

Studies on the component characters of grain production in the pod to a collection of bean genotypes (*Phaseolus vulgaris* var. *vulgaris*)

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Abstract The study was aimed at evaluation of a collection of climbing bean genotypes with regard to the manifestation of some component characters of grain production: the number of grains in the pod and the weight of the grain berries. Experimentation was carried out in field conditions, for three years. The experimental parcels comprised a representative number of plants for each genotype. The biological material consisted of 57 climbing bean landraces. Their origin is in the west and southwest of Romania. Their comparison was made with the Romanian „Aurie de Bacau” variety. The experimental data was obtained by biometric measurements. The data processing aimed at determining the indices of intrapopulation variability and variance analysis by applying some tests for determine the differences between populations. Were also determined the correlation coefficients and „parth” coefficients, for the character links. In the collection, the weight of the grains in the pods has shown great variability, but the intrapopulation variability is lower. The collection shows variability also for the number of grains in the pod. High values, over 7 grains produced only 2 genotypes (Julita 3 and Olari 2 landraces). Between the studied characters there are very close correlations, with statistical insurance. Apply selection to increase the value of these characters has a direct effect on improving the weight of the grain in the pod. According to the values of the "path" coefficients, a direct contribution to the weight of grain in the pod, have: the pod diameter (P = 0.441) and the grain number of pod (P = 0.364). The pod length and the grain weight of the pods, are directly influenced by the pod diameter and the grain number in the pods.

Key words

bean, grain production/pod, variability, landraces

Common beans (*Phaseolus vulgaris* L.) is cultivated both in its own culture system, but it can be cultivated and intercalated with corn. In Romania, the intercalated system is still practiced on extremely low surfaces, but landraces for this system still exist. In other countries the interstitial system is still practiced. Depending on the system, must be chosen the varieties adapted to the crop-specific conditions. Studies in Ethiopia show that the genotype reactions to maize intercalated cultivation are very different in terms of plant productivity. In intercalating cultivation, plant production is lower than in the pure culture. Are affected the grains number in the pod and the grain size. The grain production is positively correlated with pod productivity. Productivity of pods, by the number and weight of the grain, may be selection criteria to create more productive forms, irrespective of the culture system[1].

Common beans can be grown under different ecological conditions. Very important is the study of

genotypes from high altitude areas which can be productive under stress conditions. The study of such populations in Nepal, highlights the fact that there are very large variations at the level of many morphological characters, including the number of grain in the pod (4-8 grains) and their weight per plant (18.3-54.7g). The study concludes that production at the surface unit is correlated with the grain number in the pod, this is the main character that is recommended in applying selection [4].

The analysis of germplasm variability from Poland shows that the most stable characters are the protein content in the grains and the duration of the vegetation period, and lower stability show the components of production: the number of grains and pods per plant and the weight of the grains on the plant. An important finding is that the manifestation of variability does not depend on the area of origin of landraces. This shows that the exploring local resources in different regions is very important for the

breeding process. Within them can be found useful genes to improve the productivity, quality and disease tolerance [3].

In studying of variability for the breeding process, it is necessary to observe a larger number of characters. To achieve the plant production contributes a large number of characters, both those related to plant growth as well as those related to fructification. Each of these characters has its own contribution to the production of the surface unit. The results revealed important differences between genotypes for most characters, regardless of the location of the experiment. Coefficients of phenotypic and genotypic variation vary from one character to another. