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THE EFFECTIVE METHOD OF THE YIELD OF PEA INCREASING IN THE STEPPE ZONE OF UKRAINE

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Abstract

Global warming leads to a significant decrease in the yield of most crops in the steppe zone of Ukraine, which has led to large losses of moisture due to evaporation from the soil and leaf cover of plants. To prevent this, it is possible to make better use of winter-spring moisture and avoid the effects of high temperatures on plants in summer. Our research has shown that such requirements are met by winter sowing of pea, which allows to accelerate the growth of plants, improve their water regime, harvest 15-20 days earlier. Sowing varieties of Moroz and Enduro in mid-October makes it possible to get good seedlings in autumn, which survive the winter without significant damage.

Key words : pea, winter pea, varieties Moroz and Enduro, yield stability, productivity, sowing time, moisture.

Introduction

Pea are the main legumes of the world. Its seeds are rich in protein, contain a significant amount of carbohydrates, mineral salts and vitamins needed for human nutrition and animal feeding. Protein pea include all the essential amino acids, they are complete and are absorbed by the human body by 83-87%, only slightly lower compared to proteins of animal origin (meat, fish, etc.). In addition, the prominent place is pea in the production of vegetable products. Unripe beans are eaten fresh or canned. Green pea contain an average (absolutely dry weight) of 29.5% protein. Carbohydrates in vegetable pea are mainly sugar, that is, in the form of easily digestible by man. Also cultivated pea crops for livestock feed. In the vegetative weight of fodder pea the protein content is 18-22% (by air mass). The introduction into the diet of protein-rich sources, such as pea, makes it possible to significantly increase the output of livestock products per unit of feed consumed. By providing a protein-rich crops, the pea not only depletes the soil with nitrogen, but also stores it in the soil with nodules stubble residues and roots in the soil remaining about 50 kg / ha of bound nitrogen. Pea roots have a high solubility, making the plant absorb nutrients from poorly soluble compounds.

Most of the pea seeds obtained in Ukraine (60-70%) are exported mainly to India, Pakistan, Turkey and other countries, a considerable amount of which is used domestically for food and feed needs. Despite some difficulties that have arisen in recent years with the sale of pea to India, it still remains the main importer of this type of seed. In the 2017 - 2018 marketing year (July - April), 41.9% of Ukrainian peas (303.8 thousand tonnes) were exported to it. Thus, growing pea can significantly replenish foreign exchange earnings in the country and provide their own needs for high-quality food and feed protein products. In addition, it is necessary to recall the important positive impact of pea plants in rotation. It is clearly demonstrated that it is capable of accumulating up to 90 - 100 kg / ha of nitrogen in the active substance on each hectare sowing. Most of this element goes into forming its own productivity, but some of it remains in the soil and assimilated by other crops that follow it in rotation. In this regard, it is the best pre-crop for a many crops, especially winter wheat. Research by scientific institutions and production practices has shown that sowing winter wheat after pea produces the same yields

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as after black fallow. Early pea free up the field, which allows to accumulate a considerable amount of moisture in the autumn, to prepare the soil well, to sow winter wheat in time and to obtain good seedlings. Nitrogen-absorbed capacity of pea and increased solubility of its roots are important factors in increasing soil fertility. Expertise of scientific institutions and production practice has shown that pea in crop rotation significantly increase the yield of the next grain crops, sugar beets and other crops. When growing pea, in addition to marketable seeds, get grain waste, halves, which have great forage value.

