays there has been a reorientation of the crop exports, which in general can be considered a positive trend, as the market for the purchase of Ukrainian pea has significantly expanded. The situation with India remains uncertain. The fixation on self-sufficiency is not entirely paid off, as in 2019 the pea production in India, on the contrary, decreased. In 2018, 997,700 hectares were sown with pea, while in 2019, the area was reduced to 606,700 hectares. The gross output has become a positive signal for Russian agricultural producers, who in 2019 increased pea exports to India to 108,000 tons. In 2020, supplies of pea seeds continued.

Another crop that deserves attention due to climate changes is chickpea. Chickpea bush have a typical xerophytic structure: small bushes, small leaves, high osmotic pressure of cell sap. Its leaves and pods are densely covered with hairs excreting a lot of oxalic acid, which scares away many pests. Chickpea is quite common in the global agriculture; in 2018 the area under chickpea amounted to 17.8 million hectares; and the gross output amounted to 17.2 million tons. The main producers of this crop are India, Pakistan, Australia, Iran, Turkey, and Russia. It is important to note that chickpea is highly drought-resistant, hence, it is a valuable component of crop rotations in arid areas. The crop is easily producable: it does not lodge; pods do not shed or dehisce. Pods are set at a height of 20–25 cm from the soil surface, which facilitates high-quality harvesting. Given these beneficial features, recently, chickpea has occupied a niche in the steppe and southern Forest-Steppe our country. Because of the climate aridization, the area sown with chickpea will be constantly expanding in the future.

During the last 25 years, the Plant breeding and genetics institute – National center of seed and Cultivar Investigation created 12 chickpea cultivars, and they were included in the State Register of Plant Varieties Suitable for Dissemination in Ukraine. The creation of large-seeded cultivars is an important achievement, because they are highly valued at the world market (Table 4).

Under the production conditions of our country, the most common cultivars are Rozana, Triumf and Pamiat. In addition, the first two cultivars have passed the state trials and been entered in the State Register of the Russian Federation.

Multi-year studies of chickpea collection accessions helped to identify sources of increased seed productivity, large seeds, high protein content, tolerance to pathogens, and improved technological qualities of seeds. Individual genotypes with improved valuable economic indicators were identified. It was shown that by combining traits of accessions of different eco-geographical origins in one genotype there is a high probability of obtaining valuable recombinant forms through accumulation of beneficial adaptive genes. A great diversity of starting material is required to prevent epiphytotic diseases and mass spread of pests, which are especially dangerous with homogeneous gene pool.

Table 4

Characteristics of chickpea cultivars, average values for the southern Steppe

Cultivar	Seed yield, cwt/ha		Growing period, days	Height of attachment of lower pods, cm	1000-seed weight, g	Protein content, %
	average	maximum				
Rozana	15.6	28.3	92	22	320	27.0
Alexandrit	17.8	29.1	88	18	275	26.5
Pamiat	15.4	27.1	91	21	315	27.1
Antej	14.8	25.6	88	20	390	28.3
Pegas	15.9	27.8	85	18	265	27.5
Triumf	15.5	27.9	93	21	405	28.7
Bujak	16.0	26.1	91	22	412	27.9
Odisej	16.1	24.6	91	22	415	28.5
Skarb	16.5	25.8	94	22	420	26.9

During the breeding period, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT, India, Patancheruvu) became our partner and provided us with more than 2,000 collection accessions. They were studied under our conditions, and the best of them were involved in hybridization.

Yet another crop is worth paying attention to, as its drought resistance is comparable with that of chickpea – lentil. To date, it is rare in production, although in the near future lentil will take its rightful place. The soil and climate in Ukraine are fully suitable for its cultivation on a large scale. Once in the past, it was positively assessed in our country. Before the start of hostilities in 1941, lentil was grown on an area of about 100,000 hectares, but in the postwar period the crop was forgotten.

The experience of some producers shows that in the steppe Ukraine is lentil yields are similar to those in Canada, Turkey and Australia. On most lentil-growing farms, 1.5–2.0 t/ha was harvested. As to economic indicators, this is equal to the winter wheat yield of 7.0–7.5 t/ha, but the cost of lentil growing is almost twice less.

