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PRODUCTIVITY AND ADAPTIVE ABILITY OF GARDEN PEA GENOTYPES

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ABSTRACT. *The adaptive capabilities of pea specimens regarding some quantitative characteristics were assessed. Ten garden pea genotypes were used, three of them (Echo-af., Kazino-af. and line 22/16- af.) had afila leaf type, while the other seven (Marsy-n., Plovdiv-n., line 22/16-n., Shugar dwarf-n., Vecherniza-n., line B4/34-n. and line 1/17-n.) normal leaf type. The highest adaptive capacity was showed by: Marsi (41.94) and Plovdiv (20.70) in terms of total number of pods per plant; Casino-af. (225.80), Plovdiv (85.44) and Shugar duarf (42.50) with regard to weight of pods per plant; Plovdiv (28.42), Shugar duarf (17.46) and Marsi (13.64) concerning weight of green grains per plant; Marsi (551.22), Vechernitza (46.94) and Casino-af. (40.25) for number of nodules. The selection value of the genotype was more pronounced in: Shugar duarf (13.09), line B4-34 (13.09) and line 22/16-n. (10.69) in terms of the total number of pods; for Marsi (69.66), Shugar duarf (40.81) and line 22/16-n. (38.51) regarding number of nodules. All genotypes were found stable and slightly variable in the weight of nodules, but did not have high breeding value. The best combination of both adaptability and productivity for most of the traits was found in the genotypes Marsi, Kazino-af., Plovdiv and Shugar duarf, which can be used in the combinative breeding to create adaptive and highly productive genotypes.*

KEYWORDS: *Pisum sativum L., Pods, Grains, Nodules, Homeostatic*

INTRODUCTION

Pea (*Pisum sativum* L.) is one of the oldest crops in the world together with cereals and lens. Pea is primarily used for human consumption or as livestock feed, and it is an important source of proteins and a potential alternative to soybean in Europe (Barac et al. 2010).

If genotype significantly interacts with environment, it is necessary to obtain detailed information on the performance of each cultivar across environmental variations. Thus, the adaptability and stability analyses become extremely important and necessary in order to identify and recommend superior genotypes for different environments (Cruz et al. 2004).

The correlation between the selection directions to the productivity potential and adaptability to the complex of abiotic, biotic and techno-genic environmental factors in the theory of selection has not been completely determined. In practice, most breeders do not deny the complexity of the problem of combining high productivity and adaptability in one genotype, but consider such a combination possible and desirable (Menibaev & Syukov 2015).

Agricultural production has always been limited by some factors such as global, regional, and local climate changes which have been evident in recent decades and have made it problematic obtaining stable crop yields (Schebarskova et al. 2017).

In most cases, quantitative traits are formed and modified over a period of time in the process of ontogenesis, depending on the duration, strength and nature of the limiting factors. Quantitative traits as a major object of selection can be improved by obtaining transgressive segregates (in self-pollinating species) or by heterosis (in cross-pollinating species), as well as by transferring a genotype to a new ecological niche (effect of interaction genotype - environment) (Dragavtsev 2002).

The aim of the study was to assess the adaptive capabilities of pea specimens with regard to some quantitative characteristics and to determine appropriate parental components for future breeding programs.

MATERIAL AND METHODS

The study was conducted in 2018 and 2019 at the experimental fields of the Maritsa Vegetable Crop Institute, Plovdiv, Bulgaria. Ten garden pea genotypes were used. Three of them (Echo-af., Kazino-af. and line 22/16- af.) had afila leaf type, while the other seven (Marsy-n., Plovdiv-n., line 22/16-n., Shugar dwarf-n., Vecherniza-n., line B4/34-n. and line 1/17-n.) normal leaf type. The experiments were laid out using a randomized complete block design with four replicates and a plot area of 6.4 m^{-2}. The sowing was done at the end of February on a high flatbed according to the scheme 80 + 20 +40 + 20 / 4–5 cm (4 rows high flat bed); the seeds were planted in two couples of double rows 40 cm apart. The distance between the seeds in the row was 4–5 cm, and the distance between the rows in the couple was 20 cm. Garden peas were grown according to the common farming practices of this crop in the research area.

The next characteristics of the aboveground plant parts were measured at the technical maturity of 10 plants per each replication: plant height (cm), the total number of pods per plant, weight of pods per plant (g), weight of green grains per plant (g), average number of grains per pod.

