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Selection of high-yielding, high-tech varieties of field pea (*Pisum sativum* L.)

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ABSTRACT

One of the major challenges facing the selection of leguminous crops, and pea in particular, is to increase their technological properties and yield. An important problem is also the increase of protein content in the seeds. The aim of this work was to create a high-tech variety of field peas with a short growing period. By repeated individual selection from the hybrid population of the Chishminsky 95 × Usach field pea, a precocious, highly productive PamyatiHangildina variety of pea (leafless) was obtained. The combination of new mutant traits in one plant (seed shedding - *def* gene, leafless type - *af* gene) and elements of productivity structure with optimal level of their development allowed the variety to successfully pass all tests and in 2012 it was included in the State Register of Selection Achievements of the Russian Federation . For an average of 5 years of competitive testing, the variety had a seed yield of 1.62 t/ha, exceeding the standard (control) by 0.67 t/ha. The created variety has a short growing period and a high content of protein in the seeds. The research results could be successfully used in the selection of improved peas.

Key words: Field peas, Gene, Individual selection, Selection, Variety, Yield.

INTRODUCTION

Leguminous crops have important food and feed value (Dahl W.J. *et al*., 2012; Rungruangmaitree *et al*., 2017). They can satisfy the increasing demands for high-protein feed and nutritious food (Jensen *et al*., 2003).

Pea seed (*Pisum sativum* L.) is a valuable leguminous crop, widely used in feeding and food purposes, however, it has drawbacks: low productivity of forage and grain, crop subsistence, and shedding seed. Peas (*Pisum sativum* L.) is considered an export vegetable that is highly demanded by the European Union and the United States of America markets (Fuchs *et al*., 2017). Field peas (*Pisum sativum* L. var. arvense) is one of the most important legumes of India (Keshav *et al*., 2017; Sandeep *et al*., 2018). Pea is also the main grain crops in the Republic of Bashkortostan. Its share in the structure of sown areas in individual agricultural enterprises reaches 9% (Davletov *et al*., 2013). However, the yield of this crop is low, and it varies greatly from year to year (Obuhova *et al.*, 2012).

An important role in increasing yields and the gross yield of pea grain belongs to breeding and seed production, the most relevant area of which is the creation of more productive, high-tech varieties suitable for mechanized (direct) harvesting (Smıkal *et al.*,2012; Aybegün *et al*., 2018). Sweet varieties are of particular interest. For animals, the sugar content in feed is very attractive (Kuznetsov *et al*., 2018).

In recent years, with the aim of increasing the productivity and manufacturability of peas, breeders at various stages of selection use forms with mutant traits: a determinant type of stem growth, leafless type, a multiple fruit, nonshedding seed (Zhang *et al.*, 2006; Ayeh *et al.*, 2009). Years of experience show that early maturing, highly productive forms of leafless type are of great practical value (Tar′an *et al*., 2004; Wilson *et al*., 2005). Due to the powerful development of tendrils, pea plants adhere firmly to each other, creating a hard herbage. The beginning of lodging is postponed to a later date and its degree decreases. Herbage is better lit and blown (Gajnullina, 2013). Consequently, the level of development of diseases, pests, as well as damping, rotting of the leafy part is minimum. As a rule, the phytosanitary condition of such a field is better (Gajnullina *et al.*, 2011). Many breeders indicate the feasibility of the use of biological means of protection in the selection of peas. However, it should be noted that plant protection machines need further improvement.

The review of the research conducted in the direction of plant selection with field pea shows the need for targeted selection of field pea to combine in one plant new mutant traits (seed nonshedding - *def* gene, leafless type - *af* gene) and productivity structure elements with optimal level of their development.

In this regard, the goal of our research (2001-2017) was to create a high-yielding, technological pea variety that

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is resistant to diseases, pests, lodging and shedding of seeds, characterized by high indicators of grain quality.

MATERIALS AND METHODS

Field experiments were conducted on the experimental fields of the Bashkir Research Institute of Agriculture of the Ufa Center of the Russian Academy of Sciences (Southern forest-steppe zone of the Republic of Bashkortostan) in 2001-2017. The soil is leached chernozem with heavy loamy granulometrical composition.

In view of the biological characteristics of the variety, the main attention should be paid to measures aimed at preserving and accumulating moisture in the soil, providing pea plants with nutrients, destroying weeds, fighting nodule weevil, pea crop moth, aphids. In the cultivation of seeds, the best predecessors are winter rye, sown on a fertilized fallow land, and spring wheat, following winter rye. In the experiment the predecessor was winter rye.