In recent years, along with spring varieties of pea, agrarians of Ukraine began cultivating its winter crops. Since 2013, winter pea of the Serbian breeding Moroz have been sown for three years at the varietal farms of Ukraine and successfully passed the test. Along with valuable economic features, it was highly rated for winter hardiness, disease resistance and showed a high yield of 4,3 t / ha in Ukraine. Under Serbia, this figure reached 6,2 t / ha. In 2016, for the first time, the Moroz variety was sown in Zhytomyr (Ukrainka Agro) and Vinnitsa (Komora LLC), respectively, 70 and 150 ha. Autumn 2016 with frosts and snow did not damage the seedlings, and cold winter (-26ºÑ) with good snow cover such sowing carried no worse than winter wheat crop [Pavlenko O. 2017]. In Vinnitsia region, the Moroz variety provided a yield of 4,7 t / ha, in Zhytomyr it was slightly lower. Sowing pea in the autumn gives a number of benefits. First, plants make better use of winter and spring moisture reserves. Secondly, they avoid the negative effects of high temperatures in May - early June. As a result, a more stable over the years yield is formed. In addition, the presence of seedlings in early spring protects the soil from wind and water erosion. It is important to note that global warming, which is particularly pronounced in the steppe zone of Ukraine, contributes to the introduction of this technology of growing pea. Winters have become milder in recent decades, and spring comes earlier. As forecasts suggest that this trend will continue, the new cultivation method has significant prospects. Significant positive value is that the ripening of winter crops takes place 15 - 20 days earlier than spring sowing, which allows you to accumulate more moisture for the next crop rotation, usually winter wheat.

In recent years, significant interest among European farmers is the winter sowing of pea, due to global warming. In this century, winters in this area have become milder, to some extent shifted the timing of autumn and spring weather changes. The advantage of such a scheme is to avoid soil drought and high temperatures.

In addition, sowing in late September and during October allows it to be better, than sowing in the spring in moist soil. Particularly significant advantages of this technology occur when sowing directly in the stubble after harvesting cereals [McPee.2003]. Winter sowing of pea has been practiced in Serbia for a long time. Initially, these were crops for green mass, and recently sown created by hybridization of French and Serbian material variety of grain type Moroz. Its introduction into production makes it possible to obtain very early products (a week earlier than winter barley) [Mikic *et al.,* 2011].

Chinese researchers have identified a number of winter-hardy collection varieties [Liu *et al.,* 2017]. Their genetic analysis using 267 polymorphic markers showed a significant level of variability. This made it possible to divide the variety samples into two groups within the studied gene pool. It is important to note that the study of the geographical origin of both groups showed that one of them includes mainly material from China. The winter-hardy line of English origin Pl 269818 revealed in his research was also characterized by this feature in the United States much earlier [Auld *et al.,* 1983]. 7 molecular markers are described, which are closely related to the high level of frost resistance.

The study of hybrid populations in Michigan (USA) showed an advantage in winter hardiness of plants in which anthocyanin was synthesized, those belonging to the group of Austrian winter pea. In addition, the presence of brown pigmentation on the seeds had a positive effect on overwintering [Markarian *et al.,* 1968]. Similar results were obtained in Bulgaria at the Institute of Forage Crops in Pleven [Kosev 2015]. Field studies have clearly shown that some varieties of pea are able to tolerate frosts down to -8...- 12 ° C [Homer *et al.,* 2016].

In the works of Murfet [1971à, 1971 b, 1971 c] found that three genes Lf, Sn and E have a noticeable effect on the nature of pea flowering. In further studies, a fourth Hr gene was identified, which causes a very noticeable phenotypic effect in a short day [Murfet I.C. 1973]. Low temperatures inactivate the effect of the Hr gene. It has little effect on the nature of flowering on a long day, but quite significantly prolongs vegetative growth in a short day, especially in combination with the Sn gene. Subsequent studies have found a significant association between the Hr gene and resistance to low temperatures [Liesenfeld *et al.,* 1986]. The effect of this gene is to delay the formation of flowers until the coldest period passes. Field and laboratory studies on recombinant pea lines have shown that the Hr locus plays a major role in determining the level of resistance to cold stress.

Molecular genetics identified 6 QTL locus that affect the cold resistance of pea [Liesenfeld *et al.,* 1986]. Of

these, the effect was detected in all three test sites. They are localized in chromosomes 3, 5 and 6. By studying in detail the genetic factors influencing the resistance of pea to low temperatures, French scientists note that in addition to the Hr locus, there are other genetic components that significantly affect this trait [Dumont *et al.,* 2009].

Extensive scientific work on the genetic basis of inheriting the cold resistance of pea was carried out in Turkey [Ceyhan 2006]. Here 4 maternal forms with three testers were crossed. Populations of F1 and F2 hybrids were grown in the field at fairly low temperatures. Installed that young plants without special damage withstood a temperature of -16.8° C. A number of hybrid populations were found, the cold resistance of which was higher than the maternal forms. The maximum level of resistance to low temperature was observed in hybrid populations, where the maternal form was the variety Sprinter. It was found that the general and specific combination ability on this basis in the parental forms differed significantly, the largest positive value of general combination ability was the variety Sprinter. There is a high level of inheritance coefficient in a broad sense according to the level of winter hardiness of pea. Extensive scientific research has been performed by French scientists in order to study the genetic indicators of cold resistance and create on their basis a valuable source material for winter pea [Klein *et al.,* 2014]. During 2005-2010 new sources of resistance to low temperatures were identified, frost-resistant recombinant lines were created, and 679 markers were described, which are localized in 7 linkage groups. Of these, 161 locus account for 9-71% of phenotypic variability for the 6-site test. The two QTL clusters in linkage group III and one in group I are genetically related by phenological and morphological characteristics, as well as yield and winter hardiness. The other two QTL, which are localized in the linkage group V, were independent of phenological and morphological features, which indicates the presence of different mechanisms of protection against freezing.

A number of experiments have clearly shown that resistance to survival at low temperatures is a rather complex property and largely depends not only on air temperature but also on soil condition, the presence of snow cover and other weather factors.

Observations have shown that the following temperature regime is best suited for the isolation of cold-resistant genotypes under laboratory conditions - an adaptation period of 4 weeks at 4 ° C. Then there is a freezing of seedlings at temperatures from -7 ° C to -9 ° C [Swensen *et al.,* 1983; Liesenfeld *et al.,* 1986]. A relatively clear selection of cold-resistant genotypes bearing the Hr allele occurred during the 11-day adaptation period and 5-day freezing of hybrid pea populations [Dumont 2009]. In this study, the low temperature tolerance rate was assessed based on the number of dead plants after the recovery period, electrolyte levels, and RuBisCo activity. Increased amount of raffinose and higher activity of RuBisCo had a positive effect on the transfer of the cold period by pea plants. The obtained hybrid lines from crossing cold-resistant variety Melrose, medium-resistant Romack and sensitive to low temperature Garfield were frozen in the laboratory and grown during autumn sowing in the field [Liesenfeld *et al.,* 1986]. Based on the obtained results, it was concluded that the level of cold resistance depends on the action of 3-4 genes.

Materials and Methods

The first practical results of winter pea seed production in Ukraine give grounds not only to look more closely at this new culture, but also to study its developmental biology, economic and valuable features in other pea-growing regions of Ukraine. Due to such exceptional economic value of pea in forage production and the importance of this culture, the Odessa State Agricultural Research Station under the scientific guidance of Professor Sichkar V.I started working with varieties of winter pea Moroz (Serbia), Enduro and Balltrap (France). The main issues of this program are to explore the possibility of growing and producing winter pea seeds in the Northwestern Steppes of the Black Sea. Determined the influence of sowing dates on overwintering, the dynamics of growth and development of plants and productivity in the central zone of Odessa region.

In 2017, experiments with pea varieties for winter sowing Moroz and Enduro, as well as common varieties of domestic selection Svit and Darunok Stepu were established in the central zone of Odessa region. The Moroz variety was bred at the Institute of Field and Vegetable Crops (Novi Sad, Serbia). It is currently listed in the state register plant varieties of Ukraine. The Enduro variety was created in France, its seeds are propagated and sold by the Czech company Oseva. A brief description of this variety is as follows. Seeds yellow, rounded. Weight of 1000 seeds - 170-200 g. The recommended sowing rate is 1 million seeds per hectare (170 - 200 kg / ha). The variety was characterized by high yields both in tests and in production crops (from 4 to 6 t / ha). The protein content is 22.7%. Sowing is best done on October 10-15.

Seed place depth of 5-6 cm. The plants tolerate low winter temperatures well (at the level of winter wheat). The variety shows the best results in the southern regions, for which it is actually intended.