Fertilizers were supplied according to soil nutrient content and garden peas requirements. Prior to sowing, 200 kg ha^{-1} of triple superphosphate, 250 kg ha^{-1} of potassium sulphate and 30 kg ha^{-1} of magnesium sulphate were applied in the first experimental year, and 300 kg ha^{-1}, 250 kg ha^{-1} and 50 kg ha^{-1} of the same fertilizers in the second year. A month after seedling emergence, 50 kg ha^{-1} ammonium nitrate and 80 kg ha^{-1} potassium sulfate were supplied both years. For quantitatively assessing plasticity and stability, Kilchevsky and Khotyleva method (1985a, 1985b) was used. The latter is based on variety testing in different environments (years) and allows to reveal general adaptive ability (GAA), specific adaptive ability (SAA) and their stability (Sgi). The mentioned criterion for the estimation of genotype ability to interact with the environment (GxE) gi, as well as selective value of genotype (SVG), in order to select high productive and stable forms. Stress resistance (Y) was determined by Rossielle & Hamblin method (1981), homeostaticity (Hom) by Khangildin method (1984). Nonparametric analysis using rank (R) according to Huehn (1990) and Pi parameter modeled by Lin & Binns (1988) were used. The analysis of adaptability of varieties in different environment was performed according to the methods proposed by Nascimento et al. 2009, and the parameter of general adaptability "A^2" by Valchinkov 1990. The results of the parameters of stability and plasticity and the weight of green pods per plant were subjected to correlation analysis, according to Dimova & Marinkov 1999 in order to establish the relationships between the parameters measured. The Fisher's method - multiple range tests - least significant difference (LSD) procedure was used. All experimental data were processed statistically, using the computer software GENES 2009.7.0 for Windows XP (Cruz 2009).

RESULTS

The ability of the varieties to produce both stable and high yields in different years of cultivation was determined by the resistance of the plants to adverse environmental factors. The agro-meteorological conditions during the study period are presented as sum of precipitation and the average daily air temperature (Figure 1). In 2019, air temperature and rainfall have shown a combined positive effect on plant productivity and number of pods, grains and nodules per plant. The first year of the study (2018) was less favorable for the growth and development of plants.

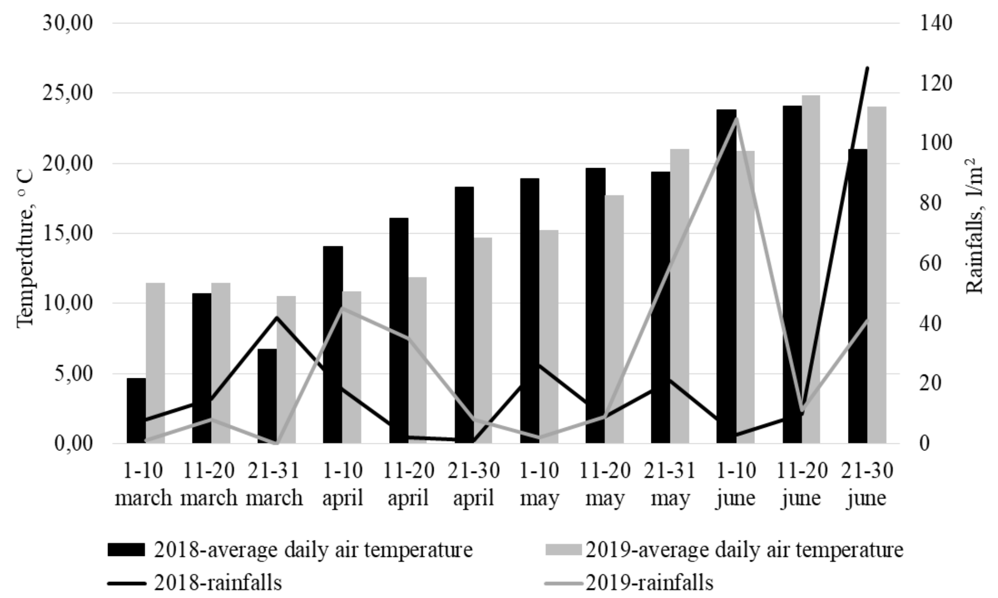

Figure 1. Meteorological characteristics in 2018 and 2019 (National Institute of Meteorology and Hydrology - branch Plovdiv, Bulgaria)

The genotype ability as a result of the regulatory mechanisms to maintain a certain level of trait in a different background environment is represented by the relative stability parameter Sgi% (which is analogous to the coefficient of variation). The results obtained show that the garden pea genotypes achieving a low productivity (Table 1) due to the total number of pods per plant (X av.) were slightly variable under changing environmental conditions.

