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CORRELATION OF BREEDING TRAITS THAT DETERMINE PRODUCTIVITY OF CHICKPEA (*Cicer arietinum* L.) ACCESSIONS FROM THE VIR COLLECTION IN THE CONDITIONS OF TAMBOV REGION

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A b s t r a c t

Increasing global temperature recently leads to climatic changes towards more drought conditions over large areas, so drought resistant plants should be wider cultivated. Chickpea is a drought resistant crop commercially cultivated in 2013 at 800 000 ha in some region of the Russian Federation with periodic droughts, except the Tambov region, though its geographic and climatic conditions could be appropriate for chickpea growing. For the first time in the Tambov region we investigated the formation of breeding traits that determine seed productivity in 629 chickpea accessions of different origin, including 44 countries, from the VIR (All-Russian Research Institute of Plant Industry, St. Petersburg) World Collection which were selected due to prior wide geographic testing in other Russian regions and abroad. Using statistical methods, i.e. factor, dispersion analysis and clustering, we defined breeding and noticeable traits, the influence of sowing norm, and the countries which were the most perspective as originators of chickpea. It is shown that the number of branches of the 2nd order, the number of pods per plant, plant height, the length of growing period mainly contributed into determining productivity of chickpea plants in the environmental conditions of the Tambov region. The weight of 1000 seeds had a positive relationship with the period from flowering to ripening. A significant association between the weight of seeds per plot and the number of plants was observed with the maximum rate found at 70-80 plants per plot. The variability of accessions in plant dray weight was the greatest and reached the value of Cv = 98.3 %. A total of 73 % of the variability of the investigated traits were influenced by three factors. The first one causing 38 % of variability comprised of a block of correlated traits, namely the number of branches of the 1st and 2nd order, the number of pods per plant and plant dry weight, which were associated with the number of seeds per plant. The second one of a 25 % influence included the periods from germination to flowering and from flowering to ripening, the height of the lower bean attachment and the plant height, and the third one with a 10 % effect on variability was the weight of 1000 seeds. In 330 studied forms the bean cracking rate was 10 % that met the standards of Volgogradskii 10 variety, in 202 accessions it exceeded 10 %, and 96 accessions were resistant to bean cracking being valuable for breeding. A total of 147 accessions were not affected by fusarium wilt, and another 120 accessions were very weakly attacked and damaged. By clustering we identified three groups of countries where the forms with higher seed weight per plant and weight of 1000 seeds as the most economically valuable traits were originated from. Accessions from the United States were characterized by larger weight of 1000 seeds and weight of seeds per plant, while in accessions from the former Soviet Union, Bulgaria and Afghanistan the weight of 1000 seeds and the weight of seeds per plant were low. For the rest countries both these parameters were close to average values. So in the Tambov region the k-3720, k-3721, k-3740, k-3771, k-3783, k-3785 from Syria; k-604, k-2340 from Turkey; k-431, k-437, k- 2176 from Mexico; k-1188, k-1335, k-1480, k-2197, k-2397 from Russia; k-2144 from Afghanistan; k-1491, k-1724, k-1727 from Uzbekistan and k-2597, k-2949 from the U.S. are the most perspective form in breeding for seed productivity. A total of 178 most prospective accessions were further tested in 2011-2013.

Keywords: chickpea, collection accessions, valuable breeding traits.

With regard to cultivated areas and grain production, the chickpea is in the third place in the world among legume crops after the soya and haricot bean: every year, the area under this crop is equal to about 12 million ha, and annual grain production is up to 9-10 million tons [1, 2]. The chickpea is cultivated in more than 55 countries with arid climate; it is a basic legume crop in South Asia, the Middle East, East Africa, the Western Mediterranean, Australia and

Mexico [3]. In countries with the rapid growth of the population (India, Pakistan, Mexico, Ethiopia), the chickpea holds a leading position among food products. Its seeds contain a large amount of protein (up to 30 %) with all amino acids and vitamins necessary for humans [4-6]. At the same time, chickpea seeds (unlike other legume crops) are characterized by reduced antinutrient content [7-9]. Due to symbiosis with nodule bacteria, the chickpea, like the other legumes, is a nitrogen-fixing plant and is considered to be the best predecessor for other crops in cultivation zones [10, 11].

