CORRELATION DEPENDENCES OF QUANTITATIVE TRAITS IN GARDEN PEA (*Pisum sativum* L.)

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Abstract. Correlation dependences of quantitative traits are of importance for further breeding process in crops. Trial with 10 samples of garden pea was performed during three years period. Both phenotypic and genotypic relationships between major quantitative traits have been evaluated. For most of the quantitative indicators, the phenotypic relationships were found insignificantly lower than the values of their genetic correlation coefficients. The next correlation coefficients were found with significant genotype dependencies: between the plant height and internode length (r = 0.936); height to first fertile node and average number of grains per pod (r = 0.826); 2 pods per fruiting handle with pod weight per plant (r= 0.717); number of tillers with average number of grains per pod (r= 0.709); total number of pods per plant with 2 pods per fruiting handle (r= 0.981). Strong to average was found the dependence on the green grains weight with the pods weight (r = 0.942), % of unfilled grains (r = 0.813). The described correlations between the quantitative traits showed the prospects for their use in the breeding process, depending on the tasks given.

Key words: garden pea; correlation; trait; interrelations.

INTRODUCTION

Pea (*Pisum sativum* L.) is an important and wide spread legume crop [2, 15]. There is a great need to develop high yielding cultivars in order to achieve future crop improvement of both, quantitative and qualitative traits [21].

The knowledge of the interrelationships between quantitative traits in a certain ecological niche will allow to reveal the value of each feature for yield selection, the plasticity of varieties and to make changes in the practice of breeding process technology [10].

In the progress of selection, the study of the contiguity of breeding indicators, the identification of their contribution to the formation of productivity and yield are important stage in the development of varietal models and the improvement of the selection process technique. In pea breeding, these issues are given close attention in connection with the creation of new varieties with a new combination of morphological and quantitative traits [22].

In the creation of new pea varieties, the determination of the relationships of quantitative traits at the genotypic level is of great importance, in which particular importance is attached to the study of the relationships between groups of traits with a certain level of correlation coefficients, direct or indirect effect on productivity, and when these effects are multidirectional, their optimal combination, respectively [19].

To achieve further progress, it is of great importance to identify signs that have a direct or an indirect effect on yield, or their optimal combination if these influences are differently directed. To improve the model of a pea plant with a new feature, an in-depth study of crop dependence and its constituent elements of productivity is necessary.

The work aimed at to determine the correlation dependences of some quantitative traits in garden pea plants.

MATERIALS AND METHODS

The study was conducted in the experimental fields of the Institute of Vegetable Crops Research Institute, Plovdiv, Bulgaria during the period of 2017-2019. Ten genotypes of garden pea, i.e. GEN 1 (22/16-n.), GEN 2 (22/16-af.) , GEN 3 (Casino-af.), GEN 4 (Plovdiv-n.), GEN 5 (Echo-af.), GEN 6 (Marsy-n.), GEN 7 (Shugar duarf-n.), GEN 8 (B4-34- n.), GEN 9 (1/17-n.), GEN 10 (Vechernitza-n) were tested. Three of them (GEN 2, GEN 3, and GEN 5) had afila leaf type, while the other seven normal leaf type. The experiment was performed by randomized complete block design, four repetitions with a working plot area of 6.4 m^2. The sowing was done out at 16.03.2018, 05.03.2019 and 01.03.2020 on a high flat bed according to the scheme 80 + 20 + 40 + 20 / 4–5 cm. The pea was grown according to the technology adopted for the culture. The main morphological (biometric) characteristics of the aboveground biomass were measured at the technological maturity of plants. For this, 10 plants were used from the four replications of the trial. Plant height (cm), height to the first fertile node (cm), internode length (cm), tillers number, branches number, ineffective nodes number, the total number of nodes, the total number of pods per plant, 1 pod per fruiting handle, 2 pods per fruiting handle, pod length (cm), pod width (cm), pod weight per plant (g), the green grains weigh per plant (g), % filled grains, % unfilled grains, the average number of grains per pod were measured. Correlation analysis was used to process the data [7]. Coefficient of correlation was found following the technique of Dewey and Lu (1959) [5]. Additionally, GENES 2009.7.0 for Windows XP software was used also [4].