The soil tillage - is common to the respective zone. Mineral fertilizers (phosphorus in a dose of 40-60 kg of P_2O_5 per hectare and potash - in accordance with the indicators of soil cartograms) are applied in autumn under a plowing, and preferably in spring, after prefield cultivation by the local-tape method just before field. When field, granulated superphosphate is added to the rows with seeds at the rate of 15-20 kg of P_2O_5 per hectare. On soils poor in nitrogen, instead of granulated superphosphate, 50 kg of ammophos should be added. Mineral fertilizers in high doses can lead to an increase in acidity. Field is carried out in an ordinary way in the early stages. The seeding rate is 1.2-1.3 million germinating seeds per hectare. The depth of seeding is 7-8 cm.

From agrotechnical measures of weed control in the system of plant care, one should widely use harrowing before germination and harrowing on shoots in the phase of 3-5 leaves. The greatest effect in weed control is achieved with a combination of agrotechnical and chemical control measures. It is advisable to use the recommended herbicides - soil and flooding on Pamyati Hangildina pea varieties.

In the phase of budding - flowering, crops are protected from a pest complex (pea aphid, pea weevil, pea moth, thrips) (Marullo and Ravazzi, 2016; Woźniak *et al.*, 2017). For treatment they apply Karate, K. *et al* a rate of 0.1 l / ha, Fastak, c. - 0.1 l / ha, Decis, K. e. - 0.2 l / ha or other recommended insecticides (Vahitova, 2015).

The method of harvesting is direct or separate. Direct combining is used in areas relatively weed-free, and in conditions of dry and hot weather. If it is planned to harvest unevenly ripening or clogged pea crops directly, they are treated with desiccants. For the treatment of crops they use Reglon super, 15%. R. at a rate of 1.5-1.8 l / ha. The possibility of using direct combining is expanding in connection with the introduction into production of standing and non-shedding Pamyati Hangildina pea varieties.

Weather: The climate of the Republic of Bashkortostan is characterized by moderately warm summers and cold long winters. The frost-free period is 95-125 days. The last frosts are in early June, the first autumn frosts are in late August. Annual precipitation is about 400–500 mm, including 130–180 mm during the growing season. The sum of biologically active temperatures (above + 10ºC) for the growing season is equal to 1,800-2,200ºC. In general, the weather conditions for the period of selection work with the new variety were for the mist part unfavorable, which made it possible to evaluate it for resistance to biotic and abiotic environmental factors.

Methodology: The selection of peas was conducted in accordance with the guidelines of the All-Russian Institute of Plant Genetic Resources named after N.I. Vavilov on the study of leguminous crops and methods of State variety trials (Methodical instructions…, 1975; Methods of State crop testing, 1985).

Statistical analysis: Experimental data were analyzed by statistical methods (dispersion, regression and correlation analyses) using STATISTICA 5.0 for Windows and Excel 2007. Determination of crude protein content in plant samples (GOST 13496.4-93). In order to reduce the possible error, the chemical composition of plants is additionally determined on the computer - analytical system NIR SCANNER model 4250, infrared analyzer SpectraStar 2200. As a standard, in all nurseries the variety Multik was used (leafless morphotype).

RESULTS AND DISCUSSION

In recent years, the successes of Bashkir breeders in improving the adaptability of pea cultivation are associated with the creation of leafless varieties. In plants of this morphotype, the stipules were preserved and the leaves were modified into tendrils, which fix the stems and keep them from lodging (Davletov *et al.,* 2011).

In the Bashkir Research Institute of Agriculture of the Ufa Center of the Russian Academy of Sciences, breeding work on lodging resistance has been conducted since 2001. As a result of many years of work, Pamyati Hangildina pea variety was created - the first variety recommended for cultivation of peas of the Bashkir selection. It was derived by the method of multiple individual selection from the Chishminsky 95 hybrid population ×Usach (Fig 1).

The maternal form - Chishminsky 95 variety - is distinguished by a rapid growth rate in the initial phases of development, friendly flowering and ripening. The paternal form, the Usach variety, is characterized by leafless (tendril) type.

