Pak. J. Bot., 54(3): 953-968, 2022. DOI: http://dx.doi.org/10.30848/PJB2022-3(41)

BIOLOGICAL POTENTIAL ASSESSMENT OF SAMPLES OF GARDEN PEA (*PISUM SATIVUM* L.) THROUGH THE ORTHOGONAL ANALYSIS METHOD

SLAVKA KALAPCHIEVA[1], VALENTIN KOSEV[2] AND VILIANA VASILEVA[2*]

[1]*Maritsa Vegetable Crops Research Institute, 32 Brezovsko shosse Str., 4003 Plovdiv, Bulgaria*
[2]*Institute of Forage Crops, Agricultural Academy, 89 General Vladimir Vazov Str., 5800 Pleven, Bulgaria*
[*]*Corresponding author's email: viliana.vasileva@gmail.com*

Abstract

Plant material from aboveground biomass of 53 samples of pea different originated was analyzed during two consecutive years. The ecological-genetic model for the organization of the quantitative traits and the method of orthogonal regression were used. The following characteristics were studied: number of unproductive nodes per plant, number of productive nodes per plant, total number of nodes per plant; number of pods per plant, weight of pods per plant (g), weight of one pod (g), number of grain (green) per plant; weight of grains per plant (g), weight of one grain (g) and number of grains per pod. Mira, Marsi and Lincoln were distinguished by a larger total number of nodes per plant and a larger number of productive nodes per plant. Marsi (69.18 g), Lincoln (54.63 g), Izomrud (53.52 g) and Paldin (52.93 g) formed a larger number of pods in good combination with the weight of one grain per plant. Mira (105.50), Marsi (101.83), Vyatovo (97) and line 1855/3 (78.50) were distinguished by a large number of grains per plant, and Marsi (38.80 g), Izomrud (25.88 g), Mira (24.92 g), Puldin (24.38 g) and line 101i (24.22 g) had the highest weight of grains per plant. Lincoln, Marsi, Vyatovo and Mira were of interest and can be included in future hybridization schemes to obtain forms combining in one genotype a larger number of fertile nodes and a high weight of grains.

Key words: Pea, Quantitative trait, Phenotype, Adaptability.

Introduction

Pea (*Pisum sativum* L.) is a rich source of protein, carbohydrates, vitamins, minerals and biologically active substances. Garden pea used in cooking can fill the deficiency of many useful components needed to maintain the normal vital activity of the human body. Processed grains of pea are widely used in the food and canning industries (Maystrenko, 2019).

As a result of the scientifically based selection activity, the yield of agricultural crops has increased several times. At the same time, resistance to environmental stressors has significantly weakened. Breeders face the challenge of creating varieties that are well adapted to changing growing conditions (Novikov, 2013; Zotikov, 2017).

A similar problem exists with annual legumes, including pea. Many years of research have shown that as a result of selection the yield of pea for grain in the last 50-60 years has increased to 300-450 kg/da, and some varieties under favorable soil and climatic conditions and a high level of agricultural technology can be get higher grain yields. The contribution of the variety as a genetic endowment in the formation of the yield can reach 60% (Goncharenko, 2017).

One of the weaknesses in the selection process, where 95% of the most valuable genotypes can be lost, is the selection by phenotype of individual plants. In plant selection, many quantitative traits do not have a stable correlation between them, which is why the genotype must be presented as a system of indicators. The action of each limiting factor corresponds to a specific set of manifestations of the traits that increase the stability of the genotype. Breeders are paying attention to new methods, including the orthogonal regression method, which makes it possible to identify genotypes by phenotype most compatible traits with each other (Petrova & Egorov, 2009). This method makes it possible to quickly, without changing generations, to identify the genotype of an individual organism by phenotype. Information is obtained as to whether the phenotypic value of a particular trait in an individual is determined by its genetic systems or whether it is a modification resulting from the effect of the microecological niche on the habitat of that individual. The influence of genotype and environment on the expression of the traits is quantified in the scale of parameter measurements (Dragavtsev, 2003).

The aim of our study was to evaluate the productive potential of collection samples of pea by using the ecological-genetic systems of organization of the quantitative traits.

Material and Methods

The study was conducted during two consecutive years 2019-2020 at Maritsa Vegetable Crop Research Institute (MVCRI), Plovdiv, Bulgaria with garden pea. 53 garden pea (*Pisum sativum* L.) accessions from the working collection of Maritsa Vegetable Crop Research Institute (MVCRI), Plovdiv, Bulgaria were chosen as objectives of the present study.

Musala (1); Zornitsa (2); Ran 1 (3); line 22-4 (4); Pulpudeva (5); line B4-33 (6); line B4-34 (7); Reina (8); Sugar dwarf (9); Dendi (10); Visto (11); Ilowiecki (12); Amitie-af. (13); Viridis (14); Pinokio (15); Dunav (16); Debreceni (17); Luxsor (18); line 22/16-n. (19); Echo-af. (20); Kazino-af. (21); line 22/16-af. (22); Skinado (23); Denitsa (24); line 101i (25); Flora 6 (26); Paldin (27); Plovdiv (28); line 1857/3 (29); line 1855/3 (30); Mifelia (31); Dinga (32); line 2/17-6/00 (33); line 3/17-6/00 (34); Victori frizer (35); Ballet-af. (36); Lincoln (37); line 1/17-6/00 (38); Plovdivska perla (39); Marsi (40); Prometei (41); Vyatovo (42); Vechernitsa (43); Uspex 72 (44); Duet (45); Multistsr

(46); Mira (47); Ofelia (48); Bravado (49); Izomrud (50); Mantika(51); Zelena perla (52); Vendevil (53);

Five of them (Amitie-af. (13); Echo-af. (20); Kazino-af. (21); line 22/16-af. (22); Ballet-af. (36);) had afila leaf type, while the other - normal leaf type. Line 22/16-n. and line 22/16-af. are F_{10} generation of the cross Plovdiv x Kazino. Musala (1), Zornitsa (2), Pulpudeva (5), Denitsa (24), line 101i (25), Paldin (27), Plovdiv (28), line 1857/3 (29), line 1855/3 (30), line 2/17-6/00 (33), line 3/17-6/00 (34), line 1/17-6/00 (38), Plovdivska perla (39), Marsi (40), Prometei (41), Vyatovo (42), Vechernitsa (43), Uspex 72 (44) are varieties developed at MVCRI, while the other were received through non-cash exchange from Plant Genebanks.

Seeds of the genotypes were sown in the field in the second decade of March on a high flatbed by scheme 80 + 20 + 40 + 20/4–5 cm (4 rows high flat bed – 160 cm width); 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. The experiments were laid out in a randomized complete block design with three replicates. Plot size was 1.6 × 4.0 m with 20 seeds in a metre in a row. Measurements: 1-number of unproductive nodes per plant, 2-number of productive nodes per plant, 3-total number of nodes per plant; 4-number of pods per plant, 5-weight of pods per plant (g), 6-weight of one pod (g), 7-number of grain (green) per plant; 8-weight of grains per plant (g), 9-weight of one grain (g) and 10- number of grains per pod.

The data obtained were processed by analysis of variance and rank analysis.

The modular organization of the quantitative feature is presented according to the model of Dragavtcev (2002). According to this model, the genetic formula of a trait consists of many discrete, functionally mutually ordered components of a single system. Due to the integration of the elements of the genetic system within the whole organism, the phenotype can be presented as the realization of two hierarchies - structural and temporal. The module as an elementary unit describes the organization of the quantitative feature, which consists of three interrelated features-one resultant and two component. The module reflects all stages of realization of genetic formulas depending on the level of environmental factors during ontogenesis.

In the modular organization of the quantitative traits, the resultant can be considered as a component in another subsequent module (component trait 1 x component trait 2 = resultant trait). The so-called orthogonal regression was used, where the method is called the orthogonal regression method. This regression was different from the usually used ones in regression analysis, which are always two - A x B and B x A. The orthogonal regression is always only one - this is the major axis of the scattering ellipse or the geometric location of the points, the sum of the squares of the distances of which is minimal.

The software products MS Excel (2003) and STATGRAPHICS Plus for Windows Version 2.1 were used in the statistical processing of the experimental data, including regression, dispersion and rank analysis.

Results

Drought is one of the most dangerous natural phenomena of the climate due to the uneven distribution of atmospheric precipitation against the background of high air temperatures. The productivity of pea depends more on the amount of precipitation that falls during flowering and grain filling (Voziyan *et al*., 2017).

The agro-meteorological conditions for the study period are presented by the average daily air temperature and the amount of precipitation (Fig. 1). The average daily temperatures are above the climatic norm in March for both experimental years, the third ten-day period in April and May for 2019 and the second in May for 2020. The temperatures during the first ten days of April and May for both years are below the average norms. The remaining ten days are around the norm. Rainfall were below normal in March, late April and early May 2019 and throughout the vegetation of 2020, except for the last ten days of March and the first of April. Under such agrometeorological conditions, it was necessary to water the pea. The high temperatures in May created conditions for abortion of flowers and nodes, the rapid transition of the phenological stages, and the fallen rains in the beginning of June 2019 made it difficult to harvest the plants and worsened the quality.