The field experiment was sown in autumn with plots of 10 m2 in 4 repetitions in three terms: 1st - 5.10, 2nd - 15.10, 3rd - 25.10. 2017, the interval between autumn sowing dates was 10 days. Phenological observations were performed according to the method of state varietal testing, morphobotanical description in accordance with the textbook prepared by scientists of the Institute of Plant Production nd. a V.Ya. Yuriev [Kirichenko *et al.,* 2009].

Results and Discussion

Seedlings of the first sowing period appeared in 13 days (Fig. 1). Detailed characteristics of plants in the process of their growth and development are given below. As can be seen from Fig. 2, the pea Svit (A) variety are the most developed in comparison with other varieties, their height is almost twice as high as other plants and reaches 18-20 cm. Other varieties had a length of the ground part of the plants approximately the same, which was 12-15 cm, and the highest among them was the variety Darunok Stepu (15 cm). According to the length of the underground part of the plant - roots, the variety Moroz stood out.

If in other varieties the length of the roots was 5-9 cm, in the variety NS Moroz 12-15 cm. Also on the plants of this variety were observed lateral branches of the stem, which is characteristic of genotypes of this type. Calculation of plant density of the first sowing period did not reveal a large difference between varieties. At the same sowing rate of seeds of each variety (1-1.1 million seeds / ha) the number of plants was as follows: variety Svit - 89.2; Enduro - 91.3; Darunok Stepu - 100.7; Moroz - 87.5 pcs / m2. The slight difference in plant density between varieties is primarily due to the field germination of the seeds and possibly to the variety differences.

Comparative features of seedling growth of different sowing dates are shown in tables 1 and 2. As we see, the characteristics of seedlings significantly depend on sowing dates. Plants of the second term have a height of ground mass twice less than plants of the first term. This difference is especially pronounced in the typical spring varieties Svit (A) and Darunok Stepu (B). The root system of plants is also distinguished by a similar tendency. The only exception may be the wintering variety NS Moroz (Ã), in which the plants of the second term had a root length approximately the same as in the first term, and the aboveground part of this variety did not differ much during the growing season. Only in plants of the first sowing period the lateral branches reached almost the length of the main stem.

Plants of Svit variety of the 1st sowing period had a well-developed aboveground vegetative mass longer than 20 cm, the stem consisted of 9-10 nodes. Plants of the 2nd sowing period had a less developed stem 16-18 cm long with 7-8 nodes. The third term looked half less than the second, the plants had a stem length of 10-12 cm and 5-6 nodes with stipules and tendrils. The wintering variety of the French breeding Enduro in comparison with the typically spring variety Svit looked less high for all sowing dates. Thus, the plants of the first term had a stem length in the range of 17-19 cm and 7 nodes, the roots remained the same size. Plants of the second term were 10-11 cm long and carried 6-7 nodes, the third 4-5 cm and 3-4 nodes.

Plants of the Darunok Stepu variety of the first sowing

First time of sowing **Second time** **Third time of sowing**

Fig. 1: Appearance of pea sowing dates on January 9, 2018.

Fig. 2: Pea plants of the first sowing period one month after sowing (November 7, 2017), varieties: A -Svit, Á - Enduro, B - Darunok Stepu, Ã - Moroz.

growth of plants of the NS Moroz variety remained without noticeable changes, especially the root system.

Plants of the 2nd term of the varieties Svit and Darunok Stepu in the period from 24.11 to 9.01 actively increased the ground weight from 12 to 18 cm, while the growth of wintering varieties Enduro and NS Moroz in this period remained virtually unchanged, both ground and underground mass.Plants of the 3rd term of different varieties also differed in the size of the ground vegetative mass, especially the variety Svit (11 cm) and Enduro (10 cm). The size of the root system in wintering varieties of pea was slightly larger (2 cm) than in spring varieties. The spring period was marked by unfavorable conditions for normal growth and development of pea plants. There

Table 1: Dynamics of growth of pea plants of different varieties of the 1st sowing period (5.10.2017) in the autumn-winter period of 2017-2018.