Plovdiv (106.51) and Marsi (64.5) were the most unstable, while Shugar duarf and line B4-34, which formed almost the same number of pods per plant, exhibited enviable stability of this trait (3.18). In general, adaptive ability (GAA) stood out in Marsi, followed by Plovdiv and line 22/16-n, and in this respect the higher the general adaptive ability, the more the genotype was adapted to the limiting environmental conditions.

Table 1. Parameters of adaptive ability and stability based on the characteristics studied in the garden peas genotypes. (Ig1- linearity of genotype response (for Ig1>1 - linear; for Ig1<1 - nonlinear); GAA - general adaptive ability; SAA - specific adaptive ability; Sgi - relative stability of the genotypes; σ(GxE)gi - criterion for estimating the genotype ability to interact with environment; SVG - selective value of genotype.)

Variety/line	Ig1	GxEgi	GAA	SAA	Sgi, %	SVG
	Total number of pods per plant					
22/16-n.	1.41	8.79	6.23	2.53	3.82	10.69
22/16-af.	1.33	6.36	4.80	47.53	4.28	9.44
Kazino-af.	0.42	0.24	0.58	85.15	4.51	8.89
Plovdiv	1.00	20.71	20.70	4.96	106.51	-12.50
Echo-af.	0.58	0.61	1.05	4.06	4.37	11.24
Marsi	1.26	52.78	41.94	211.15	64.05	-6.01
Shugar duarf	0.83	0.38	0.46	73.81	3.18	13.09
B4-34	1.05	2.56	2.45	73.81	3.18	13.09
1/17-n.	1.12	3.21	2.87	170.20	4.96	7.99
Vechernitza	0.68	0.84	1.23	27.01	4.12	9.84
	Weight of pods per plant (g)					
22/16-n.	1.78	61.60	34.68	0.01	0.01	39.72
22/16-af.	-3.13	-4.72	1.51	0.07	0.28	26.33
Kazino-af.	1.22	276.53	225.80	36.74	195.72	-54.33
Plovdiv	1.88	160.77	85.44	0.01	0.02	38.32
Echo-af.	-2.03	-4.81	2.37	0.15	0.59	25.10
Marsi	1.25	40.78	32.73	2.17	3.55	56.91
Shugar duarf	1.84	78.02	42.50	0.01	0.04	31.97
B4-34	1.53	22.91	14.93	0.03	0.09	37.45
1/17-n.	2.45	54.67	22.31	17.43	50.97	-0.49
Vechernitza	1.09	9.73	8.94	0.12	0.01	27.37
	Weight of green grains per plant (g)					
22/16-n.	1.17	6.98	5.97	0.32	2.32	12.01
22/16-af.	0.20	0.53	2.69	1.74	18.66	-0.29
Kazino-af.	0.40	1.22	3.04	0.72	7.36	5.81
Plovdiv	1.54	43.72	28.42	1.08	6.72	10.06
Echo-af.	-0.01	-0.02	2.14	0.72	7.10	6.17
Marsi	0.87	11.81	13.64	8.54	38.47	-24.98
Shugar duarf	1.69	29.50	17.46	0.14	1.20	11.04
B4-34	1.37	9.25	6.73	0.14	1.25	10.63
1/17-n.	-1.27	-0.95	0.75	0.01	0.07	12.34

