AGRICULTURAL BIOLOGY,
2018, V. 53, № 1, pp. 179-188
(SEL'SKOKHOZYAISTVENNAYA BIOLOGIYA)

ISSN 2412-0324 (English ed. Online)
ISSN 0131-6397 (Russian ed. Print)
ISSN 2313-4836 (Russian ed. Online)

UDC 635.656:631.522/.524:581.134.1

doi: 10.15389/agrobiology.2018.1.179eng
doi: 10.15389/agrobiology.2018.1.179rus

SEED CARBOHYDRATE COMPOSITION AND ITS RELATION TO ANOTHER BREEDING IMPORTANT TRAITS OF GARDEN PEA (*Pisum sativum* L.) IN KRASNODAR REGION

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The authors declare no conflict of interests
Received June 11, 2017

Abstract

Starch is the main pea (*P. sativum* L.) seed carbohydrate in which the amylose to amylopectin ratio is controlled genetically. Recessive allele *r* of locus RUGOSUS determines an increase in the amylose fraction which leads to the wrinkled-seed character of vegetable peas. A high proportion of amylose in pea starch (more than 70 %) promotes a slow transition of sugars to starch and results in a longer period of technical ripeness. High-amylose starch determines the use of peas in dietary nutrition, and also as raw materials for biodegradable plastics and films. Pea diversity on amylose content is poorly studied, and no data about the relationship between this trait and other agronomically valuable parameters is available. This study is the first to report polymorphism of VIR Collection accessions (Vavilov Institute of Plant Genetic Resources, St. Petersburg, Russia) and breeding forms from Krymsk Experimental Breeding Station (Krasnodarskii krai, Russia) on carbohydrate composition under contrast weather conditions, and a relationship between the amylose content in seeds, smaller seed size and seed number per pod. The objectives of this work were to reveal garden pea polymorphism on starch carbohydrate composition, to seek for genotypes with high-amylose starch in mature seeds and to estimate the relationships between the seed starch composition and other valuable traits in pea plants. In 2015 and 2016, 39 vegetable pea specimens were tested in field trials in Krasnodarskii krai. Starch content in seeds was determined polarimetrically, and iodine-based calorimetry was used for amylose assessment. The biochemical traits were influenced by environmental conditions. In more favorable 2016 as compared to 2015, seed productivity per plant was 4.5 g higher, the starch accumulation decreased by 3.6 %, whereas the amylose content in starch increased by 1.6 % ($p < 0.05$). There was no statistically significant difference in amylose content detected between accessions of leafy (*Af*) and semi-leafless (*af*) morphotypes in contrast weather conditions of 2015 and 2016 which indicates that both types may be involved in breeding programs. In both years, the highest amylose proportion in starch was in accessions with smaller 1000 seed weight ($r = -0.34$ in 2015, $r = -0.32$ in 2016; $p < 0.05$) and the largest seed number per pod ($r = 0.47$ in 2015, $r = 0.41$ in 2016; $p < 0.05$). Starch and amylose contents correlated inversely ($r = -0.60$ in 2015, $r = -0.49$ in 2016; $p < 0.05$). Varieties Grundy, Durango, and Gropesa were starch-rich with the high amylose level in starch and could serve as donor genotypes. Starch and amylose contents, as averaged over a two-year period, were 31.9 and 75.1 % ($p < 0.05$), respectively, for Grundy, 32.0 and 74.1 % ($p < 0.05$) for Durango, 35.1 and 75.4 % ($p < 0.05$) for Gropesa. Among the varieties studied, SV 0987 UC, Vinco, Omega, Gropesa, and Butana possessed the high amylose level in seeds (79.5, 72.2, 74.0, 75.4 and 72.4 %, respectively, as averaged over 2 years) and small-sized seeds ($p < 0.05$). Varieties Mucio and Olinda were high in amylose (77.5 and 71.4 %, respectively) in combination with more than 8 seeds per pod ($p < 0.05$).