Our production experiments on 12 farms in Odeska, Mykolaivska, Kyrovohradska and Dnipropetrovska Oblasts in 2017 showed the significant value of lentil for the agricultural sector of Ukraine. The accumulated experience is a basis for a significant increase in plantings of this valuable crop.

For Ukraine, Canadian experience is very valuable, as Canada began to grow lentils in the steppe (Saskatchewan and Alberta) at the end of the last century. First in 1975, it was only sown on 400 hectares, and then the area began to grow rapidly, and soon this country became the main producer and exporter of lentils in the world. In recent years, the yields amounted to 14–16 kg ha there.

At the National Center for Plant Genetic Resources of Ukraine (Kharkiv), the collection of lentils has about 1,000 accessions and is constantly enriched [34]. Studies of the collection under the arid steppe conditions revealed a number of genotypes that are lodging resistant, tall, suitable for combine harvesting, and have high seed productivity [35]. To date, in the field, we have detected no harmful diseases. Thus, our country has all the necessary prerequisites for further ramping up the production of this crop. Eight lentil cultivars are in the State Register of Plant Varieties Suitable for Dissemination in Ukraine; of them Linza is the most common in production. Under optimal cultivation conditions, its yield in the steppe exceeds 2.0 t/ha. Our station has submitted a new cultivar, Kometa, for qualification examination.

Since the bulk of legume seeds grown in Ukraine are exported, we believe that it is necessary to sow several crops to ensure a more reliable pricing policy. Unfortunately, the world market nowadays is not stable and quite often prices change significantly within a short period of time. This happened to pea and chickpea in the second half of 2018. On the other hand, now there is a significant rise in prices of commercial seeds of all grain legumes.

A very intensive international trade in legume seeds should be highlighted. In 1980, 2.9 million tons of lentil seeds were sold, while in 2011, the trade exceeded 12 million tons, although the cereal exports only experienced 1.5-fold increase during this period [36]. The main exporters are developed countries (USA, Canada, Australia), and developing countries are importes (South and East Asia and Africa). In 2019, their imports amounted to 23.3 million tons worth more than $ 10 billion, and the exports amounted to almost 19 million tons worth $ 9.9 billion.

Given the crucial importance of grain legumes as a source of high quality food for humanity, 2016 was declared as the International Year of Pulses by the UN, and from 2018 on, World Pulses Day is observed every year on 10 February.

Conclusions. Summarizing the above, we can conclude that at present grain legumes play important roles in the global agricultural sector. Most of them are heat- and drought-resistant, they are unpretentious to the soil quality, on the contrary, are they are soil improvers. It is impossible to compose high-quality crop rotations without them, and they are essential for organic production. As a result, the areas under grain legumes will continue to grow, especially in countries caring about the soil quality for future generations.

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СТРАТЕГІЧНІ НАПРЯМИ ЗБІЛЬШЕННЯ ВИРОБНИЦТВА ЗЕРНОБОБОВИХ КУЛЬТУР В УКРАЇНІ

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Мета. Метою дослідження було обґрунтування необхідності суттєвого збільшення посівів зернобобових культур в Україні на основі аналізу харчових і кормових показників їх насіння, впливу на якість ґрунту та навколишнє середовище.

Матеріали і методи. Польові – визначення показників росту та розвитку рослин, елементів насіннєвої продуктивності; біометричні та вимірювально-вагові – встановлення врожайності та загальної біомаси; біохімічні – визначення вмісту протеїну, олії та інших хімічних складових насіння; статистичні – варіаційний, регресійний та дисперсійний аналіз.

Обговорення результатів. Значна продовольча цінність насіння зернобобових визначається високим вмістом високоякісного білку, ізофлавонів, важливих для життя мікроелементів. Воно виділяється високими смаковими якостями, швидко набухає та розварюється, має приємний аромат. Ця група культур здатна фіксувати азот із повітря, забезпечувати ним власні потреби та залишати значну його кількість в ґрунті для наступних в сівозміні культур. Зернобобові потрібно розглядати в системі сівозмін спільно з озимою пшеницею як парові культури. Їх синергічний вплив на наступні в сівозміні культури пояснюється особливістю мікрофлори прикореневої зони, де зосереджені симбіотичні та вільноживучі бактерії.