RESULTS

In a breeding aspect, the presence of correlations is of particular importance because of the possibility of using them as an important criterion for conducting a more efficient selection on two or more traits. The significance of the interrelated traits is often specifically manifested and depends on both the genotypic features of the selection materials examined and the differences in the conditions under which the studies are performed.

Correlation analysis

The analysis of the relationships between the traits studied showed the coefficients of phenotypic dependencies lower than their genetic coefficients of correlations.

The exceptions were the dependencies of nodes total number with the ineffective nodes number, the pods total number and 2 pods per fruiting handle with pods weight green grains weight, pods weight with grains weight (Table 1). The higher values of the phenotypic correlation coefficients for some traits can be considered as an indication that the environment has a significant influence on the manifestations of strict genetic inheritance.

Strong genotype correlation relationships were found between the plant height and first fertile node height (r = 0.690) and length of internode (r = 0.936); height to first fertile node with pod length (r = 0.691) and average number of pods per plant (r = 0.826); number of tillers with average number of grains (r = 0.709); number of ineffective nodes with total nodes number (r = 0.705); total pods number with the 2 pods per fruiting handle (r = 0.981), pods width (r = 0.701) and % unfilled grains (r = 0.756); 2 pods per fruiting handle with pods weight (r = 0.717), % filled grains and % of unfilled grains (r = 0.849), weight of pods per plant with green grains weight (r = 0.942) and % unfilled grains (r = 0.948) and green grains weight with % unfilled grains (r = 0.813).

The genotypic correlations of plant height with pods total number (r = 0.445), 2 pods per fruiting handle (r = 0.510) and pod length (r = 0.415) are relatively weaker but also significant; the height to first fertile node with number of ineffective nodes (r = 0.624) and with % unfilled grains (r = 0.348); number of ineffective nodes with pod length (r = 0.406); the pods total number with green grains weight (r = 0.552); 2 pods per fruiting handle with green grains weight (r = 0.530) and pod length with green grains weight (r = 0.498) and average number of grains per pod (r = 0.513). The % filled grains trait interacts negatively with almost all other indicators (except for the number of tillers), with a very strong dependence in many of them - with the pods weight (r = - 0.949), with pods length (r = - 0.904), with the 2 pods per fruiting handle (r = -0.849), the green grains weigh (r = -0.813) and the pods total number (r = -0.756). The relationships between % filled grains and % unfilled grains (r = - 0.990) and the number of ineffective nodes and 1 pod per fruiting handle (r = - 0.894) were found similar. The values of genetic correlation coefficients between the height to first fertile node with 1 pod per fruiting handle (r = - 0.569), % filled grains (r = - 0.348), and pod width (r = -0.151) and tillers number ineffective nodes number (r = -0.418) and total number of nodes (r = -0.482).

The presence of significant, strong and positive genetic dependencies between some of the traits studied indicates that there are good opportunities for successful selection to be carried out simultaneously on several interrelated traits. In this regard, some of the negative genetic correlations identified are also of interest, thus contributing to increasing the breeding value of the genotypes generated.

Very high phenotypic correlation coefficients distinguish between pods total number with the 2 pods per fruiting handle (r = 0.966); length of internode with plant height (r = 0.917) and green grains weight with pods weight (r = 0.949). Between the traits themselves, there is a weak to medium and statistically significant phenotypic relationship of 0.132 between the pod width and plant height to 0.656 between the pod heights to the first fertile node. A significant positive correlation with green grains weight the next signs showed: pods weight (r = 0.942); % unfilled grains (r = 0.813); 2 pods per fruiting handle (r = 0.530); pods total number (r = 0.552) and pods length (r = 0.498). The grains weight was significantly negatively correlated with % filled grains (r = -0.813) and with no significant correlation with the branches number (r = - 0.472) and the number of ineffective nodes (r = - 0.384). That showed that an increase in productivity could lead to a minimal decrease in % of filled grains, the branches number and the ineffective nodes number.