Keywords: starch, amylose, seed productivity, morphotypes, *Pisum sativum* L., garden peas, relations of the traits

Vegetable pea (*Pisum sativum* L.) is the most important food crop being a source of high quality proteins, carbohydrates, micronutrients and vitamins in its technical ripeness stage. Main form of carbohydrates in pea seeds is presented by starch. Polysaccharide ratio of amylose to amylopectin ratio forming the starch is controlled genetically. At least 60% of amylose is known to be accounted for pea starch with wrinkled seed character (marrowfat pea) typical to vegetable pea variety, while 25-30% — to smooth-seeded pea [1]. It is similar to cellulose (which is very important in supporting bowel action thereby preventing colon cancer) in nature of monomers from which starch polysaccharide is made of, i.e. α-form of glucose in starch and β-form in cellulose, while structure of homopolymers to be formed is not the same [2-4].

High amylose starch identifies slow overripenning of seeds at technical ripeness stage [5], which is required in vegetable pea processing. High amylose starch is also considered as valuable stock in chemical industry when manufacturing biodegradable plastics [6], e.g. technical and packing (including edible packing for food industries), as well as thermoplastic films for medicine [7]. Thus, development of vegetable pea cultivars, with seeds thereof containing larger content of both vitamins, micronutrients and amylose, is becoming the most important direction in breeding especially considering biofortification strategy i.e. increase of nutrition crop.

At least 6 genes (loci) responsible for synthesis of starch, amylose and amylopectin (*r, rb*, *rug3*, *rug4*, *rug5, lam*) [8] are described in peas. Recessive allele *r* of locus RUGOSUS is the most important one to be used for breeding. If it is in homozygous state it defines marrowfat (wrinkled) seed character. Activity of SBE (starch branching enzyme) responsible for amylopectin synthesis is greatly decreasing in *rr* genotypes in germs resulting accordingly in reducing of starch amount, increase of amylose and 2-fold sucrose accumulation as compared with similar values for smooth-seeded peas. These plant seeds are sweeter and absorb more water which they give back at ripening thereby becoming wrinkled over surface. Relative fraction of reserve protein legumin is reducing therewith [9]. Recessive mutation of *rb* gene reduces activity of ADP-Glucose Pyrophosphorylase responsible for rate of sucrose-to-starch transformation, thereby resulting in two-fold reducing of starch synthesis (as compared with wild type) and glucose and fat content increasing [10, 11]. Recessive allele *rug3* is revealed by reducing starch content both in seeds (up to 1% of dry substance, while in wild types it reaches 50%), and in leaves due to no activity of plastid phosphoglucomutase (PGM) catalyzing transformation of glucose-6-phosphate to glucose-1-phosphate [12]. Mutation in locus *rug4* results in reducing of sucrose (Sus) synthetase activity in growing seeds, roots, tubercules and leaves [13]. Recessive allele *rug5* results in reducing of starch synthase activity II (SSII) involved in amylopectin synthesis by elongating molecules thereof as compared to the molecules of wild type [14]. Allele *lam* is encoding relaxed version of starch synthase I related to granules, affecting neither seed shape change, not starch content thereby resulting in great changing of amylose synthesis in embryos [15, 16]. Amylose content in starch is known to be increased in final stage of seed growth [17].

There are few papers in the world scientific literature devoted to screening of the pea varieties by amylose content in seeds and by type of this trait variation [2, 3, 18, 19]. M. Hybl et al. [19] in spite of large volume of the material analyzed (over 400 samples) have made evaluation within one year and they think the achieved results as preliminary ones. Therewith, there is absolutely no information on relation between vegetable pea starch composition and other traits important for breeding. Besides, more leafless morphotypes (*af*) and forms with determinant growth type (*det, def*) with vast changes in morpho-physiological plant state are involved in vegetable pea breeding [20]. Formation of leafless high amylose pea variety was reported, with starch content in seeds being 28.8% and 70.9% amylose in starch [21]. Generating of forms with stem fasciation combined with determinant growth type (*det* and *fa* gene alleles) is promising [22-24]. Therefore, to plant high amylose varieties possessing the above traits one should know relations between such traits and carbohydrate composition of seeds.