In many agricultural regions of the Russian Federation which are prone to periodic droughts, chickpea cultivation areas have increased over the last years, because the chickpea is one of the most drought- and heat-resistant crops among grain legumes [12, 13]. In such territories, the chickpea remains the only crop which can be profitably cultivated in the structure of planted areas, and its cultivation contributes to soil amendment and improves the productivity of the crops following it (the winter wheat rotating the chickpea has the same yielding capacity as after black fallow, or even higher in some cases). The rapid growth of areas under the chickpea in Russia is associated with increase in demand for its grain both in the domestic and external market [14]. In 2001, they were equal to about 25,000 ha; in 2008 and 2011, they exceeded 100,000 ha; and in 2013, they achieved 800,000 ha. The chickpea is cultivated in the North Caucasian, Middle and Lower Volga, Ural and West Siberian Regions of the Russian Federation. The cultivated areas under the chickpea have also increased in the Central Black Soil region, particularly, in the Voronezh and Belgorod Regions.

The new millennium is characterized by global climate change towards warming. Increasingly larger territories are periodically prone to droughts. In this regard, in crop farming, a need arises to expand the zone where drought-resistant crops, including the chickpea, are cultivated [15-20].

Preliminary 2-year studies of the limited number of specimens confirmed that, in principle, it is possible to cultivate this crop in the Tambov Region [21], and, by this reason, we have investigated the world chickpea collection of VIR (N.I. Vavilov Research Institute of Plant Industry).

Genotype selection by one property often does not produce the desired result. In order to improve the efficiency of obtaining plants with high seed productivity, early ripeness and other properties which are significant in terms of breeding, we should know what interrelationships between their determinant characters are.

Under the conditions of the central part of European Russia, we have studied correlative relationships between yielding capacity elements for the chickpea specimens of various origin which are stored in VIR's collection.

Technique. Chickpea specimens (629 from 44 countries) were compared at the Yekaterininskaya experimental station of VIR (Tambov Region). Varieties Krasnokutsky 36 and Volgogradsky 10 released in the Russian Federation were used as standards. Seeding was carried out on April 26, 2011. Standards were seeded after every 10 plots; plot area in the trial was 1 m^2. Chickpea specimens from the collection were studied and assessed in compliance with the procedural guidelines and classifier of VIR [22-24]. Bean shattering before harvesting was described according to the classifier of the International Board for Plant Genetic Resources (IBPGR), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and International Center for Agricultural Research in the Dry Areas (ICARDA) [25], using the scale where 0 points indicates no shattering, 1 point corresponds to less than 10 % shattering, and 2 points indicate that shattering rate is more than 10 %. Within the vegetation period, specimens were assessed for damage by fusarium disease in compliance with the procedural guidelines of VIR [24].

After harvesting, plants were subjected to structural analysis by the valuable breeding characters determining seed productivity and adaptation to mechanized cultivation. The following parameters were measured: plant height from soil to its highest point (cm), height of lower bean attachment (cm), number of primary branches at the stem base, number of primary branches in the apical part of the stem, weight of one plant with beans and root residues (g), number of beans on one plant, number of seeds on one plant, weight of seeds from one plant, and weight of 1000 seeds (g). Three plants were selected for analysis for each specimen.

Statistical analysis was performed using the StatSoft Statistica v. 6.0. Quantitative characteristics of specimens with different bean shattering rates were compared by the analysis-of-variance method. The characters that provided the highest differentiation of collection specimens were revealed using the factor analysis method. Distinctive features of specimen groups from various countries were studied using the single-factor analysis-of-variance and cluster analysis method. The dendrogram was constructed using the Euclidean distance and Unweighted Pair Group Method Using Arithmetic Averages (UPGMA) [26]. The significance level of 5 % was used.

Results. Weather conditions in 2011 were consistent with the biological features of the chickpea, and grain harvest was obtained for all the specimens studied. Monthly average air temperatures in the vegetation period turned out to be higher than long-time annual average values and were equal to 7.4 °C in April (against 4.9 °C), 19.0 °C in May (against 13.9 °C), 23.5 °C in June (against 17.8 °C), and 28.0 °C in July (against 20.0 °C). Monthly total precipitation was also higher than long-time annual average values: 40.9 mm in April (against 32 mm), 47.3 mm in May (against 43 mm), 68.5 mm in June (against 57 mm), and 84.5 mm in July (against 63 mm).

Initial sprouts were noted on May 10-11 with full sprouts indicated on May 12-13; initial blossom was observed on June 1 with full blossom noted on June 3-18. Seed ripening for various chickpea specimens occurred on July 19-30. For standard varieties Volgogradsky 10 and Krasnokutsky 36, vegetation period was 69 and 73 days, respectively, and in case of collection varieties, it ranged from 67 to 78 days (70 days on average) with the range being 67-70 days for 535 of 629 specimens studied. The earliest ripeness (67 days) was noted for specimen k-3264 ILC-1289 (Turkey).