Vechernitza	-1.43	-1.17	0.82	0.72	7.37	5.79
	Nodule number					
22/16-n.	-60.47	-27.80	0.46	11.68	0.44	38.51
22/16-af.	-13.15	-23.63	1.80	45.67	0.65	24.33
Kazino-af.	1.17	46.90	40.25	142.40	0.84	19.21
Plovdiv	-47.34	-27.64	0.58	11.45	0.59	28.36
Echo-af.	-4.84	-21.22	4.39	38.57	0.64	25.76
Marsi	1.98	1093.90	551.22	274.91	0.25	69.66
Shugar duarf	0.43	8.65	20.35	19.33	0.42	40.81
B4-34	0.16	2.85	17.30	0.59	0.51	32.71
1/17-n.	-30.23	-27.19	0.90	11.94	0.58	28.46
Vechernitza	2.32	108.77	46.94	47.17	44.35	-112.50
	Weight of nodules (g)					
22/16-n.	-2.76	0.21	0.38	0.29	0.15	0.13
22/16-af.	2.41	0.93	1.02	0.77	2.93	0.01
Kazino-af.	1.18	13.63	11.47	9.24	4.62	-0.03
Plovdiv	2.87	0.38	0.60	0.36	3.09	0.02
Echo-af.	2.14	1.00	1.07	0.82	3.46	0.001
Marsi	1.03	-0.20	0.01	0.01	1.11	0.16
Shugar duarf	0.51	-0.20	0.02	0.02	0.32	0.18
B4-34	-3.59	-0.05	0.14	0.12	0.02	0.16
1/17-n.	-1.00	-0.14	0.07	0.06	0.12	0.17
Vechernitza	0.10	0.49	0.61	0.48	0.79	0.08

The adaptability of the genotype to specific environmental conditions, expressed by the low value of the specific adaptive ability indicator, indicated that line 22/16-n., Echo-af. and Plovdiv were the most stable compared to the others in the group.

The selective value of genotype (SVG) is a summary indicator that combines the trade-off between productivity, adaptability and stability and was more pronounced in Shugar duarf (13.09), line B4-34 (13.09) and line 22/16-n. (10.69).

Varieties Kazino-af. (276.53) and Plovdiv (160.77) interacted at the highest extent with the environment (σ (GxE) gi). The adaptability of the variety to the specific growing conditions, expressed by the low values of specific adaptive ability and relative stability of the genotypes showed that the varieties Plovdiv, Vechernitza and Shugar duarf, as well as lines 22/16-

n., 22/16-af. and line B4-34 were more stable.

Ranking garden peas by the selective value of genotype parameters, the first position was occupied by Marsi (56.91), which had the highest pod weight, though lines 22/16-n (39.72), Plovdiv (38.32) and line B4-34 (37.45) also showed a good breeding value.

Taking into account the results of the weight of green grains per plant, the lines 1/17-n. (0.75; 0.07) and B4-34 (6.73; 0.25) can be defined as stable and slightly variable with relatively low levels of "GAA" and "Sgi,%" parameters. In the latter respect, Marsi variety (38.47) and line 22/16-af. (18.66) are highly variable, but it can be assumed that, if grown in favourable conditions (especially Marsi), they will be able to maximize their performance and achieve an appreciable weight of green grains.

For most of the genotypes, no significant difference was found in their general adaptive ability, which ranged from 0.75 (at line 1/17-n.) to 6.73 (at line B4-34), indicating that these genotypes were with least adaptive options. Plovdiv (43.70) and Shugar duarf (29.50) according to the criterion (GxE)gi were best adapted to the diverse environmental conditions. According to the data obtained with regard to the level of the trait, the best general adaptive ability and stability as a selection material was found for the variety Plovdiv (selective value of genotype = 10.06) and line 22/16-n. (selective value of genotype = 12.01) and line 1/17-n. (selective value of genotype = 12.34).

An expression of the behavior of the genotype in certain specific environmental conditions is the specific adaptive ability (SAA). The lower its numerical value, the more stable is the genotype for a given trait. Line B4-34 (0.59), Plovdiv (11.45) and line 22/16-n (11.68) have such a characteristic in terms of the number of nodules. Some of the samples such as Marsi (GAA= 551.22), Vechernitza (GAA= 46.94) and Kazino-af. (GAA= 40.25) require more specific conditions for the good development of a larger number of nodules per plant, as they are best adapted to a variety of growing conditions. At the same time, Marsi (SAA = 274.91) and Kazino-af. (SAA = 142.40) are quite variable and, under the conditions of the present research, the varieties Marsi and Shugar duarf had higher values of the mentioned trait and great stability (Sgi,% = 0.25; 0.42), and a well-defined selection value.

With regard to the weight of nodules per plant according to the criteria GAA and SAA, variety Kazino-af. exhibited the broadest general adaptive ability, but at the same time it was very sensitive to changes in the environment. According to the parameter GxEgi, variety Kazino-af. (13.63) interacted very well with the environment. The value of the parameter Sgi (%) gives information about the variability of the respective trait of the plant.

All genotypes can be characterized as stable or low variable, but the advantage of Plovdiv, Marsi and Shugar duarf was expressed in the higher weight of nodules. Unlike the other features studied, none of the garden pea varieties showed a high selection value based on the weight of the nodules per plant. In the latter respect, aiming to increase the level of this parameter, other breeding materials for higher weights of nodules should be investigated.