Knowledge of the genotypic laws in the formation and functioning of the organs of cultivated plants is extremely important for selection.

Module total number of nodes per plant: The total number of nodes per plant is a trait directly related to the length of the stem and the resistance to lodging. The longer stem (in Luxor, Marsi, Ilowiecki and Echo-af.) is usually associated with a larger total number of nodes, but also a higher percentage of plants prone to lodging. It should be have in a mind that short-stemmed forms of peas in case of improper distribution of rainfall during the growing season suffer more from drought compared to genotypes with longer stems. Therefore, it is necessary not to look for their maximum number, but to take some optimal selection compromise.

The main components of this module are the number of unproductive nodes per plant and number of productive nodes per plant. According to the number of unproductive nodes per plant, the samples Vechernitsa, Plovdivska perla and Paldin were distinguished by a maximum number of nodes (14 -15) and according to the rank analysis regularly occupied the first positions (Table 1a).

In the second component, Uspex 72, Mira, Lincoln and Reina are characterized by a higher number of productive nodes per plant. Varieties Denitsa, Flora 6, Ballet-af. Vechernitsa and Dunav failed to form more than 5 productive nodes on the stem and had a very poor score (47-51) (Table 1b).

For the selection in the direction of plant forms with a larger number productive nodes and with a length of the main stem above the average for the sample, the varieties Mira, Marsi and Lincoln deserve attention.

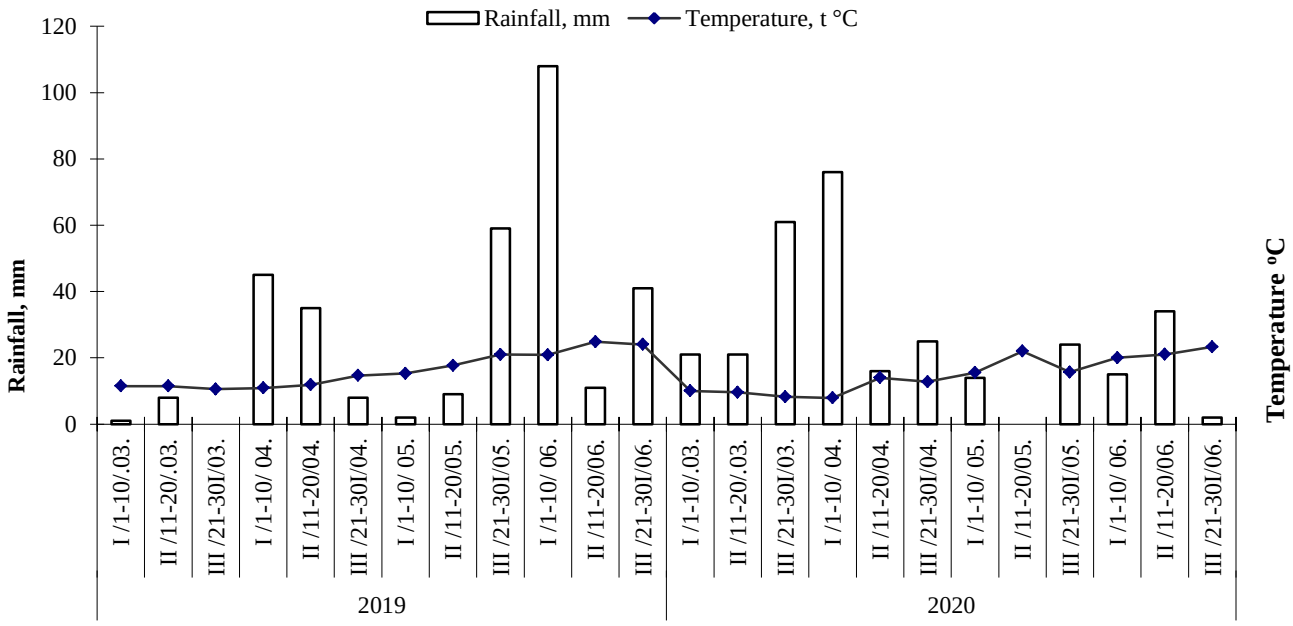

Fig. 1. Agrometeorological conditions for the study period.

Module weight of pods per plant: The weight of the total number of pods undoubtedly affects the grain yield, because the seeds develop from the seed buds in the pods and the weight of the green pod is an indication for the formation of heavier grains. When carrying out the selection process aimed at high grain productivity by increasing the number of pods, the negative correlation between the number of pods per plant and the number of grains per pod must be taken into account. By the component number of pods per plant (Tables 2a and 2b) the varieties Marsi, line 22/16 n., Line 2/17-6 /00 and Bravado with average number of pods per plant 15-16 are found of interest. By component weight of one pod, the varieties Paldin and Marsi and the lines 101i and 1855/3 have heavier pods (4.37 g - 5.40 g) compared to the rest from the working collection. The weight of pods per plant module reflects the ability of the genotype to form high grain productivity. When combined with favorable conditions for growth and development, preference may be given to the genotypes which can feed more pods than a plant with a lower pod weight than to those with a smaller number but heavier pods. Such plants are less prone to lodging. Marsi (69.18 g), Lincoln (54.63 g), Izomrud (53.52 g) and Paldin (52.93 g) form a larger number of pods in good combination with the weight of one pod per plant and a higher one. So, could be expected higher grain productivity from them.

Module weight of grains per plant: The weight of grains per plant is a relatively complex indicator, controlled polygenically and essentially a complex of interconnected elements of productivity. The total weight of the grains is directly dependent on their number per plant and the weight of one grain. The weight of one grain depends on its size and density. It is also closely related to grain yield and can serve as a reliable indicator in the selection of plant forms with higher grain weight. The change in the ranking of the test specimens relative to the weight of one grain is impressive in terms of the number of grains per plant (Table 3b). The samples Mira, Marsi, Vyatovo, Prometei and line 1855/3 are presented with ranks from 1 to 4 and with a higher number of grains per plant. The second component with the highest weight of one grain are Lincoln, Ofelia, line 101i and Izomrud, with values from 0.38 to 0.42 g, respectively, followed by Duet, Paldin, Ballet-af., Marsi and Uspex 72. From the data presented (Table 3a) it is clear that the varieties Marsi, Izomrud, Mira, Paldin and line 101i can be used in the combination selection to create hybrids with heavier grains. Like other quantitative traits, this module is highly dependent on changes in environmental conditions. The weight of grains per plant most fully reflects the biological capabilities of the genotype and shows the end result of the influence of other indicators, as well as the adaptability to abiotic stress.

Module number of grain per plant: One of the main parameters determining the productivity and yield of peas is the number of grain per plant. Like the previous traits, this indicator is also quite variable and is highly dependent on environmental factors (soil, climatic). The number of grains per plant is represented by the two component traits, i.e. number of pods per plant and number of grains per pod. Maximum number of grains per pod was found at line 1855/3 (7.66) and varieties Paldin (7.19), Mira (7.07) and Marsi (6.67). At Dunav, Visto, Ballet-af. and Ilowiecki the number of grains per pod does not exceed 3-4 and naturally they are ranked last according to the rank analysis (Tables 4a and 4b). The share of genotype in the inheritance number of grains per plant is not so high. The number of grains per plant ranges from 28.67 to 105.50. The varieties Amitie-af., Denitsa, Pinokio and Dunav are characterized by the smallest number of grains per plant, and the largest number of grains is formed by the plants of the varieties Mira, Marsi, Vyatovo and line 1855/3, occupying first places in the standings. They are suitable when the goal is to achieve a larger number of grains per plant.

Table 1a. Influence of environmental conditions on the module number of plant nodes in varieties and lines of garden peas (according to book value).