Path analysis

Using the path analysis, the direct and indirect effect of the structural elements of the yield on green grains weight was recorded (Table 2). The productivity of green grains is directly positively influenced by the total number of nodes (0.736), the pods weight (0.721), % of filled grains (0.479), the length of pods (0.395) and the % unfilled grains (0.337). Increasing the height to the first fertile node (0.196) and the average number of grains in pod (0.161), albeit to a lesser extent (with a less direct effect), lead to an increase in the productivity of green grains. The direct effect of the unfilled nodes number on the green grains weight was negative and with the lowest path coefficient value (-1.218), followed by plant height (-0.403).

The length of internode, tillers number, branches number, pods total number, 1 pod per fruiting handle, 2 pods per fruiting handle and pod width traits influence the weight of green grains per plant by a direct negative way, but not with very high impact. The indirect indicators that have a significant impact on the green grains productivity are the pods weight, expressed as % of unfilled grains (0.573), the 2 pods per fruiting handle (0.526) and the pods total number (0.513) and the nodes total number by the number of

Table 1. Correlations below the diagonal are genotype correlations; above the diagonal are phenotypic correlations

	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	x11	x12	x13	x14	x15	x16	x17
x1		0.667**	0.917**	-0.035	-0.034	0.031	0.280	0.428**	-0.091	0.481**	0.420*	0.132*	0.452	0.253	-0.342	0.342	0.330
x2	0.690**		0.389	0.099	-0.059	0.543*	0.403	-0.057	-0.451*	0.044	0.656**	-0.205*	0.229	0.121	-0.352*	0.352*	0.626**
x3	0.936**	0.439		-0.188	-0.140	-0.134	0.148	0.365	-0.041	0.392*	0.179	0.243	0.316	0.154	-0.097	0.097	0.093
x4	-0.018	0.151	-0.201		0.161	-0.430*	-0.427*	0.216	0.280	0.163	-0.096	-0.216	0.143	0.195	0.091	-0.091	0.659**
x5	-0.013	0.018	-0.225	0.171		0.165	0.096	-0.060	-0.267	0.037	0.066	-0.079	-0.118	-0.273	-0.123	0.123	-0.224
x6	0.007	0.624*	-0.139	-0.418*	0.258		0.727**	-0.591	-0.742**	-0.459	0.404**	-0.401	-0.229	-0.264	-0.234	0.234	-0.134
x7	0.285	0.538	0.186	-0.482*	0.142	0.705**		-0.094	-0.310	-0.046	0.279	-0.437	0.244	0.195	-0.545	0.545	-0.313
x8	0.445**	-0.079	0.382	0.321	-0.120	-0.731	-0.177		0.609	0.966**	0.166	0.269	0.712**	0.598**	-0.565*	0.564*	0.200
x9	-0.102	-0.569*	-0.030	0.344	-0.386	-0.894**	-0.384	0.668		0.391	-0.512	0.149	0.239	0.267	0.036	-0.036	-0.020
x10	0.510**	0.046	0.408*	0.280	-0.012	-0.613	-0.146	0.981**	0.515		0.357	0.295	0.730**	0.584**	-0.666**	0.666**	0.232
x11	0.415*	0.691**	0.191	-0.105	0.092	0.406*	0.253	0.155	-0.654	0.391		0.261	0.570**	0.447*	-0.726**	0.726**	0.495*
x12	0.152*	-0.151*	0.262	-0.193	-0.237	-0.593	-0.765	0.315	0.126	0.371	0.275		0.261	0.119	-0.077	0.077	0.069
x13	0.483	0.276	0.310	0.250	-0.280	-0.297	0.270	0.701**	0.260	0.717**	0.626**	0.238		0.946**	-0.795**	0.795**	0.349
x14	0.266	0.138	0.140	0.337	-0.472	-0.348	0.214	0.552**	0.279	0.530**	0.498*	0.077	0.942**		-0.672**	0.672**	0.343
x15	-0.417	-0.348*	-0.123	0.041	-0.190	-0.326	-0.858	-0.756*	-0.105	-0.849**	-0.904**	-0.196	-0.949**	-0.813**		-0.990**	-0.165
x16	0.417	0.348*	0.123	-0.041	0.190	0.326	0.858	0.756*	0.105	0.849**	0.904**	0.196	0.948**	0.813**	-0.990**		0.165
x17	0.337	0.682**	0.085	0.709**	-0.262	-0.129	-0.345	0.240	-0.020	0.289	0.513*	0.088	0.401	0.407	-0.223	0.223	