During the study period, the pea genotypes differed significantly in the parameter of homeostasis (Table 2), and the obtained data on stress resistance in most cases correspond to homeostasis. The total number of pods was the highest (338.00 - 3556.06) in Echo-af., Kazino-af. and Marsi, and lowest in Plovdiv (4.57), line 22/16-n. (10.30), and line 22/16-af. (12.04). The value of homeostasis was highest in Kazino-af. (339.60), which also showed very good stress resistance (-2.11), with unsatisfactory pod weight.

According to one of the major quantitative traits of green grains weight, the stress tolerance parameter was not proportional to the homeostatic nature of the Marsi variety (-4.8; 59.16) and line B4-34 (-0.10; 21.43). Plovdiv and line 22/16-n. were among the most sensitive genotypes to stressors, and Echo-af. and Casino-af. occupied the first two places in the homeostatic ranking.

The weight of the nodules per plant of the homeostatic variety Echo-af (4564.4) was much higher than that of the other genotypes, which ranged from 2.96 (line B4-34) to 46.07 (Marsi).

By applying nonparametric and rank methods (Table 3) to evaluate and determine the adaptability of genotypes in different environments, the variety Kazino-af was characterized by the poorest adaptive capacity regarding the total number of pods according to the parameters of Huehn 1990 and Nascimento et al. 2009, and according to Lin & Binns 1988. Marsi and line B4-34 were evaluated as genotypes with relatively good general adaptive capacity based on all three parameters used.

According to the weight of the pods per plant, the lowest rank “4” (Huehn 1990) entails that genotypes with very good adaptation cannot be emitted. The lines 22/16-af. and 1/17-n., and the variety Echo-af. were relatively adaptable but cannot be recommended because of their lower productivity. The most productive genotype Marsi was the best "I" and "Pi" general ranking, with a value close to zero, according to the criteria of Nascimento et al. 2009 and Lin & Binns 1988, respectively.

Table 2. Homeostaticity (Hom) and stress resistance (Y) of garden peas genotypes. (X av - average value for the years of study; Xlim - the average value on the sign at limiting conditions of growing; Y- Stress resistance, Hom – homeostaticity. Means followed by the same letter (s) did not differ significantly at 5 % level.)

Variety/line	Characteristics			
	X_{av}	X_{lim}	Y	Hom
	Total number of pods per plant			
22/16-n.	11.80bcd	9.20	-5.20	10.30
22/16-af.	10.55abc	8.40	-4.30	12.04
Kazino-af.	10.00ab	10.30	-0.60	555.56
Plovdiv	12.70cd	8.50	-8.40	4.57
Echo-af.	12.65cd	12.50	-0.30	3556.06
Marsi	15.60e	15.00	-1.20	338.00
Shugar duarf	14.20de	14.90	-1.40	205.76
B4-34	14.20de	13.00	-2.40	70.01
1/17-n.	9.10a	7.70	-2.80	21.13
Vechernitza	10.95abc	10.50	-0.90	296.06
	Weight of pods per plant (g)			
22/16-n.	39.95bc	30.23	-19.44	8.45
22/16-af.	26.205a	23.30	-5.81	40.69
Kazino-af.	27.495a	28.55	-2.11	339.60
Plovdiv	38.358bc	24.36	-28.00	3.75
Echo-af.	25.60a	22.75	-5.70	40.34
Marsi	59.30d	54.41	-9.78	73.53
Shugar duarf	31.99abc	40.27	-0.55	7.47
B4-34	37.40bc	42.14	-9.48	31.13
1/17-n.	28.45ab	24.87	-7.16	31.58
Vechernitza	27.58ab	22.60	-9.96	15.34
	Weight of green grains per plant (g)			
22/16-n.	16.45ab	12.17	-8.55	7.40
22/16-af.	10.67a	9.80	-1.74	75.21
Kazino-af.	11.45a	11.69	-0.48	1138.04