The majority (615) of the studied collection chickpea specimens had a standing bush form (sprawling at the top) (5 points); 6 of them had a creeping form (1 point); 2 specimens were characterized by a wide-branching bush form (3 points), and 9 specimens were distinguished by a compact bush form with high attachment of lower beans (7 points). In connection with the prevalence of one of the bush forms (standing, sprawling at the top), this character was not statistically analyzed.

The average plant height was 43 cm and 49 cm for the standards (variety Volgogradsky 10 and variety Krasnokutsky 36, respectively) and 36 cm (ranging from 22 to 65 cm) for collection specimens.

The plant dry weight was the most variable character (Cv = 98.3 %), which is indicative of pronounced differentiation of the collection under study, in particular, with regard to this character. The average dry weight of one plant was equal to 17 g with fluctuations from 3 to 186 g for different specimens. Significant differences between specimens were associated with increase of differentiation in a series of the characters determining the dry weight: number of lateral primary branches varied from 1 to 5 (Cv = 25.2 %), number of secondary branches ranged from 1 to 9 (*Cv* = 57.4 %), number of beans from one plant was from 5 to 259 (*Cv* = 85.0%), number of seeds from one plant fluctuated from 5 to 292 (*Cv* = 88.8 %).

The number of seeds from one plant for standard varieties Volgogradsky 10 and Krasnokutsky 36 was 25 and 28, respectively. Specimens k-910 (Czechoslovakia); k-3718 Flip 85-1C, k-3764 (Syria); k-1810 № 29 (Moldova); k-399 (Bulgaria) and k-217 (Afghanistan) were distinguished by the number of seeds per plant, which ranged from 97 to 292.

The weight of 1000 seeds was 278 g for both standards and 394 g on overage for collection specimens (minimum and maximum were equal to 150 g and 695 g, respectively). The following specimens were distinguished by this character: k-3614 (Spain, 695 g), k-3745 (Italy, 675 g), k-3412 (Syria, 660 g), k-3791 (Turkey, 640 g), k-3612 (Italy, 640 g), k-3626 (USA, 620 g), k-3689 (Portugal, 640 g), k-3609 (Greece, 640 g), k-3647 (Spain, 640 g) and k-431 (Mexico, 630 g).

The weight of seeds per plot for standard varieties Volgogradsky 10 and Krasnokutsky 36 was 418 g and 463 g, respectively; on average for the collection, it was equal to 409 g (ranging from 30 to 1302 g for some specimens), and 180 and 289 specimens surpassed varieties Krasnokutsky 36 and Volgogradsky 10, respectively. There specimens with significant exeedance of this parameter were identified: 1,302 g for specimen k-3407 from France, 835 g for specimen k-3782 from Syria, and 772 g for specimen k-2144 from Afghanistan. This character had *Cv* = 28.0 %, i.e. it was more stable than the weight of seeds per plant (*Cv* = 71.5 %), because less number of the plants sprouting on a plot was compensated by larger weight of the seeds harvested from them.

Bean shattering for standard varieties Volgogradsky 10 and Krasnokutsky 36 was less than 10 % (1 point) and more than 10 % (2 points), respectively. By this character, 330 of the collection chickpea specimens studied were referred to the same group as the best of the standards (variety Volgogradsky 10, less than 10 %, 1 point); for 202 specimens, the analyzed parameter was more than 10 % (2 points). 96 chickpea specimens which turned out to be resistant to bean shattering (0 points) are valuable for breeding

Damage by fusarium disease for various specimens was assessed to be within 0–7 points (0 points—no damage, 7 points—severe damage). Standard variety Krasnokutsky 36 was characterized by the absence of damage (0 points), and variety Volgogradsky 10 was slightly damaged (1-3 points on average). 147 of the studied chickpea specimens were not damaged by fusarium disease; 120 specimens were damaged very slightly (1 point); 132 specimens were found to be slightly damaged (3 points); 227 specimens were characterized by medium damage (5 points), and 2 specimens were severely damaged (7 points).

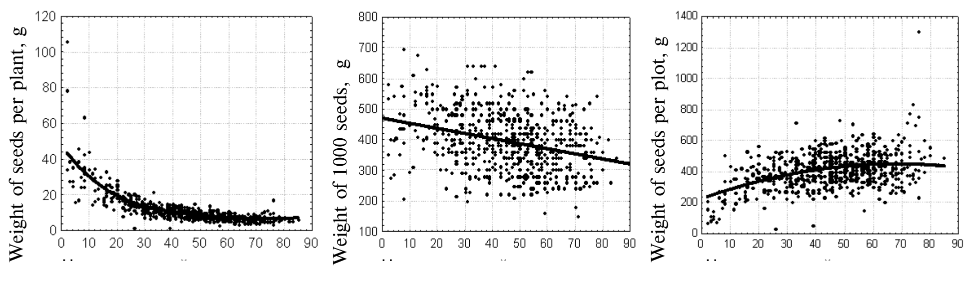

Fig. 1. The weight of seeds of chickpea (*Cicer arietinum* L.) specimens from VIR's collection, depending on the number of plants per plot (the curves were plotted using the weighted least-squares method; Tambov Region, 2011).