For the first time in this paper we have studied polymorphism of the vegetable peas samples set taken both from VIR collection and breeding forms by starch composition in ripened seeds having compared the figures in vegetation seasons at various weather conditions, and we have identified genotypes with high amylose content in starch. Therewith we have found relation between amount of amylose, smaller seed size (low weight of 1000 seeds) and amount of seeds per pod, and saw no differences in amylose accumulation between traditional morphotypes and the ones obtained under mutations thereby indicating suitability of both usual and leafless forms in breeding high amylose varieties.

This paper is devoted to quantitative evaluation of composition of starch and amylose in vegetable pea seeds and analysis of relations between this value and other plant traits important for breeding purposes.

Techniques. A total of 39 samples of vegetable peas from VIR collection (Vavilov Institute of Plant Genetic Resources) and breeding forms from Krymsk Experimental Breeding Station were taken to be analyzed. The set of samples included current varieties, perspective lines and original mutant forms from six countries: Russia (18 accessions), the Netherlands (16 accessions), Germany (2 accessions), Belgium (1 accession), USA (1 accession) and Turkey (1 accession). Seeds from all samples are marrowfat (wrinkled) suggesting availability of recession allele *r* in homozygous state in genotype. Thirty samples out of 39 possessed usual morphotype by leafy (*Af*) while 9 were leafless (no leaves) (mutation *af*). Three samples therewith were homozygotes by allele *det* regulating limited (determinant) growth type. Besides, the sampling included original fasciated form (spontaneous mutant by *fa* or *fas* alleles).

Field survey took place in 2015-2016 in seed-trial grounds of Krymsk Experimental Breeding Station (Krasnodar Territory). Soil of the ground included argillaceous compact and degraded chernozem. Seeding was made by planter SKS-6-10 with 15 cm row width and 6 cm in depth, and plot area for each sample was 10 m^2. According to vegetable pea seeding rate the plot includes 900-1200 plants from which 15 plants in the technical ripeness stage have been taken for morphostructural analysis. At biological ripeness the seeds have been harvested by Sampo130 combine (Sampo Rosenlew Oy, Finland). After the seeds reach optimum humidity (14%), the samples have been taken for biochemical analysis. Phenological, morphological and biometric parameters have been analyzed as per recommendations [25] and field test procedure [26]. Bundles to be accounted have been gathered for evaluating plant productivity at technical ripeness stage. Plants in bundles have been hand threshed, with the obtained green pea being weighed afterwards, and weight of one plant seed has been calculated.

Starch content by Ewerse was measured using rotary polarimeter SM-3 (Zagorsk Optical Mechanics Plant, Russia) [27], amylose content in starch — by a photocolorimeter (KFK-2MP, Zagorsk Optical Mechanics Plant, Russia) [27, 28]. Samples obtained have been triple analyzed biochemically.

Average (*M*) and standard errors of mean (±SEM) have been calculated. Average values of usual and mutant forms have been compared by Student's *t*-criterion (*t*-test). Differences are considered significant at $p < 0.05$. Analysis of variance (ANOVA) has been conducted by the least significant difference test (LSD test). Statistica10 (StatSoft, Inc., USA) software has been applied for mathematical data processing.

Results. Conditions of plant vegetation during the analyzing period have been harsh. In 2015 hydrothermal index (GTI) was 7.9 (optimum value is 1.0-1.2) for planting to seadling stage. During 2-3-leaf/blooming stage, the average daily temperature exceeded optimum temperature with actually no precipitations, but as at May 31, 45.5 mm precipitations came down resulting in the fact that completion of pod formation coincided with water saturation conditions (GTI from 2.0 to 2.8). In 2016 after planting and till 2-3-leaf stage amount of effective temperatures (over 10 °C) exceeded 2015 value making favorable conditions for plant growth. During 2-3-leaf/blooming stage in 2016 amount of effective temperatures was lower, while precipitation amount was higher than in 2015, with GTI being equal to 0.8. During pod formation effective temperatures (over 10 °C) and a lot of precipitations have positively affected seed productivity from plant to technical ripeness stage.