The crossing of Chishminsky 95 and Usach varieties was carried out in field conditions. In the autumn-winter period, F_1 hybrids were propagated in a greenhouse and F_2 hybrids were obtained under field conditions by the simple

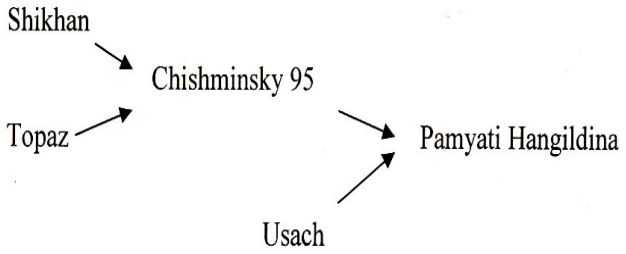

Fig 1: Genealogy of the PamyatiHangildina pea variety.

replanting method. In the second generation, a stormy formative process was observed. A large variety of morphological and economically valuable plant characteristics was obtained. Thus, in the Chishminsky 95 × Usach hybrid population, 65 plants were found in F_2 with the common leaf, 19 – of leafless type (Table 1).

The ratio of common (leaf) with leafless was 3: 1. Evaluation of the grain productivity of leafless and common (leaf) ones showed that leafless morphotypes have lower productivity (8.07 ± 0.52) as compared to leaf morphotypes (9.17 ± 0.68).

Leaf morphotypes formed high productivity due to the increased number of beans and seeds on the plant. Thus, on average, 1 plant had 5.6 ± 0.20 beans, 29.2 ± 1.25 seeds, and leafless, respectively, 5.0 ± 0.16; 24.7 ± 1.10.

For further work from the hybrid population Chishminsky 95 × Usach, F_5 elite plants were selected. Selected plants were characterized by the maximum number of seeds per plant and were distinguished by larger grain.

In 2001, the selected breeding material was evaluated in a breeding nursery. In the course of the study, the number 678 was allocated from the breeding nursery for high seed productivity and registered in the journal of selected lines under the number 28757.

Structural analysis of 40 plants showed that their length was 58–63 cm, the number of productive nodes was 4–5, the number of beans per productive node was 1.5–2.0, the number of beans per plant was 5–7, seeds - 24-30 pcs., productivity (mass of seeds from a plant) - 6.10-7.00.

After the comprehensive study in the control nursery and preliminary variety testing, the L-28757 received a full assessment of economically valuable items in competitive testing. The main indicators of competitive testing of peas Л - 28757 are given in Table 2.

Thus, as a result of breeding, we have created the line 28757, combining high seed yield with a short growing season and an increased protein content in the seeds. As can be seen from the data of Table 1, it exceeded the standard variety Multik in yield on average for 2005–2009 by 0.67 t/ha. In 2008, the Л-28757 was called Pamyati Hangildina and was transferred to the State breed testing.

The variety is early ripe, the growing season is 61-68 days. The variety *Zirrosum*. The stem is simple, green, 56-65 cm long. It is of leafless type, there are no leaves (Fig 2). Stipules are medium-sized, the axillary spot has no anthocyanin coloration. Inflorescence – is two-flowered truss. The flowers are large, corolla is white. Beans are straight or slightly curved, with a pointed tip. The length of the bean is 5-7 cm, the width is 1.2-2.2 cm, the seeds in the bean are 5-6 pcs.

The seeds are pink, rounded, smooth, of medium size with a seed blade (Fig 3). The mass of 1,000 seeds is 240-242 g. The protein content in seeds is 21.0-21.4%. Smoothness is even, taste is excellent. Variety Pamyati Hangildina is included in the list of valuable varieties.

Drought resistance is high. The incidence of ascochitis, root rot is below average - medium, it is damaged by pea moth and aphids below average. The new variety has

Table 1: Chishminsky 95 × Usach Hybrid Splitting Analysis, F_2 leaf type.

Genotype	Splitting		$d(\varphi_1-\varphi_2)$	d^2	χ^2
	fact, φ_1	theoretically, φ_2			
Common (leaf)	65	63	+2	4	0.063
Leafless	19	21	-2	4	0.190
Total	84	84			0.253

Note: p=0.80-0.50

Table 2: Indicators of competitive testing of peas Л-28757 (2005-2009).

Indicators	Multi-standard	Л-28757	± to the standard	HCP_{05}, t/ha
Length of growing season, days	65	64	-1	
Mass of 1,000 seeds, g	147	241	+94	
Content of protein in seeds, %	20.7	21.4	+0.7	
Seeds yield, t/ha	0.95	1.62	+0.67	0.17
Presnece on non-shedding gene, *def*	+	+		
Presence of leafless type gene, *af*	+	+		

Note: p, %=3,9

Fig 2: A plant of peas varieties L-28757 (PamyatiHangildina).