Plovdiv	19.01b	11.03	-15.95	2.84
Echo-af.	11.81a	11.58	-0.46	1318.30
Marsi	26.54c	24.10	-4.88	59.16
Shugar duarf	13.82ab	18.13	-0.61	5.16
B4-34	13.42ab	15.47	-0.10	21.43
1/17-n.	14.72ab	12.26	-4.92	17.90
Vechernitza	11.44a	9.96	-2.95	30.05
	Nodule number			
22/16-n.	40.30ab	30.00	-20.60	7.65
22/16-af.	26.05ab	13.20	-25.70	2.05
Kazino-af.	21.00a	18.90	-4.20	50.00
Plovdiv	30.15ab	20.00	-20.30	4.41
Echo-af.	27.55ab	19.40	-16.30	5.71
Marsi	71.45c	27.20	-88.50	1.30
Shugar duarf	42.60b	37.90	-9.40	41.08
B4-34	34.5ab	29.30	-10.40	22.01
1/17-n.	30.25ab	20.40	-19.70	4.72
Vechernitza	26.20ab	17.30	-17.80	4.33
	Weight of nodules (g)			
22/16-n.	0.1906abc	0.1472	-0.09	9.64
22/16-af.	0.1113ab	0.1306	0.04	16.63
Kazino-af.	0.0940a	0.0571	-0.07	3.24
Plovdiv	0.4590d	0.1191	-0.68	0.91
Echo-af.	0.1051ab	0.1062	-0.01	4564.47
Marsi	0.3460cd	0.3821	0.07	46.07
Shugar duarf	0.2835cd	0.1670	-0.23	2.96
B4-34	0.2362abc	0.1325	-0.21	2.59
1/17-n.	0.2590abc	0.1480	-0.22	2.72
Vechernitza	0.15505ab	0.1151	-0.08	7.53

According to the numerical expression of the parameters for assessing adaptability, the variety Marsi showed very good adaptability also in terms of the green grains weight. Ranking by the method of Nascimento et al. 2009 disadvantaged 22-16-af., Casino-af., Echo-af and Vechernitza, considered as very poorly adaptable (IV) genotypes.

The behavior of the varieties according to the nonparametric and rank analysis is quite different in the number of nodules per plant and the estimates for some of the genotypes are different. Marsi and Shugar duarf, which form many nodules, were described as inappropriate by the method of Huehn 1990, while Lin & Binns's 1988 Pi ranked them in the first two positions. Nascimento et al. 2009 ranking placed them in the group of genotypes having a very specific response to the external environment. Line 22/16-n. is the best ranking, having average general adaptability and a considerable number of nodules per plant. Similar conclusions can be drawn in the weight of nodules, as well as in their number, since these parameters did not give a clear and definite idea of the adaptability of the genotypes.

Table 3. Estimation of parameters of adaptability of garden peas genotypes, based on the nonparametric methods of Huehn 1990, Lin & Binns 1988 and Nascimento et al. 2009. (Huehn 1990: (1) Best performance, (9) Worst performance; Lin & Binns (1988) - favorable environment (Pi +) and in unfavorable environment (Pi -); Nascimento et al. 2009 - Rank I: high general adaptability; Rank II: specific adaptability to favorable environments; Rank III: Specific adaptability to adverse environments; Rank IV: Partially adapted; Rank V: Adaptability overall average; Rank VI: specific adaptability to favorable environments; Rank VII: Adaptability specific to unfavorable environments.)

Variety/line	Huehn 1990	Lin & Binns 1988			Nascimento et al. 2009
	Rank	Pi (+)	Pi (-)	Pi general	Rank
	Total number of pods per plant				
22/16-n.	8	9.06	1.56	24.04	V
22/16-af.	7	14.45	4.41	34.53	V
Kazino-af.	9	17.55	12.96	26.73	IV
Plovdiv	10	8.44	0.11	25.33	II
Echo-af.	7	5.29	4.20	7.48	V
Marsi	5	0.08	0.12	0.01	I
Shugar duarf	9	2.26	2.89	0.99	VII
B4-34	4	1.37	0.56	2.98	I
1/17-n.	5	22.75	10.24	47.77	IV
Vechernitza	6	12.02	7.56	20.94	V
	Weight of pods per plant (g)				
22/16-n.	8	194.99	146.31	292.34	V
22/16-af.	4	548.90	581.39	483.92	IV
Kazino-af.	7	517.51	609.08	334.37	IV
Plovdiv	9	246.91	144.61	451.50	V
Echo-af.	5	569.23	603.26	501.18	IV