Comparing weather conditions for the last 2 years of monitoring it may be said the second year was more favorable for vegetable pea growth and formation. Seed productivity (seed weight per plants) in technical ripeness stage in varieties and lines in 2015 was statistically far lower ($p < 0.05$) than in 2016 (by 4.5 g/plant). In 2015 productivity was varying from 3.5 to 12.9 g/plant, in 2016 — from 5.0 to 18.3 g/plant. On the contrary, average content of starch in biologically mature seeds was far higher ($p < 0.05$) in 2015 and depending on cultivar, was varying from 29.4 to 37.4%, while in 2016 — from 26.0 to 35.8%. Amylose content and variations thereof were almost the same within two years (from 61.2 to 82.1% in 2015 and from 61.9 to 82.6% in 2016) but average value in 2015 as compared with 2016 was lower by 1.6% ($p < 0.05$) (Table 1).

1. Productivity and biochemical indicators in analyzed set of varieties, lines and mutant forms of vegetable pea (*Pisum sativum* L.) by years of monitoring ($n = 39$, M±SEM, Krasnodar Territory)

Name, number in VIR catalogue (genotype)	Country of origin	Productivity, g per plant		Content, %			
				starch		amylose in starch	
		2015	2016	2015	2016	2015	2016
G-9349/5, k-9349	Russia	5.9	16.2	33.7	29.5	66.4	72.9
Uvertura, i-148154	Belgium	3.7	14.5	36.6	31.9	61.3	73.6
Salinero, i-148155	Netherlands	4.8	15.3	30.2	29.6	71.5	72.2
Asana, i-148158	Netherlands	3.5	12.0	29.6	29.6	73.8	72.7
Prim, i-0155213	Russia	5.0	12.9	32.0	27.1	70.0	70.0
Stile, i-148163 (*afaf*)	USA	4.9	10.1	31.8	30.1	67.7	72.8
Karina, i-630921	Netherlands	4.2	14.1	34.2	30.2	62.8	76.1
Khesbana, i-148159 (*afaf*)	Netherlands	7.6	9.9	33.6	29.6	68.6	75.0
Vinco, i-148164	Netherlands	5.8	8.6	31.2	29.8	68.5	75.9
Alfa 2, k-7071	Russia	9.6	7.2	31.4	28.8	68.0	71.4
Olinds, i-630922	Netherlands	6.6	17.2	34.0	31.7	70.1	72.6
G-9424/7, k-9424	Russia	8.4	14.7	36.1	31.8	69.1	74.3
Gropesa, k-9730 (*afaf*)	Netherlands	5.5	16.1	34.4	35.8	76.3	74.4
G-305/28	Russia	8.9	18.3	35.5	28.1	61.2	72.6
CB 0987 UT, к-9728	Netherlands	6.7	9.4	30.3	32.2	82.1	76.8
Grundy, i-148165	Netherlands	6.8	12.5	34.2	29.6	74.4	75.7
Mutsio, i-148166	Netherlands	8.3	8.7	32.4	29.3	75.6	79.3
Berkut, k-8856	Russia	11.6	11.0	33.8	29.5	67.5	74.6
Eshton, i-148174	Netherlands	6.0	15.1	31.9	27.9	74.3	82.6
Durango, i-148170	Netherlands	6.3	9.4	33.2	30.7	75.8	72.3
Westa, k-9352	Russia	12.5	15.7	32.7	30.8	68.1	74.0
Resal, i-148175	Netherlands	9.0	12.3	32.6	30.9	67.8	66.7
Donana, i-148177 (*afaf*)	Netherlands	7.5	5.0	32.7	32.0	66.5	64.3
Bingo, i-148178 (*afaf*)	Netherlands	9.1	12.2	34.8	31.6	70.1	68.0
Omega, i-148176	Turkey	10.1	9.4	32.4	30.2	73.0	75.0
Druzhny, k-9351 (*detdet*)	Russia	10.0	14.6	37.4	31.8	66.8	64.2
Spontanny mutant (*fafa,fasfas*)	Russia	10.5	12.4	34.3	34.2	65.2	63.5
G-388/45	Russia	10.7	15.9	35.1	31.1	64.7	66.8
Rayner, i-148181	Germany	12.0	15.0	34.8	34.6	68.0	62.4
Ambassador, i-148179	Germany	7.9	12.0	33.4	31.2	69.6	72.4
Adagumsky, k-7071	Russia	9.3	8.7	36.3	31.7	66.8	64.9
G-349/442 (*afaf,detdet*)	Russia	7.4	13.8	32.7	32.8	72.8	67.7