Years measurements / cultivars	2019	2020	Average	2019	2020	Average	2019	2020	Average
	Component trait 1			Component trait 2			Resulting trait		
	Number of unprod. nodes			Number of product. nodes			Total number of nodes		
Musala	6.00	8.00	7.00	8.67	6.00	7.33	15.33	13.67	14.50
Zornitsa	7.00	9.00	8.00	8.00	8.33	8.17	10.67	16.33	13.50
Ran 1	7.33	7.67	7.50	8.67	7.33	8.00	17.33	14.33	15.83
line 22-4	6.00	7.33	6.67	7.67	8.67	8.17	12.00	15.33	13.67
Pulpudeva	12.00	10.67	11.33	6.00	7.00	6.50	17.33	16.67	17.00
line B4-33	7.00	11.33	9.17	9.00	6.67	7.83	14.33	17.00	15.67
line B4-34	10.67	12.33	11.50	8.33	8.00	8.17	16.67	19.33	18.00
Reina	8.00	8.33	8.17	12.33	8.00	10.17	13.67	15.67	14.67
Sugar dwarf	9.67	9.67	9.67	7.00	8.33	7.67	14.33	15.67	15.00
Dendi	7.00	8.67	7.83	6.33	8.00	7.17	14.33	16.00	15.17
Visto	8.00	9.67	8.83	8.00	8.67	8.33	15.67	17.33	16.50
Ilowiecki	13.33	9.67	11.50	6.00	9.33	7.67	23.67	18.00	20.83
Amitie-af.	12.00	11.67	11.83	5.33	6.33	5.83	14.00	17.00	15.50
Viridis	5.67	9.33	7.50	7.00	7.00	7.00	11.33	15.33	13.33
Pinokio	9.67	12.33	11.00	6.33	5.00	5.67	13.67	16.33	15.00
Dunav	10.67	12.00	11.33	5.33	5.67	5.50	16.00	16.67	16.33
Debreceni	9.00	6.00	7.50	6.33	7.33	6.83	16.00	14.67	15.33
Luxor	7.67	9.00	8.33	7.00	7.00	7.00	13.00	48.67	30.83
line 22/16 n.	13.67	13.33	13.50	9.67	8.67	9.17	19.67	21.00	20.33
Echo-af.	13.00	12.33	12.67	6.67	8.00	7.33	19.67	21.67	20.67
Kazino-af.	14.33	12.33	13.33	7.33	8.00	7.67	19.00	20.00	19.50
Line 22/16-af.	13.33	12.00	12.67	9.00	8.67	8.83	19.33	21.00	20.17
Skinado	10.33	11.67	11.00	6.67	5.67	6.17	16.33	16.33	16.33
Denitsa	10.67	10.33	10.50	5.00	5.67	5.33	15.00	15.00	15.00
line 101i	12.33	14.33	13.33	4.33	8.67	6.50	16.00	23.67	19.83
Flora 6	10.00	13.00	11.50	5.00	5.67	5.33	13.00	18.67	15.83
Paldin	12.67	15.33	14.00	6.33	4.67	5.50	16.33	19.00	17.67
Plovdiv	11.33	9.67	10.50	8.33	6.00	7.17	18.33	19.00	18.67
line 1857/3	12.33	15.33	13.83	6.33	7.67	7.00	17.67	16.00	16.83
line 1855/3	11.33	14.67	13.00	7.67	5.33	6.50	17.67	19.67	18.67
Mifelia	12.00	12.67	12.33	6.33	7.33	6.83	16.00	19.00	17.50
dinga	12.67	12.33	12.50	6.00	6.67	6.33	17.00	17.67	17.33
line 2/17-6/00	9.00	12.00	10.50	5.67	7.33	6.50	13.67	19.67	16.67
line 3/17-6/00	10.67	12.67	11.67	5.00	1.67	3.33	15.33	17.67	16.50
Victori frizer	10.00	11.33	10.67	8.33	3.33	5.83	17.33	15.67	16.50
Ballet-af.	10.67	14.00	12.33	5.00	6.00	5.50	14.33	19.67	17.00
Lincoln	11.67	12.00	11.83	10.00	10.67	10.33	18.00	21.00	19.50
line 1/17-6/00	12.67	13.00	12.83	5.33	6.67	6.00	16.00	20.33	18.17
Plovdivska perla	13.33	16.33	14.83	11.33	6.00	8.67	19.33	21.33	20.33
Marsi	12.00	14.67	13.33	11.33	8.67	10.00	18.67	25.33	22.00
Prometei	13.67	12.67	13.17	9.67	8.33	9.00	19.00	19.67	19.33
Vyatovo	12.00	14.00	13.00	12.00	6.67	9.33	18.00	19.67	18.83
Vechernitsa	12.00	17.67	14.83	7.00	4.00	5.50	16.67	21.00	18.83
Uspex 72	13.67	8.67	11.17	9.33	12.33	10.83	20.33	20.67	20.50
Duet	9.33	13.33	11.33	9.00	8.33	8.67	14.67	16.33	15.50
Multistar	10.67	13.67	12.17	4.33	7.33	5.83	16.00	20.00	18.00
Mira	12.67	13.33	13.00	11.67	9.33	10.50	19.33	21.67	20.50
Ofelia	10.00	10.00	10.00	8.00	4.67	6.33	15.33	14.00	14.67
Bravado	7.67	9.00	8.33	11.33	7.67	9.50	14.33	16.67	15.50
Izomrud	9.00	12.33	10.67	8.67	9.67	9.17	15.00	20.67	17.83
Mantika	10.00	10.67	10.33	7.00	9.33	8.17	17.67	19.67	18.67
Zelena perla	9.00	13.00	11.00	7.33	6.33	6.83	13.00	19.00	16.00
Vendevil	9.67	12.33	11.00	10.00	6.33	8.17	16.33	18.00	17.17
LSD 0.05			2.97			3.23			7.48

Table 1b. Influence of environmental conditions on the modulus number of plant nodes in varieties and lines of peas (by rank).

Years measurements cultivars	2019	2020	Average	2019	2020	Average	2019	2020	Average
	Component trait 1			Component trait 2			Resulting trait		
	Number of unprod. nodes			Number of product. nodes			Total number of nodes		
Musala	51	50	52	15	39	25	33	53	50
Zornitsa	48	44	47	21	13	15	53	38	52
Ran 1	47	51	49	15	24	20	17	51	37
line 22-4	51	52	53	24	7	15	51	47	51
Pulpudeva	15	35	26	41	29	35	17	35	27
line B4-33	48	33	42	12	32	21	39	33	39
line B4-34	24	20	23	18	17	15	21	22	20
Reina	43	49	46	1	17	4	45	44	48
Sugar dwarf	35	39	41	28	13	22	39	44	45
Dendi	48	47	48	35	17	27	39	42	44
Visto	43	39	43	21	7	14	32	32	31
Ilowiecki	5	39	23	41	4	22	1	28	3
Amitie-af.	15	31	20	45	36	43	44	33	40
Viridis	53	43	49	28	29	29	52	47	53
Pinokio	35	20	30	35	48	46	45	38	45
Dunav	24	27	26	45	43	47	26	35	34
Debreceni	39	53	49	35	24	32	26	50	43
Luxor	45	44	44	28	29	29	48	1	1
line 22/16 n.	2	11	5	9	7	8	3	7	7
Echo-af.	8	20	14	33	17	25	3	4	4
Kazino-af.	1	20	6	26	17	22	8	14	11
Line 22/16-af.	5	27	14	12	7	11	5	7	9
Skinado	30	31	30	33	43	41	23	38	34
Denitsa	24	37	36	48	43	51	36	49	45
line 101i	13	7	6	52	7	35	26	3	10
Flora 6	31	14	23	48	43	51	48	27	37
Paldin	9	3	3	35	49	47	23	23	23
Plovdiv	22	39	36	18	39	27	11	23	16
line 1857/3	13	3	4	35	22	29	14	42	29
line 1855/3	22	5	10	24	47	35	14	16	16
Mifelia	15	17	17	35	24	32	26	23	24
dinga	9	20	16	41	32	39	20	30	25
line 2/17-6/00	39	27	36	44	24	35	45	16	30
line 3/17-6/00	24	17	22	48	53	53	33	30	31
Victori frizer	31	33	34	18	52	43	17	44	31
Ballet-af.	24	8	17	48	39	47	39	16	27
Lincoln	21	27	20	7	2	3	12	7	11
line 1/17-6/00	9	14	13	45	32	42	26	13	19
Plovdivska perla	5	2	1	4	39	12	5	6	7
Marsi	15	5	6	4	7	5	10	2	2
Prometei	2	17	9	9	13	10	8	16	13
Vyatovo	15	8	10	2	32	7	12	16	14
Vechernitsa	15	1	1	28	51	47	21	7	14
Uspex 72	2	47	29	11	1	1	2	11	5
Duet	38	11	26	12	13	12	38	38	40
Multistar	24	10	19	52	24	43	26	14	20
Mira	9	11	10	3	4	2	5	4	5
Ofelia	31	38	40	21	49	39	33	52	48
Bravado	45	44	44	4	22	6	39	35	40
Izomrud	39	20	34	15	3	8	36	11	22
Mantika	31	35	39	28	4	15	14	16	16
Zelena perla	39	14	30	26	36	32	48	23	36
Vendevil	35	20	30	7	36	15	23	28	26

Table 2a. Influence of environmental conditions on the modulus of pods weight per plant in varieties and lines of pea (by book value).