** / * significant correlations at the 0.01/0.05 level

x1 - plant height (cm), x2 - height to first fertile node (cm), x3 - length of internode (cm), x4 – tillers number, x5 – branches number, x6 - number of ineffective nodes, x7 - total number of nodes, x8 - total number of pods per plant, x9 - 1 pod per fruiting handle, x10 - 2 pods per fruiting handle (number), x11 - pod length (cm), x12 - pod width (cm), x13 - pod weight per plant (g); x14 - weight of green grains per plant (g), x15 - % filled grains, x16 - % unfilled grains, x17 - average number of grains per pod.

Table 2. Effects of traits studied on the green grains weight in garden pea varieties

	Indirect effect																Total effect
	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	x11	x12	x13	x15	x16	x17	
x1	**-0.403**	0.131	-0.056	0.007	0.003	-0.038	0.206	-0.037	0.016	-0.046	0.166	-0.026	0.326	-0.164	0.115	0.053	0.253
x2	-0.269	**0.196**	-0.024	-0.019	0.004	-0.662	0.297	0.005	0.080	-0.004	0.259	0.041	0.165	-0.169	0.118	0.101	0.121
x3	-0.370	0.076	**-0.061**	0.036	0.010	0.163	0.109	-0.031	0.007	-0.038	0.071	-0.049	0.228	-0.047	0.033	0.015	0.154
x4	0.014	0.019	0.011	**-0.191**	-0.012	0.524	-0.314	-0.019	-0.050	-0.016	-0.038	0.043	0.103	0.044	-0.031	0.106	0.195
x5	0.014	-0.012	0.008	-0.031	**-0.074**	-0.201	0.070	0.005	0.048	-0.004	0.026	0.016	-0.085	-0.059	0.041	-0.036	-0.273
x6	-0.012	0.107	0.008	0.082	-0.012	**-1.218**	0.535	0.051	0.132	0.044	0.159	0.080	-0.165	-0.112	0.079	-0.022	-0.264
x7	-0.113	0.079	-0.009	0.082	-0.007	-0.886	**0.736**	0.008	0.055	0.004	0.110	0.087	0.176	-0.261	0.183	-0.050	0.195
x8	-0.173	-0.011	-0.022	-0.041	0.004	0.720	-0.069	**-0.086**	-0.109	-0.093	0.065	-0.054	0.513	-0.270	0.190	0.032	0.598
x9	0.037	-0.089	0.002	-0.054	0.020	0.904	-0.228	-0.052	**-0.178**	-0.038	-0.202	-0.030	0.172	0.017	-0.012	-0.003	0.267
x10	-0.194	0.009	-0.024	-0.031	-0.003	0.559	-0.034	-0.083	-0.070	**-0.096**	0.141	-0.059	0.526	-0.319	0.224	0.037	0.584
x11	-0.170	0.129	-0.011	0.018	-0.005	-0.492	0.205	-0.014	0.091	-0.034	**0.395**	-0.052	0.411	-0.348	0.244	0.080	0.447
x12	-0.053	-0.040	-0.015	0.041	0.006	0.488	-0.322	-0.023	-0.027	-0.028	0.103	**-0.200**	0.188	-0.037	0.026	0.011	0.119
x13	-0.182	0.045	-0.019	-0.027	0.009	0.279	0.180	-0.061	-0.043	-0.070	0.225	-0.052	**0.721**	-0.381	0.268	0.056	0.946
x15	0.138	-0.069	0.006	-0.017	0.009	0.285	-0.401	0.049	-0.006	0.064	-0.287	0.015	-0.573	**0.479**	-0.337	-0.026	0.672
x16	-0.138	0.069	-0.006	0.017	-0.009	-0.285	0.401	-0.049	0.006	-0.064	0.287	-0.015	0.573	-0.479	**0.337**	0.026	-0.672
x17	-0.133	0.123	-0.006	-0.126	0.017	0.164	-0.231	-0.017	0.004	-0.022	0.196	-0.014	0.252	-0.079	0.055	**0.161**	0.343