The number of germinating plants ranged from 2 to 85 per plot (45 on average). All studied characters, except for sprouts-blossom period duration, were more or less dependent on the number of plants per plot (especially, in case of 2-30 plants) (Fig. 1). The strongest dependence on sprout density was observed for plant dry weight: for the number of plants less and more than 30, its average value was 35.6 and 12.5 g, respectively. In the same cases of sprout density, the weight of seeds per plant was equal to 21.6 and 8.7 g, respectively. Similar nonlinear variation was observed for the number of beans and seeds per plant, as well as for the number of secondary branches. For density of up to 30 plants, increase of their number by one led to increase of the weight of seeds per plot by 8.6 g on average; for larger density, the corresponding increment was equal to 1.6 g. Damage by fusarium disease on plots with up to 30 plants corresponded to 1 point on average, or 3 points for more than 30 plants; vegetation period duration decreased in a weak-linear fashion with the growth of seeding density (correlation coefficient $r = -0.36$), and decrease was also noted for plant height ($r = -0.30$) and weight of 1000 seeds ($r = -0.30$).

1. The correlation coefficients of yielding capacity elements for chickpea (*Cicer arietinum* L.) specimens from VIR's collection (Tambov Region, 2011)

Character \ Character	Sprouts-blossom period	Blossom-ripening period	Vegetation period	Plant height	Height of lower bean attachment	Number of primary branches	Number of secondary branches	Plant dry weight	Number of beans on one plant	Number of seeds on one plant	Weight of 1000 seeds	Damage by fusarium disease
Weight of seeds from one plant	0.11	0.10	0.31	0.34	–0.14	0.26	0.48	0.60	0.50	0.45	0.27	–0.34
Sprouts-blossom period		–0.77	0.27	0.53	0.57	–0.04[a]	0.06[a]	0.09	0.11	0.09	–0.28	–0.41
Blossom-ripening period			0.41	–0.25	–0.53	0.11	0.22	0.24	0.19	0.18	0.30	0.13
Vegetation period				0.38	0.01[a]	0.10	0.42	0.48	0.44	0.40	0.04[a]	–0.39
Plant height					0.62	0.09	0.37	0.42	0.39	0.36	0.03[a]	–0.60
Height of lower bean attachment						–0.24	–0.18	–0.20	–0.19	–0.20	–0.20	–0.30
Number of primary branches							0.27	0.35	0.39	0.38	0.09	–0.08
Number of secondary branches								0.78	0.76	0.75	0.11	–0.33
Plant dry weight									0.94	0.91	0.27	–0.34
Number of beans on one plant										0.98	0.03[a]	–0.32
Number of seeds on one plant											0.02[a]	–0.31
Weight of 1000 seeds												–0.01[a]

N o t e: 629 specimens from 44 originating countries were studied; a—significant values.

The analysis of relationships between yielding capacity elements (Table 1) has shown that plant dry weight positively correlates with the number of beans per plant ($r = 0.98$) and number of seeds ($r = 0.91$), as well as with the number of secondary branches ($r = 0.78$). We observed medium relationship with vegetation period duration ($r = 0.48$), plant height ($r = 0.42$), the number of primary branches ($r = 0.35$) and damage by fusarium disease ($r = -0.34$). Plant height positively correlated with the height of lower bean attachment ($r = 0.62$) and negatively correlated with damage by fusarium disease ($r = -0.60$); it also correlated with sprouts-blossom period ($r = 0.53$) and the number of secondary branches ($r = 0.37$). The weight of 1000 seeds weakly, but significantly correlated with blossom-ripening period ($r = 0.30$). Medium inverse correlation was noted between the degree of damage by fusarium disease and sprouts-blossom period ($r = -0.41$), the strong one being observed between sprouts-blossom and blossom-ripening periods ($r = -0.77$).