Years measurements / cultivars	2019	2020	Average	2019	2020	Average	2019	2020	Average
	Component trait 1			Component trait 2			Resulting trait		
	Number of pods per plant			Weight of one pod (g)			Weight of pods per plant (g)		
Musala	11.67	10.00	10.83	3.72	2.08	2.90	3.72	2.08	32.53
Zornitsa	11.33	11.33	11.33	2.92	3.54	3.23	2.92	3.54	35.87
Ran 1	13.67	13.00	13.33	3.16	3.64	3.40	3.16	3.64	45.45
line 22-4	12.67	14.67	13.67	2.92	2.86	2.89	2.92	2.86	39.65
Pulpudeva	9.00	10.67	9.83	4.71	2.44	3.57	4.71	2.44	32.63
line B4-33	13.00	10.67	11.83	1.77	3.16	2.46	1.77	3.16	27.35
line B4-34	14.33	12.33	13.33	2.88	2.33	2.60	2.88	2.33	33.93
Reina	20.00	11.00	15.50	2.92	3.53	3.23	2.92	3.53	48.77
Sugar dwarf	11.33	14.33	12.83	3.32	2.57	2.95	3.32	2.57	37.03
Dendi	7.67	17.67	12.67	1.63	2.35	1.99	1.63	2.35	26.65
Visto	14.67	11.67	13.17	2.75	3.00	2.88	2.75	3.00	37.70
Ilowiecki	12.00	16.67	14.33	2.06	1.42	1.74	2.06	1.42	24.18
Amitie-af.	8.33	11.00	9.67	2.92	2.90	2.91	2.92	2.90	27.85
Viridis	9.00	10.33	9.67	3.48	3.35	3.42	3.48	3.35	33.08
Pinokio	10.00	9.00	9.50	2.39	2.77	2.58	2.39	2.77	24.18
Dunav	9.33	9.00	9.17	2.36	2.32	2.34	2.36	2.32	20.85
Debreceni	8.67	7.67	8.17	4.04	4.56	4.30	4.04	4.56	35.43
Luxor	12.33	11.33	11.83	2.73	2.82	2.78	2.73	2.82	33.12
line 22/16 n.	16.33	15.33	15.83	3.66	2.80	3.23	3.66	2.80	50.85
Echo-af.	11.33	15.00	13.17	2.20	2.23	2.22	2.20	2.23	29.13
Kazino-af.	14.67	15.33	15.00	1.98	2.97	2.47	1.98	2.97	35.93
Line 22/16-af.	13.33	13.33	13.33	2.49	2.97	2.73	2.49	2.97	34.43
Skinado	12.00	9.00	10.50	4.16	3.70	3.93	4.16	3.70	41.45
Denitsa	8.33	8.33	8.33	3.05	2.84	2.94	3.05	2.84	24.05
line 101i	8.00	12.67	10.33	5.69	4.60	5.15	5.69	4.60	51.63
Flora 6	9.00	10.33	9.67	3.41	2.54	2.97	3.41	2.54	29.45
Paldin	11.33	8.33	9.83	5.25	5.56	5.40	5.25	5.56	52.93
Plovdiv	13.67	8.33	11.00	3.37	3.39	3.38	3.37	3.39	38.37
line 1857/3	9.67	12.67	11.17	3.60	3.60	3.60	3.60	3.60	40.33
line 1855/3	12.00	8.33	10.17	4.76	4.38	4.57	4.76	4.38	46.30
Mifelia	14.67	13.67	14.17	2.48	2.60	2.54	2.48	2.60	34.78
dinga	9.67	9.00	9.33	4.15	4.20	4.17	4.15	4.20	38.70
line 2/17-6/00	15.00	16.67	15.83	2.31	2.42	2.36	2.31	2.42	36.83
line 3/17-6/00	11.67	17.33	14.50	2.40	2.56	2.48	2.40	2.56	35.33
Victori frizer	12.67	10.33	11.50	3.95	3.03	3.49	3.95	3.03	40.13
Ballet-af.	8.67	12.67	10.67	2.40	2.75	2.57	2.40	2.75	27.98
Lincoln	12.00	14.00	13.00	4.15	4.44	4.29	4.15	4.44	54.63
line 1/17-6/00	7.67	16.00	11.83	3.30	2.71	3.00	3.30	2.71	33.67
Plovdivska perla	16.00	7.33	11.67	2.67	2.82	2.75	2.67	2.82	31.63
Marsi	17.33	14.67	16.00	4.07	4.67	4.37	4.07	4.67	69.18
Prometei	14.67	12.00	13.33	3.02	2.70	2.86	3.02	2.70	38.42
Vyatovo	18.00	11.33	14.67	2.87	3.07	2.97	2.87	3.07	43.57
Vechernitsa	12.00	8.33	10.17	2.94	2.56	2.75	2.94	2.56	27.98
Uspex 72	15.67	14.33	15.00	2.53	2.56	2.55	2.53	2.56	37.60
Duet	15.00	11.33	13.17	3.57	3.89	3.73	3.57	3.89	48.60
Multistar	6.00	11.33	8.67	2.51	3.41	2.96	2.51	3.41	26.93
Mira	14.67	15.33	15.00	3.45	2.98	3.22	3.45	2.98	47.73
Ofelia	19.00	7.67	13.33	1.93	2.57	2.25	1.93	2.57	26.82
Bravado	19.67	12.00	15.83	3.65	2.70	3.17	3.65	2.70	52.47
Izomrud	12.67	15.33	14.00	3.91	3.88	3.89	3.91	3.88	53.52
Mantika	12.00	15.33	13.67	2.06	2.54	2.30	2.06	2.54	32.05
Zelena perla	11.33	11.00	11.17	2.90	3.60	3.25	2.90	3.60	35.57
Vendevil	17.67	12.00	14.83	2.09	2.11	2.10	2.09	2.11	29.72
LSD 0.05			5.93			0.93			19.41

Table 2b. Influence of environmental conditions on the weight modulus of plant pods in varieties and lines of peas (by rank).

Years measurements cultivars	2019	2020	Average	2019	2020	Average	2019	2020	Average
	Component trait 1			Component trait 2			Resulting trait		
	Number of pods per plant			Weight of one pod (g)			Weight of pods per plant (g)		
Musala	32	41	37	12	52	30	17	50	37
Zornitsa	34	28	33	27	14	18	36	17	26
Ran 1	18	19	17	23	11	15	19	5	12
line 22-4	22	12	15	27	27	31	25	14	17
Pulpudeva	43	36	43	4	45	12	22	44	36
line B4-33	21	36	28	52	19	45	49	37	46
line B4-34	17	23	17	32	48	38	23	42	32
Reina	1	33	5	27	15	18	3	21	8
Sugar dwarf	34	14	26	21	38	27	26	23	23
Dendi	51	1	27	53	47	52	53	15	49
Visto	12	27	22	34	22	32	21	31	21
Ilowiecki	26	3	12	48	53	53	45	47	50
Amitie-af.	48	33	45	27	26	29	48	38	45
Viridis	43	38	45	17	18	14	39	30	35
Pinokio	39	42	48	43	32	39	47	46	50
Dunav	42	42	50	44	49	47	51	51	53
Debreceni	46	51	53	9	4	5	29	28	28
Luxor	25	28	28	35	29	34	33	38	34
line 22/16 n.	7	6	2	13	31	18	5	13	7
Echo-af.	34	11	22	46	50	50	42	36	42
Kazino-af.	12	6	6	50	24	44	41	9	25
Line 22/16-af.	20	18	17	39	24	37	38	22	31
Skinado	26	42	39	5	10	8	10	34	14
Denitsa	48	46	52	24	28	28	43	48	52
line 101i	50	20	40	1	3	2	15	4	6
Flora 6	43	38	45	19	43	24	37	43	41
Paldin	34	46	43	2	1	1	4	6	4
Plovdiv	18	46	36	20	17	16	14	40	20
line 1857/3	40	20	34	15	12	11	30	7	15
line 1855/3	26	46	41	3	6	3	6	25	11
Mifelia	12	17	13	40	37	42	27	33	30
dinga	40	42	49	6	7	7	20	25	18
line 2/17-6/00	10	3	2	45	46	46	34	16	24
line 3/17-6/00	32	2	11	41	40	43	40	11	29
Victori frizer	22	38	32	10	21	13	9	41	16
Ballet-af.	46	20	38	41	33	40	50	27	43
Lincoln	26	16	25	6	5	6	12	2	2
line 1/17-6/00	51	5	28	22	34	23	46	11	33
Plovdivska perla	8	53	31	36	29	35	18	52	39
Marsi	6	12	1	8	2	4	2	1	1
Prometei	12	24	17	25	35	33	16	35	19
Vyatovo	4	28	10	33	20	24	8	29	13
Vechernitsa	26	46	41	26	40	35	32	49	43
Uspex 72	9	14	6	37	40	41	24	24	22
Duet	10	28	22	16	8	10	7	10	9
Multistar	53	28	51	38	16	26	52	18	47
Mira	12	6	6	18	23	21	11	8	10
Ofelia	3	51	17	51	38	49	28	53	48
Bravado	2	24	2	14	35	22	1	32	5
Izomrud	22	6	14	11	9	9	13	3	3
Mantika	26	6	15	48	43	48	43	19	38
Zelena perla	34	33	34	31	12	17	35	20	27
Vendevil	5	24	9	47	51	51	31	45	40

Table 3a. Influence of environmental conditions on the modulus of plant grain weight in varieties and lines of peas (by book value).