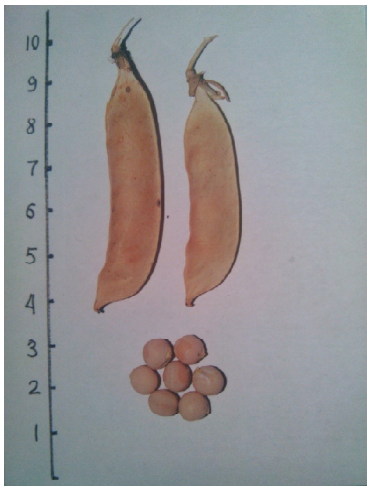

Fig 3: Beans and seeds of L-28757 (PamyatiHangildina).

a higher protein content in the seeds, has manufacturability, since it is of leafless type, controlled by the *af* gene and almost non-skimming, which greatly facilitates mechanized harvesting.

The average number of pea seed varieties Pamyati Hangildina in the variety sites of the republic in 2009–2017 was 1.88 t/ha, higher than the standard variety Aksai leafless 55 by 0.18 t/ha. A relatively high yield of seeds — more than 2.7 t/ha — was obtained in 2011 at the Karmaskaly variety plot. On Karmaskaly, Kaltasy, Buzdyak variety sites of the Republic of Bashkortostan, on average for the years 2009-2017, the yield of this variety was respectively 2.0; 1.5; 1.6 t/ha, higher than the standard variety Aksai leafless 55 by 0.29; 0.27; 0.25 t/ha.

Since 2012, Pamyati Hangildina variety has been included in the State Register of Breeding Achievements of the Russian Federation and is approved for use in the Urals, Volga-Vyatsky and Middle Volga regions. At the moment, competitive testing of new pea lines of leafless type Л-36512 and Л-42158 is underway.

Pod yield per plant exhibit positive and highly significant correlation with number of pods per plant, number of branches per plant and days to fifty percent flowering. The path coefficient studies also revealed that maximum positive direct effect was observed through number of pods per plant followed by days to first flowering (Gautam *et al.*, 2017), to fifty percent flowering. This is consistent with the results of our selection, however, leaf morphotypes form high productivity due to the increased number of beans and seeds on the plant. On average, 1 plant has 5.6 ± 0.20 beans, 29.2 ± 1.25 seeds, and leafless forms, respectively, 5.0 ± 0.16; 24.7 ± 1.10. Of considerable interest are semi-leafless varieties of field pea, differing in erect growth habit (Jermyn *et al.*, 1996). The disadvantage of this trend is partial weediness at the time of ripening and loss of yield due to shedding of seeds, which is eliminated in our variety due to the hard coupling of the tendrils. The value of leafless forms lies in their high manufacturability, since the seeding does not fall heavily. As a result of the method of repeated individual selection carried out by us, the leafless form acquired the status of 6.5 ± 0.14; 29.5 ± 1.01.

The dependence of the protein content in the seeds of pea seed on the length of internodes, the ratio of leaves and tendrils, the environment is described in (Burstin *et al.*, 2007). That coincides with the main direction of selection of our variety, but the difference in Pamyati Hangildina variety is the enhancement of the non-shedding gene, which dramatically increases its technological properties and relevance. The experience of creating field pea with a high mass of 1,000 seeds at 260 g is interesting, but these varieties have high efficiency only in a mild climate (Russell *et al.*, 1995). In our weather conditions, they are not profitable, but they are of interest for breeding in the direction of increasing the mass of 1,000 seeds.

CONCLUSION

The derived pea variety of Pamyati Hangildina pea, by repeated individual selection from the hybrid population of Chishminsky 95 × Usach, confirmed its effectiveness by increasing the seed yield and protein content in the seeds. For an average of 5 years of competitive testing, the variety had a seed yield of 1.62 t/ha, exceeding the standard (control) by 0.67 t/ha. The created variety has a short growing season. A further increase in the competitiveness of pea varieties of leafless type should be due to an increase in the number of beans on the fertile node (2-3), while maintaining three planting nodes in the plant. In the conditions of the Republic of Bashkortostan, a model pea variety should have 6-8 beans per plant. This problem can be solved by including in the selection multiple forms and new mutant traits. Selection improvement of new varieties of leafless morphotype should be carried out in the direction of reducing the weight of 1,000 seeds (coarseness), increasing the bean's grain content (up to 50%), but with the obligatory preservation of plant architectonics and other traits and properties, as in Pamyati Hangildina variety.

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