Table 1 continued

Parus, k-9350 (*afaf*)	Russia	8.1	11.2	30.3	26.0	75.0	78.4
G-344/16	Russia	10.2	12.2	31.3	30.4	68.7	61.9
Butana, i-148180 (*afaf*)	Netherlands	8.9	9.6	31.8	29.9	73.0	71.8
G-387 (*afaf, detdet*)	Russia	7.8	14.2	33.3	32.2	72.0	69.5
G-359/58	Russia	11.5	17.4	30.6	29.6	73.3	67.7
Krasavchik, k-9449	Russia	11.3	15.7	29.4	27.6	78.3	77.2
Istok, k-9353	Russia	12.9	11.8	32.5	30.9	74.4	76.8
M±SEM		8.1±0.4*	12.6±0.5*	33.0±0.3*	30.6±0.3*	70.2±0.7	71.8±0.8

* * Differences by years are statistically significant by Student's *t*-test at $p < 0.05$.

Comparison of seed productivity, starch content and composition in seeds of 35 samples with usual growth type but having different leafy morphotype by Student's *t*-criterion has testified that there are no significant difference (at $p < 0.05$) in manifestations of these traits between leafy (usual) and leafless (with no leaves) forms (Table 2). On average by years, productivity of leafy morphotypes was equal to 10.6 g/plant, starch content in seeds — 31.6%, amylose content in starch — 71.4%, while for leafless forms these values were 9.0 g/plant, 31.7% and 71.6% (at $p < 0.05$), respectively.

2. Seed productivity, starch content in seeds and amylose in starch in analyzed samples of vegetable pea (*Pisum sativum* L.) depending on morphotype by years of monitoring (*M*±SEM, Krasnodar Territory)

Morphotype	*n*	Seed weight per plant, g		Content, %			
				starch in seeds		amylose in starch,	
		2015	2016	2015	2016	2015	2016
			Leaf type				
Usual	28	8.2±0.5	13.0±0.6	32.9±0.4	30.2±0.3	70.2±0.9	72.6±0.9
Leafless	7	7.4±0.6	10.6±1.3	32.8±0.6	30.7±1.1	71.0±1.4	72.1±1.8
			Stem growth type				
Usual	35	8.0±0.4	12.5±0.5	32.9±0.3	30.3±0.3	70.4±0.8	72.5±0.8
Determinate	4	8.9±0.8	13.8±0.5	34.4±1.0	32.8±0.5*	69.2±1.9	66.2±1.4*

Note. For description of varieties (VIR collection, Vavilov Institute of Plant Genetic Resources, Saint-Petersburg) and breeding samples (Krymsk Experimental Breeding Station, Krasnodar Territory) see Table 1.

* Differences with usual type are statistically significant by Student's *t*-test at $p < 0.05$.

It should be mentioned that over several decades the general direction in grain pea breeding is based on using leafless genotypes as being more technological and adaptive. By environmental sustainability the best leafless varieties are highly competitive with leafy ones demonstrating advantages in crop yield in years contrasting by hydrothermal regime [22]. However, they are still to be considered for vegetable pea breeding in our country. Meanwhile earlier in Krasnodar Territory we have found vegetable varieties of leafless morphotype that are reliably similar in crop to standard varieties of usual morphotype [29] by green pea crop, dry matter distribution, productivity per leaf area and net productivity of photosynthesis. These results make us sure that high amylose varieties may be formed from leafless morphotypes.

Practical application of mutant forms with restricted stem growth is still to be investigated. In 2015 no certain peculiarities and significant differences in productivity and carbohydrate composition in seeds of determinate samples and stem faciation forms as compared with average values in sampling of plants with usual stem growth type was found either (see Table 2). However, in 2016 higher starch content in seeds and lower of amylose in starch as compared with the samples bearing no such mutations was found (see Table 2). On average over the years mutant forms productivity was 11.3 g/plant, starch content in seeds 33.6%, and that of amylose in starch 67.7% ($p < 0.05$). Varieties with determinate growth type are known to be technological one at cropping and they are characterized by reduced reproductive period, good ripening, and standing ability [21, 23]. Therefore, we consider that research of carbohydrate composition in such mutant seeds is to be analyzed further with more samples.