The weight of seeds per plant differed for specimens with dissimilar bean shattering rates, being equal to 14.7 (shattering-resistant), and 11.1 and 9.7 g (shattering is less and more than 10%, respectively). The analysis of variance has revealed significant differences in the weight of seeds per plant for shattering-resistant specimens (no significant differences were found for non-resistant specimens). The weight of 1,000 seeds significantly differed between three groups (440.1, 396.6 and 368.6 g for specimens with shattering rates of 0, 1, and 2 points, respectively).

The factor analysis of the components of productivity and interphase periods has shown that 73 % of the diversity of the studied characters is explained by three factors. The first factor, which provided the greatest differentiation of the collection, determines 38 % of the diversity within the collection and includes the block of the correlated characters associated with the number of seeds per plant (number of primary and secondary branches, number of beans per plant, plant dry weight); the second one (duration of sprouts-blossom and blossom-ripening periods and the corresponding values of the height of lower bean attachment and plant height) determines 25 % of the diversity; the third, independent factor explaining 10 % of the diversity is the weight of 1,000 seeds. The weight of seeds per plant stronger correlated with the first factor ($r = 0.65$), than with the third one ($r = 0.34$), and absolutely did not correlate with the second factor ($r = 0.02$). In other words, the large weight of seeds per plant is generally determined by the large number of productivity capacity elements, and, to a lesser extent, by the large weight of 1,000 seeds.

Based on the results for specimens from various countries (Table 2), we have compared valuable breeding characters for the countries represented by at least five specimens. See Figure 2 for the obtained values (minimum, first quartile, median, third quartile and maximum) providing an insight into the distribution shape and allowing visualization of the results.

2. The comparison of yielding capacity elements for chickpea (*Cicer arietinum* L.) specimens from VIR's collection, depending on the country of origin (Tambov Region, 2011)

Origin	Number of specimens, pcs	Vegetation period, days			Number of seeds per plant, pcs			Weight of 1000 seeds, g			Weight of seeds per plant, g			Weight of seeds per plot, g		
		$\bar{x}$	min	max	$\bar{x}$	min	max	$\bar{x}$	min	max	$\bar{x}$	min	max	$\bar{x}$	min	max
Tested specimens																
Azerbaijan	18	69.2	68	70	17	7	34	353	240	440	8	4	14	375	211	628
Algeria	5	70.8	69	77	23	9	47	483	370	620	9	7	12	371	272	476
Argentine	1	69.0			19			480			20	20	20	489		489
Armenia	6	69.7	69	70	21	11	34	321	240	400	6	5	8	351	235	455
Afghanistan	23	69.6	68	71	21	8	97	324	150	480	9	4	14	451	269	772
Bulgaria	10	70.2	69	73	27	6	100	330	280	410	14	6	36	376	142	553
Hungary	1	70.0			45			350			20			391		
Guatemala	1	68.0			5			280			8			270		
Germany	1	75.0			7			280			7			328		
Greece	4	69.3	69	70	18	7	28	568	510	640	12	4	19	426	300	520
Georgia	2	70.5	70	71	24	22	26	285	280	290	7	5	10	332	304	360
Israel	8	69.3	68	75	25	7	61	444	270	555	14	8	35	443	331	572
India	16	68.9	68	70	27	11	81	393	315	575	10	6	20	462	266	605
Jordan	9	69.2	68	70	13	5	25	404	290	540	9	5	13	408	287	562
Iraq	1	69.0			17			420			11	11	11	456		
Iran	24	69.8	68	77	20	6	33	377	200	560	10	5	19	411	234	753
Spain	14	70.8	68	77	27	5	95	443	270	695	14	4	35	343	68	529
Italy	13	68.9	68	70	20	7	80	459	240	675	11	6	22	441	226	702
Kazakhstan	4	69.8	68	72	16	10	22	280	180	340	7	4	11	408	282	500
Canada	1	68.0			11			500			11	11	11	474		
Cyprus	7	68.4	68	70	20	10	32	390	360	430	9	7	13	420	371	528
Kirghizia	3	68.7	68	69	22	11	31	333	280	370	10	6	15	419	410	434
Colombia	2	70.5	68	73	44	14	73	323	240	405	11	6	16	215	79	351
Morocco	9	70.6	68	77	15	7	31	437	330	520	7	3	14	350	151	552
Mexico	34	68.7	68	73	19	7	55	410	220	630	11	5	33	446	193	646
Moldova	5	71.2	68	78	43	21	113	346	280	440	10	7	17	368	100	617
Pakistan	14	68.7	68	70	19	9	33	359	220	500	9	6	19	377	260	468
Palestine	1	68.0			16			440			10			511		
Poland	1	68.0			46			480			14			362		
Portugal	4	68.8	68	69	13	10	20	490	360	640	10	6	14	416	287	615