Data	Svit		Enduro		Darunok Stepu		Moroz	
	Length, cm		Length, cm		Length, cm		Length, cm	
	Stem	Root	Stem	Root	Stem	Root	Stem	Root
07.11.2017	18-20	8	11-12	7-9	15-16	10	12-13	11-15
21.11.2017	18-20	13	11-12	14	16-18	13	12-13	12-15
09.01.2018	22-24	13	13-16	14	17-18	13	14-15	13-15

Table 2: Dynamics of growth of pea plants at different sowing dates, cm.

Indicator	Svit		Enduro		Darunok Stepu		Moroz	
	24.11	09.01	24.11	09.01	24.11	09.01	24.11	09.01
2nd time of sowing (15.10.2017)								
Stem	10-12	17-18	7-8	9-10	8-9	16-17	7-8	10-12
Roots	8-9	9-10	9-10	11-12	10-11	10-11	9-10	9-10
3rd time of sowing (25.10.2017)								
Stem	5-6	10-11	3-4	9-10	6-7	7-9	3-4	7-8
Roots	3-4	4-5	6-7	6-7	4-5	5-6	5-7	6-7

period developed a stem 16-18 cm long with 9 nodes. Plants of the second sowing period had almost the same length as the first term, which was 15-16 cm and 8-9 nodes. The plants of the last term were distinguished by a stem length of 5-8 cm and 5-6 nodes. Variety Moroz is a typical winter pea and the plants of the 1st and 2nd sowing period on the height of the stem did not differ from each other. Their height was 14-16 cm in the presence of 8-9 nodes. The plants looked well bushed with 2-4 side shoots, the height of which often reached the main stem. The third term in appearance resembled early plants only in miniature. The length of the stem was 7-8 cm, the number of nodes 4-5 pcs. As can be seen from the tables, pea plants of the 1st sowing period of all varieties in the period from 7 to 21 November actively developed root mass, and in the period from 21.11 to 9.01 vegetative ground mass. Although the nature of was no significant precipitation for almost the entire period of spring vegetation. The plants consumed the moisture that remained after the winter period, so they were characterized by low height and productivity. The formation of the crop took place in a limited time. Full ripening of beans came on June 2-3.

The technology of growing pea for winter sowing does not differ significantly from the conventional spring. It is important to choose the right variety. Studies show good adaptability to winter conditions of Ukraine varieties Moroz and Enduro. Next year, we also included in the study a relatively new French variety Balltrap, which in 2017 was included in the national register of the Czech Republic. It is distinguished by increased frost resistance, yield and resistance to lodging.

Conclusions

Based on the results of field research, it is established that the technology of growing pea during winter sowing contributes to higher plant productivity through better use of winter-spring moisture and avoidance of high temperatures in early summer. Full ripening of such crops occurs in early June, which allows you to use the vacated areas or for sowing crops with a short growing season (millet, buckwheat) in the same year, or apply them semi-fallow tillage as a pre-crop for winter wheat. The Serbian variety NS Moroz and the French Enduro are fully suitable for such crops, as they are characterized by sufficient levels of resistance to low temperatures and lodging. The optimal sowing dates come in mid-October.

References

Pavlenko, O. «Agrarnik». Elektrona versi'ya. (2017). S. 60-62.

McPhee, K. (2003). Dry pea production and breeding: a mini-review. *J. Food Agric. Environt.*, **1(1):** 64-69.

Mikiè, A., V. Mihailoviè, B. Èupine, V. Dordeviè, D. Miliè and G. Due (2011). Achievements in breeding autumn-sown annual legumes for temperate region with emphasis on the continental Balkans. *Euphytica*., **180(1):** 57- 67. DOI: 10.1007/s10681-011-0453-7.

Liu, K., L. Fang, T. Yang, X. Zhang, J. Hu, H. Zhang, W. Han and X.V. Zong (2017). Marker - trait association analysis of frost tolerance of 672 worldwide pea (*Pisum sativum* L.) collections. *Sci. reports*, **7:** 5919. DOI: 10.1038/541598:017-06222-y.