Marsi	6	0.01	0.03	0.01	I
Shugar duarf	10	430.51	595.78	99.97	III
B4-34	9	270.72	368.44	75.28	V
1/17-n.	5	476.43	496.50	436.31	IV
Vechernitza	7	503.08	501.65	505.94	IV
	Weight of green grains per plant (g)				
22/16-n.	8	52.08	42.53	71.16	V
22/16-af.	5	126.75	139.00	102.25	IV
Kazino-af.	7	116.25	135.87	77.00	IV
Plovdiv	10	38.59	15.18	85.41	II
Echo-af.	5	110.11	125.98	78.38	IV
Marsi	6	0.11	0.02	0.01	I
Shugar duarf	9	95.98	135.06	17.82	III
B4-34	9	92.79	120.56	37.24	V
1/17-n.	7	69.86	69.74	70.09	V
Vechernitza	4	114.37	121.56	99.97	IV
	Nodule number				
22/16-n.	5	878.46	1059.50	516.37	V
22/16-af.	4	1428.25	1474.56	1335.63	V
Kazino-af.	9	1913.49	2143.69	1453.10	IV
Plovdiv	5	1285.21	1421.29	1013.05	V
Echo-af.	7	1444.91	1600.00	1134.73	V
Marsi	10	19.08	0.01	57.25	VI
Shugar duarf	9	918.48	1169.64	416.16	VII
B4-34	8	1202.54	1444.00	719.63	V
1/17-n.	6	1286.51	1428.84	1001.85	V
Vechernitza	7	1494.71	1624.09	1235.96	IV
	Weight of nodules (g)				
22/16-n.	7	0.07	0.08	0.06	V
22/16-af.	9	0.11	0.13	0.09	IV
Kazino-af.	7	0.11	0.11	0.12	IV
Plovdiv	10	0.01	0.01	0.03	VI
Echo-af.	8	0.11	0.12	0.10	IV
Marsi	9	0.04	0.06	0.01	VII
Shugar duarf	7	0.04	0.04	0.04	V
B4-34	7	0.05	0.05	0.06	V
1/17-n.	7	0.05	0.05	0.05	V
Vechernitza	7	0.09	0.09	0.08	V

According to Valchinkov's criterion "A" 1990, the duarf varieties Marsi and Shugar were adaptive and highly productive in terms of the number of pods per plant (Figure 2). Line 22/16-n., Marsi and line B4-34 combined a high level of pod weight trait and very good adaptability to environmental factors; plants with lighter grains are more adaptable to the environment.

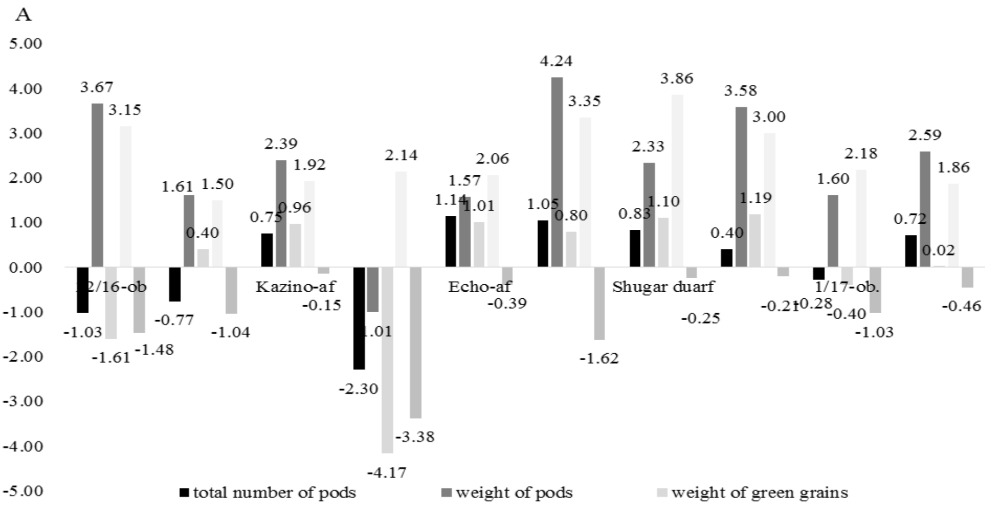

Figure 2. Adaptability (A) of the garden pea genotypes based on the traits studied, according to Valchinkov 1990.

Therefore, when selecting the appropriate genotype, the line B4-34, Shugar duarf and Marsi, which have intermediate character and adaptability, meet a breeding compromise. The parameter of general adaptability “A”, in comparison with the numerical expression of the features number and weight of nodules, suggested that Shugar duarf and line B4-34 proved to be the most suitable varieties. Variety Marsi is also noteworthy, but it is the most variable in weight of the nodules per plant.