Table 2 (continued)

Russia	32	70.1	68	76	24	9	67	318	205	540	11	3	34	397	204	616
Syria	165	69.5	68	77	24	6	203	411	220	660	13	1	106	418	50	835
USA	20	70.7	69	78	33	6	86	520	435	620	21	1	78	396	30	600
Tajikistan	2	68.5	68	69	42	26	58	415	370	460	11	10	12	417	374	459
Tunisia	2	69.5	69	70	16	14	18	445	380	510	15	8	22	378	264	491
Turkmenia	1	69.0			7			400			8			520		
Turkey	65	69.0	67	76	18	6	74	434	280	640	10	5	39	427	167	640
Uzbekistan	34	69.8	68	76	21	5	59	344	160	460	9	4	42	405	224	556
Ukraine	33	70.1	68	74	23	6	55	303	220	470	9	5	25	353	223	565
France	4	68.8	68	70	18	8	25	368	280	550	11	6	17	662	383	1302
Croatia	1	73.0			61			515			4			300		
Czech Republic	3	71.3	69	75	123	9	292	243	215	275	16	5	27	279	82	421
Chile	22	69.0	68	71	14	6	37	456	260	560	10	5	21	396	309	479
Ethiopia	2	68.5	68	69	13	13	14	285	260	310	5	5	6	357	265	449
Standards																
Volgogradsky 10 (ST 1)	65 replicates	69.4	68	74	25	16	40	278	260	295	12	10	18	418	245	600
Krasnokutsky 36 (ST 2)	65 replicates	72.5	69	74	28	22	31	278	275	280	13	5	18	463	222	691
Total	632	69.8	67	78	23	5	292	394	150	695	11	1	106	414	30	1302