Thus for two years of observation starch content in all analyzed samples of vegetable pea was changing within 26.0-37.4% range, and amylose from 61.9 to 82.6%. Such large variability requires gene pool screening of vegetable pea when searching for original material for breeding high amylose varieties.

3. Correlations between content of amylose and starch in seeds and other traits important for breeding in analyzed samples of vegetable pea (*Pisum sativum* L.) by years of monitoring (Krasnodar Territory)

Trait \ Trait	1	2	3	4	5	6	7	8	9	10	11	12
2015												
1	1.00	0.31	0.92*	0.21	0.41*	0.78*	0.67*	0.24	0.15	0.67*	0.00	0.21
2		1.00	0.24	0.06	0.02	0.03	0.44*	0.61*	–0.37*	–0.22	0.08	–0.34*
3			1.00	0.15	0.37*	0.67*	0.61*	0.25	0.20	0.61*	–0.01	0.26
4				1.00	–0.61*	0.39*	0.12	–0.10	–0.07	0.29	–0.06	–0.09
5					1.00	0.41*	0.09	0.06	–0.01	0.30	0.07	0.21
6						1.00	0.37*	–0.12	0.05	0.82*	–0.02	0.19
7							1.00	0.27	0.45*	0.50*	0.07	0.08
8								1.00	–0.28	–0.30	0.16	–0.34*
9									1.00	0.59*	–0.05	0.47*
10										1.00	–0.07	0.42*
11											1.00	–0.60*
12												1.00
2016												
1	1.00	–0.03	0.91*	0.38*	0.34*	0.41*	0.39*	–0.06	–0.29	0.17	0.24	–0.36*
2		1.00	–0.05	–0.08	–0.17	–0.62*	0.36*	0.64*	–0.35*	–0.69*	–0.38*	–0.32*
3			1.00	0.19	0.41*	0.38*	0.36*	–0.05	–0.15	0.21	0.14	–0.20
4				1.00	–0.58*	0.18	0.17	–0.23	–0.19	0.09	–0.01	–0.08
5					1.00	0.39*	0.00	–0.06	–0.04	0.26	0.29	–0.17
6						1.00	–0.04	–0.56*	0.12	0.88*	0.42*	–0.04
7							1.00	0.17	0.29	0.07	–0.12	–0.11
8								1.00	–0.26	–0.62*	–0.18	–0.23
9									1.00	0.57*	–0.06	0.41*
10										1.00	0.32*	0.17
11											1.00	–0.49*
12												1.00

Note. 1 — seadling/technical ripeness stage, days; 2 — weight of 1000 seeds, g; 3 — amount of nonproductive nodes, unit; 4 — amount of productive nodes, unit; 5 — number of pods per seedstalk, unit; 6 — number of filled pods per plant, units; 7 — pod length, cm; 8 — pod width, cm; 9 — number of seeds per pod, unit; 10 — seeds from plant, unit; 11 — starch content in seeds, %; 12 — amylose content in starch, %.

* Correlations are statistically significant at $p < 0.05$.