Table 4 shows the relationships between seed weight per plant and the parameters of adaptability, homeostatic and selection value. GxEgi and GAA showed a statistically significant positive correlation with grain weight (r = 0.886 and 0.863, respectively), and a negative correlation with “Y” (r = -0.846). Based on the data obtained from the correlation analysis, a high positive correlation of Ig1 with GxEgi (r = 0.706) and GAA (r = 0.710) was found; of GxEgi with GAA (r = 0.981) and of SAA with Sgi,% (r = 0.959). A strong negative correlation was observed between SAA and SVG (r = -0.978). This study revealed that there is not always one-sidedness in evaluating the various adaptability and homeostatic parameters. Such manifestation of quantitative trait according to Kocherina & Dragavtsev 2008 is not only a product of the action of certain gene systems, but also of the interaction of limiting environmental factors with gene complexes. Environmental conditions constantly change, which makes it difficult or almost impossible to study them using classical methods developed to study the genetics of quality traits.

Table 4. Correlation between stability, adaptability and homeostaticity parameters and the productivity expressed by the weight of grains per plant. (** and * mean that correlation is significant at the 0.01 or 0.05 level, respectively.)

	Weight of grains	Ig1	GxEgi	GAA	SAA	Sgi, %	SVG	Hom
Ig1	0.534							
GxEgi	0.886**	0.706*						
GAA	0.863**	0.710*	0.981**					
SAA	-0.047	0.121	0.041	0.222				
Sgi, %	-0.171	0.045	-0.058	0.120	0.959**			
SVG	0.225	-0.024	0.100	-0.079	-0.978**	-0.984		
Hom	-0.359	-0.147	-0.237	-0.234	-0.086	-0.050	0.032	
Y	-0.846**	-0.235	-0.618	-0.651*	-0.089	-0.017	-0.069	0.255

The absence of significant relationship between the weight of the grains from the plant and SVG and Hom suggests that there may be relatively stable and adaptive genotypes in the sample group studied, both with high and low productivity.

DISCUSSION

The results obtained in the present study from the analysis of variance of the quantitative traits are in agreement with the works of Gixhari et al. 2014 and Ouafi et al. 2016 who analyzed genetic diversity among different accessions of pea using the same traits and found significant differences. Significant difference between the studied genotypes was confirmed by the work of Habtamu & Million 2013 who found that Ethiopian field pea genotypes were highly influenced by environment. The findings were found similar in other study (Vasileva & Kosev, 2021)

In the present work, it turned out that the parameter characterizing the stability of the genotype is relative and is not directly related to the general adaptive capacity. This finding confirms the results of Abrosimova & Fadeeva 2015, who indicated the hereditary nature of this indicator and the possibility of using these genotypes in the selection of trait stability.

Our results concerning the seed weight per plants were consistent with the findings of Khabibullin et al. 2020, who reported that the seed weight per plants of open field grown peas was associated to high stress resistance and homeostaticity of the genotypes when showed middle values.

Dragavtsev 1995 considers that the genetic formula of a trait consists of a number of discrete, mutually ordered components of a single functional system. Due to the integration of the elements of the genetic system within the whole organism, the phenotype can be represented as the realization of two hierarchies: structural and temporary. The author believes that this method reflects all stages of the implementation of genetic formulas, depending on the level of environmental factors during ontogeny.

Kilchevsky & Khotyleva 1997 reported that the main feature of adaptive breeding is the control of environmental stability and, according to them, the mean value of the trait and sensitivity to the environment are under genetic control alone and are relatively independent. The selection under such conditions, where only the genetic system (of productivity, for example) is phenotypically realized, can lead to random drift of genes that determine stability and to lose them. Morozova 2014 stated that under equal experimental conditions, the main reason for the differences between the different genotypes is the different physiological and biochemical state of the seeds (embryo, endosperm, perisperm). This determines the different starting conditions for the growth and development of plant organisms throughout the growing season. In varieties of populations, as well as in linear mixtures of different genotypes, variation in quantitative trait further includes the genetic characteristics of the individual.

Yessimbekova & Mukin 2014 believe that knowledge of the main limits of the environment does not automatically lead to a higher level of breeding efficiency, but can be used to determine the level of genetic variability and responsiveness of a particular plant population.

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