Years measurements / cultivars	2019	2020	Average	2019	2020	Average	2019	2020	Average
	Component trait 1			Component trait 2			Resulting trait		
	Number of grains per plant			Weight of one grain (g)			Weight of grains per plant (g)		
Musala	66.00	38.67	52.33	0.27	0.20	0.23	16.77	7.30	12.03
Zornitsa	47.67	62.67	55.17	0.28	0.25	0.26	13.17	15.50	14.33
Ran 1	59.67	66.67	63.17	0.24	0.22	0.23	14.27	15.03	14.65
line 22-4	57.33	63.33	60.33	0.25	0.25	0.25	14.97	16.27	15.62
Pulpudeva	52.67	43.00	47.83	0.34	0.24	0.29	18.03	10.57	14.30
line B4-33	69.33	63.33	66.33	0.22	0.22	0.22	15.37	14.27	14.82
line B4-34	77.00	44.00	60.50	0.19	0.21	0.20	14.47	9.03	11.75
Reina	83.00	57.00	70.00	0.21	0.28	0.24	17.63	15.87	16.75
Sugar dwarf	62.00	67.67	64.83	0.23	0.23	0.23	14.53	15.70	15.12
Dendi	27.67	71.33	49.50	0.26	0.24	0.25	7.27	16.73	12.00
Visto	52.00	39.67	45.83	0.30	0.32	0.31	15.43	12.57	14.00
Ilowiecki	46.33	60.33	53.33	0.23	0.16	0.19	10.73	9.23	9.98
Amitie-af.	34.67	55.33	45.00	0.30	0.29	0.30	10.37	16.40	13.38
Viridis	47.67	53.33	50.50	0.25	0.29	0.27	11.77	16.03	13.90
Pinokio	31.67	38.00	34.83	0.25	0.21	0.23	7.77	8.00	7.88
Dunav	27.33	30.00	28.67	0.23	0.20	0.22	6.17	6.30	6.23
Debreceni	55.00	43.33	49.17	0.26	0.33	0.29	14.67	13.93	14.30
Luxor	44.67	49.67	47.17	0.21	0.18	0.19	10.97	10.10	10.53
line 22/16 n.	87.00	55.33	71.17	0.28	0.30	0.29	23.87	16.20	20.03
Echo-af.	46.67	87.33	67.00	0.22	0.22	0.22	10.80	18.97	14.88
Kazino-af.	57.33	77.00	67.17	0.17	0.26	0.22	10.00	19.90	14.95
Line 22/16-af.	56.33	68.00	62.17	0.25	0.22	0.24	13.70	15.00	14.35
Skinado	83.33	53.00	68.17	0.27	0.26	0.27	22.33	13.80	18.07
Denitsa	37.00	41.33	39.17	0.28	0.21	0.24	10.27	8.80	9.53
line 101i	45.33	94.00	69.67	0.49	0.29	0.39	21.53	26.90	24.22
Flora 6	56.33	74.67	65.50	0.30	0.16	0.23	17.33	12.67	15.00
Paldin	79.33	62.00	70.67	0.37	0.32	0.35	28.70	20.07	24.38
Plovdiv	78.67	56.67	67.67	0.31	0.21	0.26	23.93	13.33	18.63
line 1857/3	52.67	74.33	63.50	0.34	0.27	0.30	17.73	19.93	18.83
line 1855/3	95.00	62.00	78.50	0.28	0.28	0.28	27.07	17.40	22.23
Mifelia	63.00	77.33	70.17	0.21	0.18	0.19	13.53	13.70	13.62
dinga	70.00	41.33	55.67	0.30	0.35	0.33	21.13	14.67	17.90
line 2/17-6/00	56.00	93.67	74.83	0.18	0.19	0.19	10.23	18.30	14.27
line 3/17-6/00	50.33	100.67	75.50	0.20	0.14	0.17	9.97	13.43	11.70
Victori frizer	59.33	62.00	60.67	0.39	0.23	0.31	23.20	13.87	18.53
Ballet-af.	27.33	54.33	40.83	0.37	0.30	0.34	10.20	16.07	13.13
Lincoln	58.33	49.33	53.83	0.34	0.49	0.42	20.13	24.30	22.22
line 1/17-6/00	48.67	100.33	74.50	0.26	0.17	0.21	12.30	16.90	14.60
Plovdivska perla	75.00	36.33	55.67	0.26	0.29	0.28	20.23	10.43	15.33
Marsi	90.00	113.67	101.83	0.38	0.29	0.34	31.93	33.67	32.80
Prometei	100.33	56.67	78.50	0.23	0.27	0.25	23.57	15.07	19.32
Vyatovo	119.33	74.67	97.00	0.22	0.27	0.24	24.10	19.90	22.00
Vechernitsa	77.00	46.33	61.67	0.18	0.24	0.21	13.63	11.40	12.52
Uspex 72	70.00	60.00	65.00	0.42	0.25	0.34	28.37	15.73	22.05
Duet	80.67	54.67	67.67	0.36	0.34	0.35	28.67	18.10	23.38
Multistar	23.67	56.00	39.83	0.27	0.36	0.31	6.17	20.27	13.22
Mira	98.67	112.33	105.50	0.26	0.22	0.24	25.33	24.50	24.92
Ofelia	78.00	35.67	56.83	0.20	0.62	0.41	15.57	20.70	18.13
Bravado	94.00	61.67	77.83	0.29	0.19	0.24	27.13	12.03	19.58
Izomrud	53.00	81.67	67.33	0.35	0.40	0.38	18.73	33.03	25.88
Mantika	57.33	95.00	76.17	0.23	0.21	0.22	12.80	19.50	16.15
Zelena perla	70.33	73.00	71.67	0.25	0.29	0.27	17.43	21.07	19.25
Vendevil	68.00	56.33	62.17	0.20	0.22	0.21	13.57	12.50	13.03
LSD 0.05			38.17			0.13			9.62

Table 3b. Influence of environmental conditions on the module weight of plant grains in varieties and lines of peas (by rank).

Years measurements cultivars	2019	2020	Average	2019	2020	Average	2019	2020	Average
	Component trait 1			Component trait 2			Resulting trait		
	Number of grains per plant			Weight of one grain (g)			Weight of grains per plant (g)		
Musala	22	49	41	22	44	35	24	52	45
Zornitsa	41	22	38	18	25	24	37	28	33
Ran 1	25	19	28	35	33	35	32	30	30
line 22-4	28	20	34	30	25	26	28	21	23
Pulpudeva	36	45	45	9	28	16	19	45	34
line B4-33	20	20	23	41	33	40	27	33	29
line B4-34	14	43	33	50	39	48	31	49	47
Reina	9	29	15	44	18	29	21	25	21
Sugar dwarf	24	18	26	36	31	35	30	27	25
Dendi	50	16	43	25	28	26	51	19	46
Visto	38	48	47	13	8	11	26	41	37
Ilowiecki	44	27	40	36	51	49	43	48	50
Amitie-af.	48	34	48	13	12	14	44	20	40
Viridis	41	38	42	30	12	21	40	24	38
Pinokio	49	50	52	30	39	35	50	51	52
Dunav	51	53	53	36	44	40	52	53	53
Debreceni	34	44	44	25	7	16	29	34	34
Luxor	46	40	46	44	48	49	41	47	49
line 22/16 n.	7	34	12	18	10	16	10	22	11
Echo-af.	43	8	22	41	33	40	42	14	28
Kazino-af.	28	11	21	53	23	40	48	11	27
Line 22/16-af.	31	17	29	30	33	29	33	31	32
Skinado	8	39	17	22	23	21	13	36	19
Denitsa	47	46	51	18	39	29	45	50	51
line 101i	45	6	16	1	12	3	14	3	5
Flora 6	31	12	24	13	51	35	23	40	26
Paldin	11	23	13	5	8	5	2	9	4
Plovdiv	12	30	18	12	39	24	9	39	16
line 1857/3	36	14	27	9	20	14	20	10	15
line 1855/3	4	23	4	18	18	19	6	17	7
Mifelia	23	10	14	44	48	49	36	37	39
dinga	18	46	36	13	5	10	15	32	20
line 2/17-6/00	33	7	9	51	46	49	46	15	36
line 3/17-6/00	39	3	8	47	53	53	49	38	48
Victori frizer	26	23	32	3	31	11	12	35	17
Ballet-af.	51	37	49	5	10	7	47	23	42
Lincoln	27	41	39	9	2	1	17	5	8
line 1/17-6/00	40	4	10	25	50	45	39	18	31
Plovdivska perla	16	51	36	25	12	19	16	46	24
Marsi	6	1	2	4	12	7	1	1	1
Prometei	2	30	4	36	20	26	11	29	13
Vyatovo	1	12	3	41	20	29	8	11	10
Vechernitsa	14	42	31	51	28	45	34	44	44
Uspex 72	18	28	25	2	25	7	4	26	9
Duet	10	36	18	7	6	5	3	16	6
Multistar	53	33	50	22	4	11	52	8	41
Mira	3	2	1	25	33	29	7	4	3
Ofelia	13	52	35	47	1	2	25	7	18
Bravado	5	26	6	17	46	29	5	43	12
Izomrud	35	9	20	8	3	4	18	2	2
Mantika	28	5	7	36	39	40	38	13	22
Zelena perla	17	15	11	30	12	21	22	6	14
Vendevil	21	32	29	47	33	45	35	42	43

Table 4a. Influence of environmental conditions on the module number of grains per plant in varieties and lines of peas (by book value).