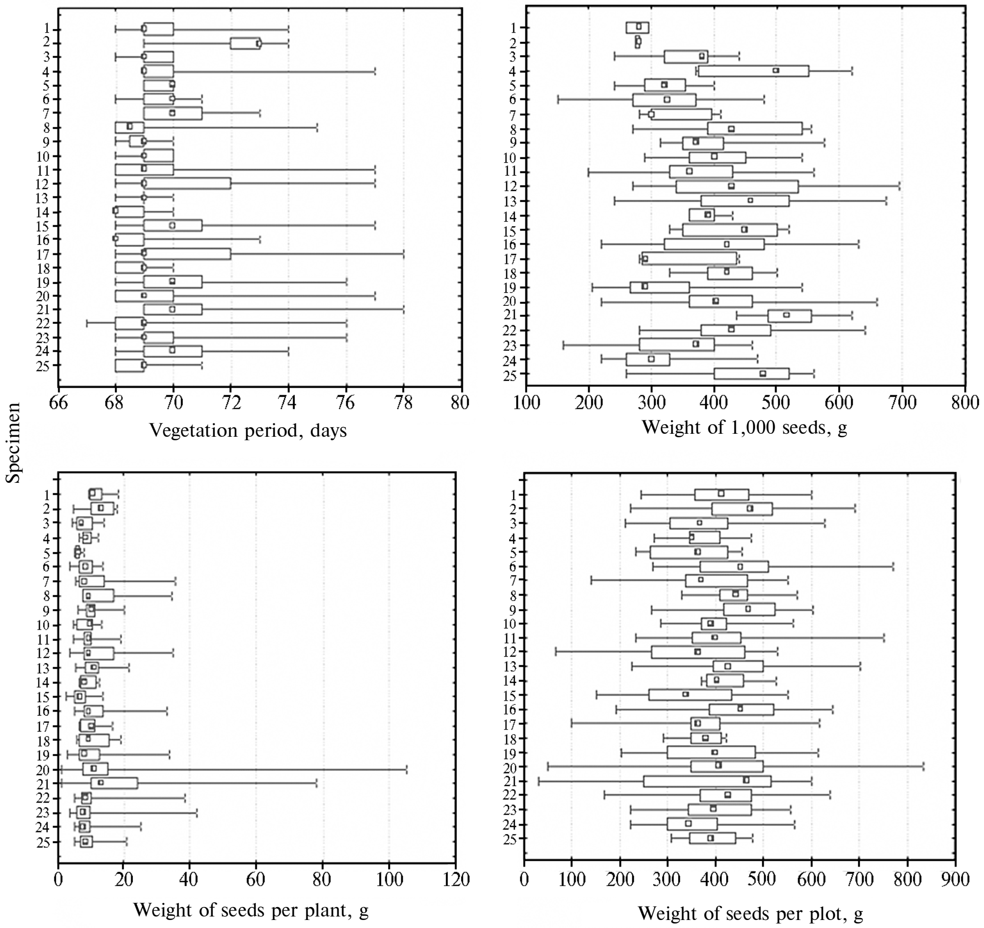

Fig. 2. Comparison of four economic characters for the chickpea (*Cicer arietinum* L.) specimens of various origin: 1 — ST 1 (variety Volgogradsky 10), 2 — ST 2 (variety Krasnokutsky 36) (standards for the Russian Federation), 3 — Azerbaijan, 4 — Algeria, 5 — Armenia, 6 — Afghanistan, 7 — Bulgaria, 8 — Israel, 9 — India, 10 — Jordan, 11 — Iran, 12 — Spain, 13 — Italy, 14 — Cyprus, 15 — Morocco, 16 — Mexico, 17 — Moldova, 18 — Pakistan, 19 — Russia, 20 — Syria, 21 — USA, 22 — Turkey, 23 — Uzbekistan, 24 — Ukraine, 25 — Chile; □ — median, ▭ — first and third quartiles, ├─┤ — minimum and maximum values (for the countries represented in VIR's collection by at least five specimens; Tambov Region, 2011).

The analysis of variance and subsequent pair-wise comparisons by the least significant difference have shown the absence of countries with the vegetation duration significantly shorter than in case of standard variety Volgogradsky 10 (69 days). The largest number of seeds per plant was noted for specimens from Moldova (43 pcs), USA (33 pcs), Spain (27 pcs), Bulgaria (27 pcs), India (26 pcs) and Israel (25 pcs), however they were not significantly different from the standards (varieties Volgogradsky 10 and Krasnokutsky 36; respectively, 25 and 28 seeds per plant). The weight of 1,000 seeds for the standards (278 g) was the least among average values for large originating countries. The average weight of 1,000 seeds for specimens from Iran, Cyprus, India, Jordan, Mexico, Syria, Pakistan, Turkey, Spain, Israel, Chile, Italy, Algeria and the USA was significantly higher than that of the standards. The weight of seeds per plant for a group of specimens from the USA was significantly higher than that of the standards (21 g). The largest weight of seeds per plot was observed for standard variety Krasnokutsky 36 (463 g); specimens from India (462 g), Afghanistan (451 g), Mexico (445 g), Israel (443 g) and Italy (441 g) were comparable and were not significantly different from it.

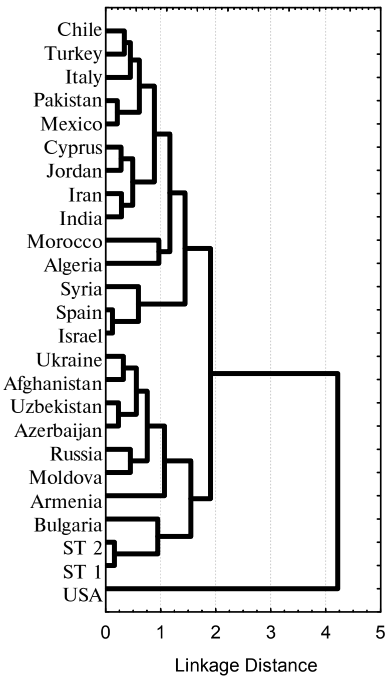

Fig. 3. The dendrogram reflecting degree of closeness of the chickpea (*Cicer arietinum* L.) originating countries: ST 1 and ST 2 — varieties Volgogradsky 10 and Krasnokutsky 36, respectively as standards for the Russian Federation (data on the weight of seeds per plant and weight of 1,000 seeds were analyzed for the countries represented in VIR's collection by at least five specimens; Tambov Region, 2011).

The degree of similarity of the chickpea-originating countries represented in VIR's collection by at least five samples (with regard to the weight of seeds per plant and weight of 1,000 seeds for the studied forms) was investigated by the cluster analysis method (Euclidean distance, UPGMA). As a result, three groups have been distinguished (Fig. 3): first, USA; second, Russia, ex-USSR countries, Bulgaria and Afghanistan; third, the other countries. Specimens from the USA were characterized by the large weight of 1,000 seeds and weight of seeds per plant; in the second group, the average weight of 1,000 seeds and weight of seeds per plant was small, whereas both parameters for the other countries were close to average values.

We identified 180 chickpea collection samples surpassing the more productive standard (variety Krasnokutsky 36) in the weight of grains per plot. With regard to the origin, the analysis of these specimens has shown (Table 3) that they were 53 specimens from Syria (34.6 % of 153 Syrian specimens studied), 17 specimens from Turkey (26.2 % of 65 specimens studied), 16 specimens from Mexico (47.1 % of 34 specimens studied), 11 specimens from Russia (34.4 % of 32), 11 specimens from Afghanistan (47.8 % of 23), 11 specimens from Uzbekistan (32.4 % of 34), 10 specimens from the USA (50.0 % of specimens from this country).