Correlation analysis (Table 3) has revealed stable relationship within two years. Starch and amylose contents correlated inversely ($r = –0.60$ in 2015, $r = –0.49$ in 2016). It should be mentioned that scientific literature information on correlation between amylose and starch content in wrinkled seeds is contradictory. R.Kosson et al. [30] indicate negative correlation, while M. Hybl et al. [19] discovered positive relationship between these traits. However, the latter consider their results preliminary, and they also think such screening is to be used for breeding in improving carbohydrate composition in seeds of vegetable pea. We were the first in finding negative relationship between amylose content in starch and 1000 seed weight ($r = –0.34$ in 2015, $r = –0.32$ in 2016) and positive with the seed number per pod ($r = 0.47$, $r = 0.41$ over years). I.e. the less is weight of 1000 seeds, the more is their number per pod and the higher is amylose content in starch, and higher starch content in seeds suggested decrease of amylose content. Therefore, the following samples with amylose content in starch exceeding 70% and weight of 150 g per 1000 seeds may be considered promising varieties for breeding: SV 0987 UT (k-9728, 87g), Vinko (i-148164, 131g) and Omega (i-148176,135g) of traditional morphotype, leafless varieties of Gropesa (k-9730, 87g), Butana (i-148180, 146g) and varieties with 8-10 seeds per pod Mutsio (i-148166, 10.0 seeds), Grundy (i-148165, 8.5 seeds), SV 0987 UT (8.4 seeds), Butana (8.4 seeds), Olinda (i-630922, 8.3 seeds), Gropesa (8.0 seeds). Varieties Mutsio and Olinda are noted to be characterized by average variation of number of seeds per pod for two years of monitoring (*Cv* from 10 to 20%), while this number was higher for the others.

For two years of monitoring we have chosen 15 samples out of 39 with high amylose content in starch (over 70%) (Table 4). Varieties significantly exceeding the control variety by starch content in seeds have also been found/ These are Grundy with average starch content of 31.9% and amylose in starch of 75.0% by years, Durango with 31.8 and 74.1%, respectively, and Gropesa of leafless morphotype with 35.0 and 75.4% (see Table 4).

4. Vegetable pea varieties (*Pisum sativum* L.) with high content of starch and amylose among 39 analyzed samples (by years of monitoring, Krasnodar Territory)

Variety	Country of origin	Content, %			
		starch		amylose in starch	
		2015	2016	2015	2016
Prima (C)	Russia	32.2	27.1	70.0	70,0
Salinero	Netherlands	30.3*	29.6*	71.5	72,2
Asana	Netherlands	29.6*	29.6*	73.8*	72,7*
Olinda	Netherlands	33.8*	31.7*	70.1	72,6*
Gropesa[a]	Netherlands	34.2*	35.8*	76.3*	74,4*
SV 0987 UT	Netherlands	30.1*	32.2*	82.1*	76,8*
Grundy[a]	Netherlands	34.1*	29.6*	74.4*	75,7*
Mutsio	Netherlands	32.1	29.3*	75.6*	79,3*
Eshton	Netherlands	31.8	27.9*	74.3*	82,6*
Durango[a]	Netherlands	32.9*	30.7*	75.8*	72,3*
Omega	Turkey	32.3	30.2*	73.0*	75,0*
Parus	Russia	30.4*	26.0*	75.0*	78,4*
Butana	Netherlands	31.8	29.9*	73.0*	71,8
Krasavchik	Russia	29.4*	27.6	78.3*	77,2*
Istok	Russia	32.3	30.9*	74.4*	76,8*
M±SEM		31,8±0,4	29.9±0.6	74.5±0.8	75.2±0.9

Note. C — control variety; [a] — sources of alleles with high content of starch in seeds and amylose in starch. For description of varieties (VIR collection, Vavilov Institute of Plant Genetic Resources, Saint-Petersburg) and breeding samples (Krymsk Experimental Breeding Station, Krasnodar Territory) see Table 1.
* Differences from control are statistically significant at $p < 0.05$.

So, the dependence of carbohydrate composition of vegetable pea seeds (amount of starch in seeds and amylose content therein) on vegetation conditions is found, and relationship between these biochemical parameters and number of trait important for plant breeding is revealed. Both amylose content in seed and weight of 1000 seeds, as well as amount of starch in seeds and amylose content in starch correlate negatively; whereas the correlation between amylose content in starch and number of seed per pod is positive. No statistically significant differences by seed productivity, starch content in ripened seeds and amylose in starch between leafy (usual) and leafless (with no leaves) morphotypes are found. Consequently, breeding with higher content of starch and amylose in seed is possible with the use of both morphotypes. Samples that may be used in breeding as gene sources identifying high content of starch in seeds and amylose in starch are revealed. Traits positively correlating with high accumulation of amylose, i.e. small-sized seeds (weight of 1000 seeds less than 150 g), and number of seeds per pod over 8, are also found.

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