Years measurements / cultivars	2019	2020	Average	2019	2020	Average	2019	2020	Average
	Component trait 1			Component trait 2			Resulting trait		
	Number of grains per pod			Number of pods per plant			Number of grain per plant		
Musala	5.42	3.74	4.58	11.67	10.00	10.83	66.00	38.67	52.33
Zornitsa	4.34	5.60	4.97	11.33	11.33	11.33	47.67	62.67	55.17
Ran 1	4.29	5.08	4.69	13.67	13.00	13.33	59.67	66.67	63.17
line 22-4	4.46	4.38	4.42	12.67	14.67	13.67	57.33	63.33	60.33
Pulpudeva	6.04	4.19	5.12	9.00	10.67	9.83	52.67	43.00	47.83
line B4-33	5.31	6.14	5.73	13.00	10.67	11.83	69.33	63.33	66.33
line B4-34	5.48	3.60	4.54	14.33	12.33	13.33	77.00	44.00	60.50
Reina	4.14	5.25	4.70	20.00	11.00	15.50	83.00	57.00	70.00
Sugar dwarf	5.55	4.70	5.13	11.33	14.33	12.83	62.00	67.67	64.83
Dendi	3.65	3.92	3.78	7.67	17.67	12.67	27.67	71.33	49.50
Visto	3.49	3.40	3.44	14.67	11.67	13.17	52.00	39.67	45.83
Ilowiecki	3.83	3.60	3.71	12.00	16.67	14.33	46.33	60.33	53.33
Amitie-af.	4.18	5.02	4.60	8.33	11.00	9.67	34.67	55.33	45.00
Viridis	5.54	5.25	5.39	9.00	10.33	9.67	47.67	53.33	50.50
Pinokio	3.17	4.34	3.75	10.00	9.00	9.50	31.67	38.00	34.83
Dunav	3.07	3.31	3.19	9.33	9.00	9.17	27.33	30.00	28.67
Debreceni	6.13	5.59	5.86	8.67	7.67	8.17	55.00	43.33	49.17
Luxor	3.56	4.26	3.91	12.33	11.33	11.83	44.67	49.67	47.17
line 22/16 n.	5.23	3.68	4.45	16.33	15.33	15.83	87.00	55.33	71.17
Echo-af.	4.27	5.89	5.08	11.33	15.00	13.17	46.67	87.33	67.00
Kazino-af.	4.22	5.02	4.62	14.67	15.33	15.00	57.33	77.00	67.17
Line 22/16-af.	4.45	5.38	4.92	13.33	13.33	13.33	56.33	68.00	62.17
Skinado	6.94	6.00	6.47	12.00	9.00	10.50	83.33	53.00	68.17
Denitsa	4.47	5.07	4.77	8.33	8.33	8.33	37.00	41.33	39.17
line 101i	5.79	7.31	6.55	8.00	12.67	10.33	45.33	94.00	69.67
Flora 6	6.19	7.06	6.62	9.00	10.33	9.67	56.33	74.67	65.50
Paldin	6.98	7.41	7.19	11.33	8.33	9.83	79.33	62.00	70.67
Plovdiv	5.78	6.63	6.21	13.67	8.33	11.00	78.67	56.67	67.67
line 1857/3	5.41	5.82	5.61	9.67	12.67	11.17	52.67	74.33	63.50
line 1855/3	7.90	7.42	7.66	12.00	8.33	10.17	95.00	62.00	78.50
Mifelia	4.35	5.95	5.15	14.67	13.67	14.17	63.00	77.33	70.17
dinga	7.32	4.88	6.10	9.67	9.00	9.33	70.00	41.33	55.67
line 2/17-6/00	4.01	5.62	4.81	15.00	16.67	15.83	56.00	93.67	74.83
line 3/17-6/00	4.32	5.85	5.08	11.67	17.33	14.50	50.33	100.67	75.50
Victori frizer	4.54	6.25	5.40	12.67	10.33	11.50	59.33	62.00	60.67
Ballet-af.	3.13	4.24	3.69	8.67	12.67	10.67	27.33	54.33	40.83
Lincoln	4.93	3.82	4.37	12.00	14.00	13.00	58.33	49.33	53.83
line 1/17-6/00	6.53	6.31	6.42	7.67	16.00	11.83	48.67	100.33	74.50
Plovdivska perla	4.79	4.99	4.89	16.00	7.33	11.67	75.00	36.33	55.67
Marsi	5.59	7.74	6.67	17.33	14.67	16.00	90.00	113.67	101.83
Prometei	6.89	4.55	5.72	14.67	12.00	13.33	100.33	56.67	78.50
Vyatovo	6.58	6.54	6.56	18.00	11.33	14.67	119.33	74.67	97.00
Vechernitsa	6.37	5.55	5.96	12.00	8.33	10.17	77.00	46.33	61.67
Uspex 72	4.49	4.23	4.36	15.67	14.33	15.00	70.00	60.00	65.00
Duet	5.39	4.74	5.07	15.00	11.33	13.17	80.67	54.67	67.67
Multistar	3.93	4.96	4.45	6.00	11.33	8.67	23.67	56.00	39.83
Mira	6.77	7.38	7.07	14.67	15.33	15.00	98.67	112.33	105.50
Ofelia	4.39	5.20	4.79	19.00	7.67	13.33	78.00	35.67	56.83
Bravado	4.68	5.02	4.85	19.67	12.00	15.83	94.00	61.67	77.83
Izomrud	4.48	5.36	4.92	12.67	15.33	14.00	53.00	81.67	67.33
Mantika	4.62	6.22	5.42	12.00	15.33	13.67	57.33	95.00	76.17
Zelena perla	6.21	6.77	6.49	11.33	11.00	11.17	70.33	73.00	71.67
Vendevil	4.08	4.79	4.43	17.67	12.00	14.83	68.00	56.33	62.17
LSD 0.05			1.56			5.93			38.17

Table 4b. Influence of environmental conditions on the module number of grains per plant in varieties and lines of peas (by rank).

Years measurements cultivars	2019	2020	Average	2019	2020	Average	2019	2020	Average
	Component trait 1			Component trait 2			Resulting trait		
	Number of grains per pod			Number of pods per plant			Number of grain per plant		
Musala	20	48	39	32	41	37	22	49	41
Zornitsa	37	20	27	34	28	33	41	22	38
Ran 1	39	28	36	18	19	17	25	19	28
line 22-4	33	40	44	22	12	15	28	20	34
Pulpudeva	13	45	23	43	36	43	36	45	45
line B4-33	23	13	15	21	36	28	20	20	23
line B4-34	19	50	40	17	23	17	14	43	33
Reina	43	25	35	1	33	5	9	29	15
Sugar dwarf	17	38	22	34	14	26	24	18	26
Dendi	48	46	48	51	1	27	50	16	43
Visto	50	52	52	12	27	22	38	48	47
Ilowiecki	47	50	50	26	3	12	44	27	40
Amitie-af.	42	30	38	48	33	45	48	34	48
Viridis	18	25	20	43	38	45	41	38	42
Pinokio	51	41	49	39	42	48	49	50	52
Dunav	53	53	53	42	42	50	51	53	53
Debreceni	12	21	14	46	51	53	34	44	44
Luxor	49	42	47	25	28	28	46	40	46
line 22/16 n.	24	49	41	7	6	2	7	34	12
Echo-af.	40	16	24	34	11	22	43	8	22
Kazino-af.	41	30	37	12	6	6	28	11	21
Line 22/16-af.	34	23	28	20	18	17	31	17	29
Skinado	4	14	9	26	42	39	8	39	17
Denitsa	32	29	34	48	46	52	47	46	51
line 101i	14	5	7	50	20	40	45	6	16
Flora 6	11	6	5	43	38	45	31	12	24
Paldin	3	3	2	34	46	43	11	23	13
Plovdiv	15	8	11	18	46	36	12	30	18
line 1857/3	21	18	17	40	20	34	36	14	27
line 1855/3	1	2	1	26	46	41	4	23	4
Mifelia	36	15	21	12	17	13	23	10	14
dinga	2	35	12	40	42	49	18	46	36
line 2/17-6/00	45	19	32	10	3	2	33	7	9
line 3/17-6/00	38	17	24	32	2	11	39	3	8
Victori frizer	29	11	19	22	38	32	26	23	32
Ballet-af.	52	43	51	46	20	38	51	37	49
Lincoln	25	47	45	26	16	25	27	41	39
line 1/17-6/00	8	10	10	51	5	28	40	4	10
Plovdivska perla	26	33	30	8	53	31	16	51	36
Marsi	16	1	4	6	12	1	6	1	2
Prometei	5	39	16	12	24	17	2	30	4
Vyatovo	7	9	6	4	28	10	1	12	3
Vechernitsa	9	22	13	26	46	41	14	42	31
Uspex 72	30	44	46	9	14	6	18	28	25
Duet	22	37	26	10	28	22	10	36	18
Multistar	46	34	41	53	28	51	53	33	50
Mira	6	4	3	12	6	6	3	2	1
Ofelia	35	27	33	3	51	17	13	52	35
Bravado	27	30	31	2	24	2	5	26	6
Izomrud	31	24	28	22	6	14	35	9	20
Mantika	28	12	18	26	6	15	28	5	7
Zelena perla	10	7	8	34	33	34	17	15	11
Vendevil	44	36	43	5	24	9	21	32	29

Ortogonal regression method: To identify high-yielding varieties and lines of peas with genetically determined higher total number of nodes on the main stem, higher number of productive nodes per plant and higher weight of green grains per plant the orthogonal regression method was used. To assess the ratio of the studied indicators, this method is considered optimal. With its help, the pea specimens included in the study can be successfully indexed by shifting their projections relative to the axes of the orthogonal regression of the coordinate system "number of productive nodes" and "total number of nodes per plant / weight of grains per plant".