With regard to the weight of 1,000 seeds, the vast majority of specimens surpassed the standards (278 g), except for only 56 specimens.

3. The characteristics of yielding capacity elements for the chickpea (Cicer arietinum L.) specimens of various origin which surpass the standard (variety Krasnokutsky 36) in the weight of seeds per plot (in ascending order of parameter value; Tambov Region, 2011)

Origin	Number of specimens, pcs	Weight of seeds per plot, g	Vegetation period, days	Number of seeds per plant, pcs	Weight of 1,000 seeds, g
Krasnokutsky 36		463.0	72.5	27.7	278.3
Pakistan	1	468.0	68.0	19.7	320.0
Canada	1	474.0	68.0	11.0	500.0
Algeria	1	476.0	69.0	8.7	550.0
Chile	1	479.0	69.0	36.7	480.0
Argentine	1	489.0	69.0	19.3	480.0
Tunisia	1	491.0	69.0	14.0	380.0
Greece	2	497.0	69.0	23.2	560.0
Uzbekistan	11	497.1	69.4	18.7	385.9
Kazakhstan	1	500.0	68.0	22.0	340.0
Spain	3	500.7	69.7	19.1	333.3
Palestine	1	511.0	68.0	16.3	440.0
Ukraine	3	512.3	69.0	17.8	376.7
Bulgaria	3	518.7	69.3	15.7	370.0
Turkmenia	1	520.0	69.0	7.3	400.0
Israel	2	522.5	68.5	8.2	500.0
Jordan	2	527.5	70.0	11.7	480.0
Cyprus	1	528.0	70.0	23.7	360.0
Russia	11	528.6	69.5	22.0	331.5
Afghanistan	11	531.4	69.3	19.3	346.4
USA	10	531.5	69.7	18.9	509.0
Azerbaijan	3	533.3	68.7	12.9	360.0
Mexico	16	533.6	68.3	16.8	416.3
Turkey	17	537.4	68.8	17.3	436.5
India	8	538.3	68.8	27.2	365.6
Iran	6	546.3	69.2	19.8	418.0
Syria	53	551.4	69.5	24.9	411.2
Morocco	1	552.0	72.0	31.3	490.0
Italy	4	564.8	69.3	16.6	510.0
Portugal	1	615.0	69.0	12.3	500.0
Moldova	1	617.0	68.0	21.0	280.0
France	2	939.5	69.0	16.0	425.0
Total	180	539.2	69.2	20.5	410.5

Thus, in 2011, the heat provision and moisture content in the Tambov Region made it possible to differentiate chickpea forms by their breeding value for the region. As a result, 178 of 629 specimens studied had been distinguished as most promising for further investigation which was carried out in 2011-2013 (data are not presented). The large number of the studied specimens and assessed parameters has allowed us to arrive at substantiated conclusions about regional regularities of yield buildup for the crop forms of various geographical origin.

So, in the conditions of the Tambov Region, the significant breeding characters determining chickpea plant productivity should include the number of beans and seeds on one plant, number of secondary branches, plant height and vegetation period duration. The weight of 1,000 seeds positively correlated with blossom-ripening period duration. The weight of seeds per plot substantially correlated with the number of germinating plants and achieved maximum values at 70-80 plants per plot. Based on the most significant economic characters (weight of seeds per plant and weight of 1,000 seeds), we have distinguished three groups of chickpea-originating countries using the cluster analysis method. Specimens from the USA are characterized by the large weight of 1,000 seeds and weight of seeds per plant. Specimens from the former Soviet states, Bulgaria, and Afghanistan have the small weight of 1,000 seeds and weight of seeds per plant. For the other originating countries represented in the collection of the N.I. Vavilov Research Institute of Plant Industry (VIR), both parameters are close to average values. With regard to breeding for seed productivity in the conditions of the Tambov Region, the following specimens are most promising: k-3720, k-3721, k-3740, k-3771, k-3783, k-3785 from Syria; k-604, k-2340 from Turkey; k-431, k-437, k-2176 from Mexico; k-1188, k-1335, k-1480, k-2197, k-2397 from Russia; k-2144 from Afghanistan; k-1491, k-1724, k-1727 from Uzbekistan and k-2597, k-2949 from the USA. In total, 178 of 629 specimens studied had been distinguished as most promising for further investigation which was carried out in 2011-2013.

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