Auld, D.L., R.L. Ditterline, G.A. Murray and J.B. Swensen (1983). Screening peas for winterhardiness under ûeld and laboratory conditions. *Crop Sci*., **23(1):** 85-88. DOI: 10.2135/cropsci 1983.0011183x002300010024x.

Markarian, D., R.R. Harwood and Ph.R. Rowe (1968). The inheritance of winter hardiness in *Pisum.* II. Description and release of advance generation breeding lines. *Euphytica.,* **17(1):** 110-113. DOI: 10.1007/BF00038971.

Kosev, V. (2015). Evaluation of genetic divergence and heritability in winter field pea genotypes. *Selekciya I Nasinnictwo.,* **108:** 106-115.

Homer, A., M. Sahin and U. Kucukozdemir (2016). Evaluation of pea (*Pisum sativum* L.) germplasm for winter hardi-ness in Central Anatolia, Turkey, using field controlled environment. *Czech j. Genet. Plant Breed.,* **52(2):** 55–63. DOI: 10.17221/186/2015-CJGPB.

Murfet, I.C. (1971a). Flowering in *Pisum*. Three distinct phenotypic classes determined by the interaction of a dominant early late gene. *Heredity*, **26:** 243–257. DOI: 10.1038/hdy. 1971.30.

Murfet, I.C. (1971b). Flowering in *Pisum*. A three – gene system. *Heredity.*, **27:** 93–110. DOI: 10.1038/hdy. 1971.74.

Murfet, I.C. (1971c). Flowering in *Pisum*. Reciprocal grafts between known genotypes. *Aust. J. Biol. Sci*., **24(4):** 1089–1102. DOI: 10.1071/B1971089.

Murfet, I.C. (1973). Flowering in *Pisum*. Hr, a gene for high response to photoperiod. *Heredity*., **31(2):** 157–164. DOI: 10.1038/hdy. 1973.72.

Lejeune-Henaut, I., E. Hanocq and L. Bethencourt (2008). The flowering locus Hr colocalizes with a major QTL affecting winter frost tolerance in *Pisum sativum L. Theor. Appl. Genet*., **116(8):** 1105–1116. DOI: 10.1007/s00122-008-0739-x.

Dumont, E., V. Fontaine, C. Vuylsteker, H. Sellier, S. Bodele, N. Voedts, N. Devaux and B. Delbreil (2009). Association of sugar content QTL and PQL with physiological traits relevant to frost damage resistance in pea under field and controlled conditions. *Theor. Appl. Genet*., **118(8):** 1561-1571. DOI: 10.1007/s00122-009-1004-7.

Ceyhan, E. (2006). Genetic analysis of cold hardness in peas (*Pisum sativum* L.). *J. Plant Sci*., **1(2):** 138–143. DOI: 10.3923/ps. 2006.138.143.

Klein, A., H. Houten, C. Rond, P. Marget, F. Jacquin, K. Boucherot, M. Huart and J. Burstin (2014). QTL analysis of frost damage in pea suggests different mechanisms involved in frost tolerance. *Theor. Appl. Genet*., **127(6):** 1319-1330. DOI: 10/1007/s00122-014-2299-6.

Swensen, J.B. and G.A. Murray (1983). Cold acclimation of field peas in a controlled environment. *Crop Sci*., **23(1):** 27-30. DOI: 10.2135/cropsci 1983.0011183x002300010009x.

Liesenfeld, D.R., D.L. Auld, C.A. Murray and J.B. Swensen (1986). Transmittance of winterhardiness in segregated populations of peas. *Crop Sci.,* **26(1):** 49-54. DOI: 10.2135/ cropsci 1986.001183 x0026 00010011x.

Kirichenko, V.V., L.N. Kobyzeva, V.P. Petrenkova, V.K. Ryabchun, O.M. Bezugla and T.Yu. Markova (2009). Identification of the characteristics of legumes (pea, soybean) (textbook). Kharkiv, Plant Production Institute nd. a. V. Ya. Yuriev of NAAS. 172 p. (in Ukrainian).