Developing the principle of background traits, Dragavtsev initially set himself the task of finding a way to distinguish genotypic from ecological variability of quantitative trait, and on this basis to assess the genotype of each individual in the population by its phenotypic characteristics. In these studies, an approach similar to the control plot principle was used in field trials to test yield genotypes.

(Fig. 2A) shows the graphical analysis of the ratio "total number of nodes per plant / number of productive nodes" for 2019, which allowed the differentiation of varieties and lines with positive changes in the number of productive nodes per plant.

The varieties Mira, Plovdivska perla, Marsi and Vyatovo were identified as highly adaptive with positive changes along the axis of the regression line with respect to the number of productive nodes per plant. In contrast, a significant part of the genotypes are very poorly adaptive and difficult to adapt to changes in breeding conditions. Multistar and line 101i occupied the extreme left part of the regression line, but are characterized by positive attractiveness in total number of nodes per plant. The location of Zornitsa, Viridis, line 22-4, Luxor and Zelena perla in the quadrant of the coordinate system, limited by the negative parts in terms of adaptability and attraction, shows the narrow limits of the range of growing conditions in realizing their potential to form a larger total number of nodes per plant and a larger number of productive nodes per plant.

The projections of the indicators of the Prometei and Lincoln varieties are concentrated within the optimal trend of the genetic response of the pea specimens to increase the number of productive nodes per plant with increasing stem length. An important point in the assessment can be considered the high positive attractiveness of the total number of nodes per plant of genotypes line 22/16-af., Line 22/16 n. and Uspex 72, which requires the search for individual solutions in the selection of appropriate adaptive genotypes as parental components for hybridization.

Vyatovo, line 1855/3, Bravado, Mira and Prometei can be assigned to the group of selectively valuable genotypes (Fig. 2B) with positive adaptability and attraction by weight of grains per plant. Marsi, Paldin, Duet and Uspex 72 have similarly high adaptability. Their location below the regression line suggests that they are less attractive under these growing conditions. From the point of view of hybrid variability, they are still of interest due to the high grain productivity. When crossing them with other suitable starting forms, new transgressive genotypes can be expected with a better combination of desired traits.

The similar graphs for 2019 and 2020 can be compared by overlapping each other and observing the displacements of the points of the varieties and the lines along the coordinate system. Very important information is obtained about the effect of the limit of the environment, causing the new distribution of the samples and the change in the action of the genes for adaptability and attraction. The comparison of these graphs gives information about the work of the genetic-physiological systems in the manifestation of the respective traits.

In 2020 the varieties and lines of pea studied are characterized by a wide range of response to the limiting factor – drought (Fig. 3A). The evaluation makes it possible to determine the varieties Izomrud, Lincoln and Uspex 72 with high adaptation, but also with unsatisfactory attractiveness in terms of the total number of nodes per plant. Variety Prometei retains its position in the same quadrant, but shifts so that it does not show attractiveness in the new conditions of development. Only Luxor, located at the top of the ellipse and forming a significant total number of nodes per plant, is characterized by "strong" attraction genes.

Realization of the positive tendency of increase of the number of productive nodes per plant depending on increase of the total number of nodes per plant, can be expected in the samples Multistar and Echo-af., and more weak at line 2 / 17-6 / 00, which are located in the sector overlapped by the ellipses of adaptability and attraction. Outside this range, but proportionally distant from the regression and orthogonal lines are line 101i and Marsi. This shows that their performance on the studied traits is influenced by other "noise-factors" - the reason for the scattering around the regression line.

In the two-dimensional system of trait coordinates (Fig. 3B) "total number of nodes per plant" and "weight of grains per plant", when plotting the mean values of the traits of the genotypes (varieties or lines), polymorphism on adaptive polygenes will "stretch" the ellipse around the regression line, and polymorphism due to attraction genes - along the orthogonal.

If there is no genetic diversity in the attraction genes, then all points of the mean values will lie directly on the regression line; if there is a polymorphism in attractiveness and no in the genes for adaptability, then all points of the mean values will fall on the orthogonal line. If the adaptive polymorphism differs from the attraction polymorphism, the graph will show an ellipse with a shape depending on the degree of variability of the traits. In case the amplitudes of the variability are the same, the ellipse will become a circle.

When analyzing the specific situation, it is understood that a significant part of the samples have a clear genetic effect, leading to poor adaptability (scattering of the sample points along the negative part of the regression line, to the right and left of the major axis of the scattering ellipse). The Marsi, Mira and line 101i samples have gene complexes that allow them to better adapt and form more productive nodes per plant than the other genotypes and at the same time have good attractiveness, expressed in the total number of nodes per plant. The Izomrud variety also has a positive adaptability, but also a negative attractiveness.

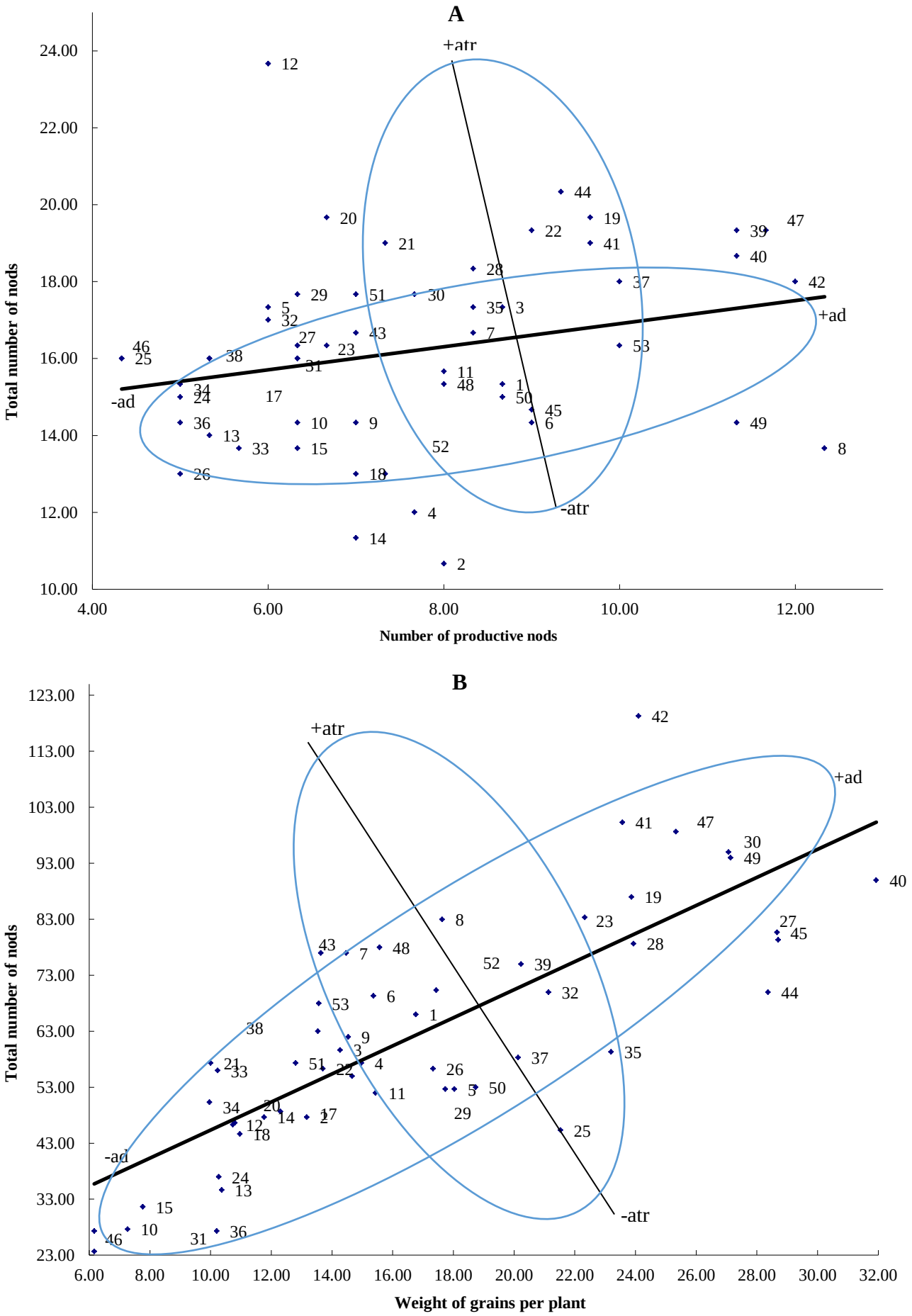

Fig. 2. Distribution of mean values of varieties from garden pea for 2019.