x1 - plant height (cm), x2 - height to first fertile node (cm), x3 - length of internode (cm), x4 - number of tillers, x5 - number of branches, x6 - number of ineffective nodes, x7 - total number of nodes, x8 - total number of pods per plant, x9 - 1 pod per fruiting handle, x10 - 2 pods per fruiting handle (number), x11 - pod length (cm), x12 - pod width (cm), x13 - pod weight per plant (g); x14 - weight of green grains per plant (g), x15 - % filled grains, x16 - % unfilled grains, x17 - average number of grains per pod.

unfilled nodes (0.535). Other indirect indicators affecting the productivity of green grains are the length of pods by % unfilled grains (0.287) and the pods weight (0.225), as well as % unfilled grains mainly by the signs of the weight of pods per plant (0.268), the pods length (0.244) and 2 pods per fruiting handle (0.224).

Path analysis showed pods weight (0.946), % filled grains (0.672), the total number of pods per plant (0.598), 2 pods per fruiting handle (0.584), the number of pods per plant (p = 0.724) and the number of green grains per plant (p = 0.279) had the highest positive overall effect on the green grains weight. Positive, but with a lesser effect on the expression of productivity are the signs height to first fertile node, length of internode, number of tillers, total number of nodes and width of pods, while % unfilled grains (-0.672), number of branches (-0.273) and the number of unfilled nodes (-0.264) are characterized by a negative overall effect on the green grains weight.

DISCUSSION

The genotypic correlations were found higher than the phenotypic ones for all the traits studied. Our results confirmed the results obtained by other authors [6, 12, 14]. It shows that the strong association between these characters which indicates environment plays minor role in the modification of the expression of the genes.

Other authors [1, 8] reported the positive correlations between grain yield and pod number, plant height, grain numbers, days to flowering, 100 seed weight for field pea. Some researchers [24] found negative and significant correlations between grain yield and days to 50 % flowering. Positive and significant correlations between the seed yield and harvesting index in field pea were found also. Other authors [16] showed that seed yield negatively associated with days to 50 % flowering. The path coefficient analysis revealed yield per plant was directly affected by pods number, harvest index and seeds number. Some researchers [18] suggested pods, seeds per plant and harvesting index must be taken to account during the course of selection for high yielding varieties in pea.

Opposite to our findings, some researchers reported the positive correlations between grain yield and pods number, plant height, grain number and days to flowering [3, 9, 11]. There were observations [23] which showed the seeds weight positively correlated with pods number, pods weight, biological weight per plant and harvest index, respectively. Other researchers [20] performed an experiment in order to study the character association in 26 genotypes of garden pea. Path coefficient analysis revealed that days to 50% flowering, days to 50% harvest, branches number, pods number, seeds number and 100 seeds weight had positive direct effect on seed yield. Other workers [13] studied the association of yield attributes traits and their direct and indirect effect of the seed yield in pea. These analyses showed that pods number, seed weight, pod length, number of primary branches and seeds number have direct effect on yield. That's resulting in positive and strong correlation between these characters.

Using the Path analysis other authors [14] found that the pods number, the grains number, the 100 seeds weight and pod length have the greatest direct effect on grain yield. They consider that these traits can be used as major components of the yield with maximum direct effect. The other indicators - time to flowering and plant height, have an indirect effect on the yield and therefore their importance is defined as weak.

In other studies was found the major branches number and pods number showed the greatest positive effect and therefore, in the selection, particular attention should be paid to the number of generative organs [17]. This results show that the correlations among traits in garden pea can variable according to the initial material and ecological conditions.

The next correlation coefficients were found with significant genotype dependencies: between the plant height and internode length (r = 0.936); height to first fertile node and average number of grains per pod (r = 0.826); 2 pods per fruiting handle with pod weight per plant (r= 0.717); number of tillers with average number of grains per pod (r= 0.709); total number of pods per plant with 2 pods per fruiting handle (r= 0.981). Strong to average was found the dependence on the green grains weight with the pods weight (r = 0.942), % of unfilled grains (r = 0.813).

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