Висновки. Проведені спостереження свідчать про необхідність нарощування посівів гороху, нуту і сочевиці в Україні, так як для цього є всі необхідні умови – адаптовані до недостатньої кількості вологи сорти, напрацьована технологія їх вирощування, позитивний досвід одержання високої врожайності.

Ключові слова: *горох, нут, сочевиця, симбіотична азотфіксація, сорт, експортно-імпортні відношення.*

СТРАТЕГИЧЕСКИЕ НАПРАВЛЕНИЯ УВЕЛИЧЕНИЯ ПРОИЗВОДСТВА ЗЕРНОБОБОВЫХ КУЛЬТУР В УКРАИНЕ

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Цель. Целью исследования было обоснование необходимости существенного увеличения посевов зернобобовых культур в Украине на основе анализа пищевых и кормовых свойств их семян, влияния на качество почвы и окружающую среду.

Материалы и методы. Полевые – определение показателей роста и развития растений, элементов семенной продуктивности; биометрические и измерительно-весовые – установление урожайности и общей биомассы; биохимические – содержание протеина, жира и других составляющих семян; статистические – вариационный, регрессионный и дисперсионный анализ.

Обсуждение результатов. Значительная продовольственная ценность семян зернобобовых определяется высоким содержанием высококачественного белка, изофлавонов, важных для жизни микроэлементов. Семена характеризуются высокими вкусовыми качествами, быстро набухают и развариваются, имеют приятный аромат. Эта группа культур способна фиксировать азот из воздуха, обеспечивать им собственные потребности и оставлять значительное количество азота в почве для следующих в севообороте культур. Зернобобовые следует рассматривать в системе севооборотов совместно с озимой пшеницей как паровые культуры. Их синергическое влияние на последующие в севообороте культуры объясняется особенностью микрофлоры прикорневой зоны, где сосредоточены симбиотические и свободноживущие бактерии. Проведенные наблюдения

свидетельствуют о необходимости наращивания посевов гороха, нута и чечевицы в Украине, так как для этого имеются все необходимые условия – адаптированные к недостаточной увлажненности сорта, наработанная технология их выращивания, положительный опыт получения высокой урожайности.

Выводы. На основе собственных результатов и анализа опыта многих стран мира раскрыто значение зернобобовых культур для нашей страны. Отмечена их роль для обеспечения высококачественными продуктами питания, улучшения качества почвы, увеличения экспортного потенциала страны.

Ключевые слова: *горох, нут, чечевица, симбиотическая азотфиксация, сорт, экспортно-импортные отношения.*

STRATEGIC DIRECTIONS OF INCREASE OF BEAN PRODUCTION IN UKRAINE

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Goal. Based on the results to substantiate the need for a significant increase in legume crops in Ukraine on the basis of analysis of food and feed indicators of their seeds, the impact on soil quality and the environment.

Material and methods. Field – determination of features of growth and development of plants, elements of seed productivity; biometric and measuring-weight – accounting of yield and total biomass; biochemical – determination of protein, fat and other components of seeds; statistical – variation, regression and analysis of variance.

Results and discussion. The significant nutritional value of legume seeds, which is rich in high-quality protein with a high content of essential amino acids, isoflavones, essential micronutrients, is substantiated. It is distinguished by high taste, quickly swells and boils, has a pleasant aroma. This group of crops is able to fix nitrogen from the air, provide for their own needs and leave a significant amount of it in the soil for subsequent crop rotations. Legumes should be considered in the crop rotation system together with winter wheat as fallow crops. Their synergistic effect on subsequent crop rotations is explained by the peculiarity of the microflora of the root zone, where symbiotic and free-living bacteria are concentrated. Observations indicate the need to increase crops of pea, chickpea and lentil in Ukraine, as there are all the necessary conditions - adapted to insufficient moisture varieties, developed technology for their cultivation, accumulated positive experience for obtaining high yields.

Conclusions. Based on our own results and analysis of the experience of many countries around the world revealed the importance of legumes for our country. Their role in providing high-quality food, improving soil quality, increasing the country’s export potential is noted.

Key words: *pea, chickpea, lentil, symbiotic nitrogen fixation, variety, export-import relations.*