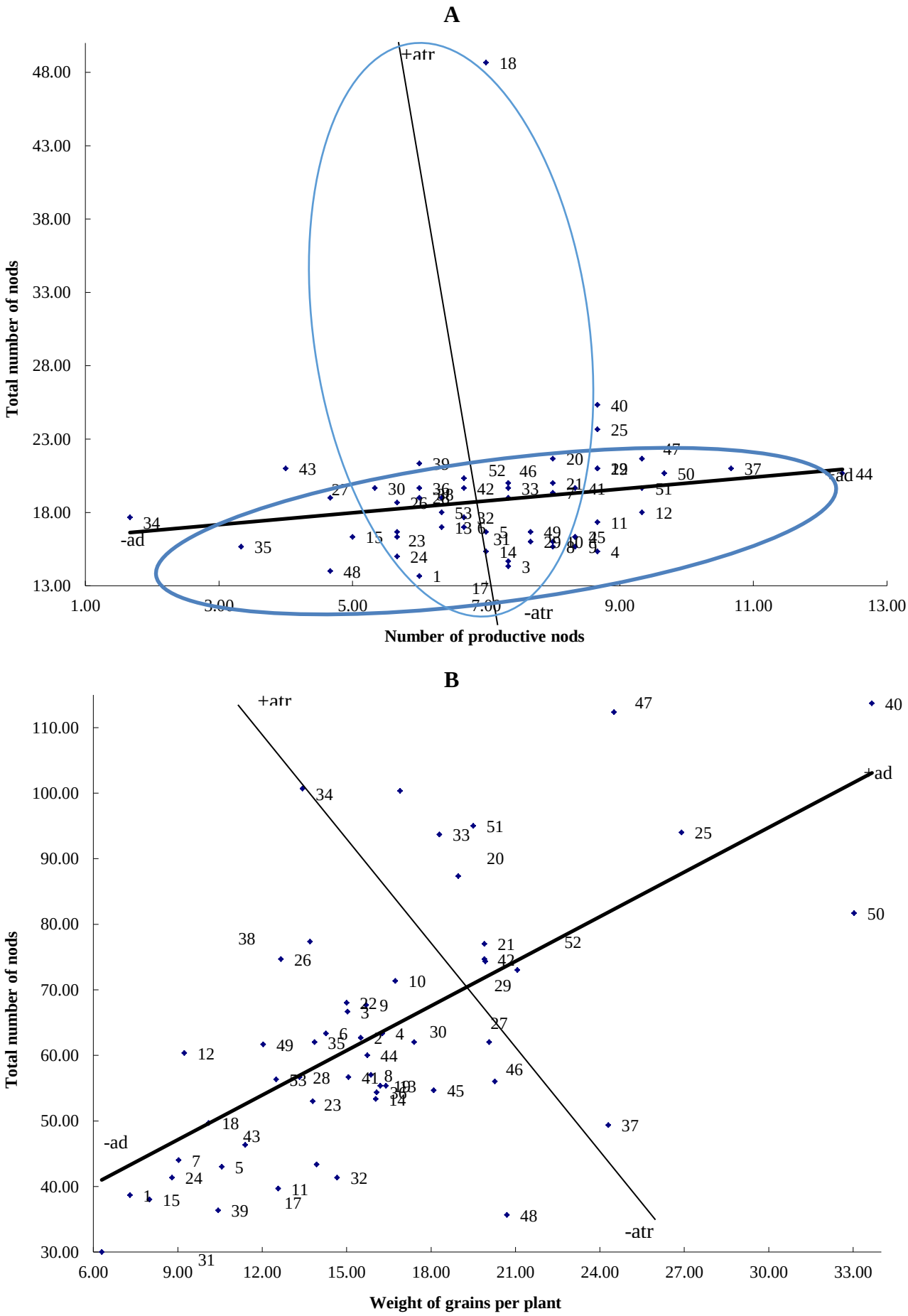

Fig. 3. Distribution of mean values of varieties from garden pea for 2020.

The genetic systems presented in the graphs show that the scattering of the points is mainly along the broad axis of the ellipse of the regression line. When comparing them, it turns out that in fact the situation has changed significantly compared to 2019. It can be noted for genotypes such as Luxor, Debreceni, Multistar, Denitsa and Mifelia, which do not change their location in the quadrant, limited by negative adaptation and attractiveness, the effects of gene action can be assessed unambiguously. Such samples are not suitable for carrying out the selection task aimed at creating genotypes with a larger number of productive nodes per plant and with a weakly sloping stem.

In this sense, Vyatovo and Mira are of interest, which in the total number of nodes per plant are characterized by a higher weight of grains per plant. Noteworthy is Marsi, which has the highest grain productivity at both limits.

By changing the location of the varieties and lines of peas on the quadrants of the coordinate system, varieties - donors of the respective traits can be offered. By including them in hybridization schemes with appropriate parental components in other physiological systems, it is possible to determine the optimal selection program for the specific purpose.

Using these algorithms, the breeders can determine the amplitude of the genetic variability of any genetic-physiological system for each set of varieties, and using other algorithms, determine the degree of additivity of one system to another.

Discussion

According to Ponomareva (2018) at present the opportunities for breeders to improve the agrocoenotic properties of varieties in terms of elements of productivity are far from exhausted. The authors confirm their thesis with the comparative fact that the primitive forms of peas, unlike modern varieties, have reduced productivity in the agrophytocenosis due to insufficient resistance to lodging and especially due to the limited nutrient area of plants.

Shamsutdinov (2007), applying similar to the schemes of purposeful selection process in peas made in the present study, found that the competition between plants for the main factors (such as light, mineral nutrients, water and oxygen) is significantly weakened due to improved habit and resistance to lodging of the assessed genotypes. The authors believe that the ecological-genetic model offers a unique opportunity to unambiguously determine one of the essential characteristics - adaptive properties of genotypes, limiting environmental limits or genetic parameters of the population, provided that the other two parameters are known.

The performed researches confirm the theory of Dragavtsev & Averyanova (1983), according to which when the strength of the given limiting factor changes, the activity and the spectrum of action of the respective gene change. In their large-scale studies, the authors report that when the environmental factors and the rank of the studied genotypes change, the spectrum of the genetic actions of the trait also changes, which leads to the effect of genotype-environment interaction. According to them, the biological mechanism that leads to the phenomenon of "genotype-environment interaction" is the redefinition of the genetic formulas of the quantitative trait, i.e. change of gene spectra by a given indicator.

Dragavtsev *et al.*, (1984) note that plant genetics cannot give the breeder a certain constant genetic "passport" of the population in terms of quantitative traits. All traditionally evaluated parameters, such as heredity coefficient, genotypic variance, genotypic coefficient of variation, genotypic correlations, retain their level only at a certain point in time, at specific environmental limits and at a given sowing density of plants. When the moment of time changes to another, when the plant population finds itself in a different environment and the density of plants per unit area changes, then all the estimated parameters will acquire new values.

According to the method of Dragavtsev *et al.*, (2012) it is very important for the breeder who starts the selection of the best genotypes in the early stages of the selection process, especially in decaying populations (in F2, M2 or wild populations), to know the magnitude of the genotypic variability of the quantitative trait in a given population. If the subject of genetic improvement by the breeder is a self-pollinating species propagated by seeds, such as peas, then it is necessary to know the value of the additive variability of the trait.

Dyakov & Gronin (2006) express an opinion similar to the results of the study, according to which, if in a team of grain productivity from the populations are selected mainly plants with higher grain weight, the reasons for this are not only the individual hereditary qualities of the plants themselves, and the beneficial effect of other factors. The authors report that such may be better soil fertility, development of individual seeds with increased nutrient area, non-hereditary competitive advantage when seeds fall into the soil during sowing and others. In order to eliminate such errors in the identification of the desired genotypes, it is recommended to use the developed principle based on the phenomenon of diversity of covariances of traits due to their selective - useful variability and the components of ecological and genotypic variance that are useless for the breeder.

According to Amelin & Chekalin (2019) in peas, which is a model crop in plant genetics, research related to increasing resistance to abiotic and biotic stressors of the environment, adaptability and stability of plant populations play a very important role in the modern selection process to achieve higher level of productivity.

The developed algorithm for calculation according to the ecological-physiological systems allows to determine the genotypes, combining in an appropriate way the studied traits. The search for individual genotypes of selection interest through the method proposed by Dragavtsev makes it possible to identify valuable forms, ensuring an increase in the productivity of the green grain through the optimal value of the features that make up this module. The method of orthogonal analysis is a reliable way to identify the best genotypes, which helps speed up the selection process.

Conclusions

Mira, Marsi and Lincoln were distinguished by a larger total number of nodes per plant and a larger number of productive nodes per plant. Marsi (69.18 g), Lincoln (54.63 g), Izomrud (53.52 g) and Paldin (52.93 g) formed a larger number of pods in good combination with the weight of one grain per plant. Mira (105.50), Marsi (101.83), Vyatovo (97) and line 1855/3 (78.50) were distinguished by a large number of grains per plant, and Marsi (38.80 g), Izomrud (25.88 g), Mira (24.92 g), Puldin (24.38 g) and line 101i (24.22 g) had the highest weight of grains per plant. Lincoln, Marsi, Vyatovo and Mira were of interest and can be included in future hybridization schemes to obtain forms combining in one genotype a larger number of fertile nodes and a high weight of grains.

Acknowledgement

The research leading to these results has received funding from the National Science Fund, Bulgaria [Grant КП-06-Н26/12].

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(Received for publication 18 November 2020)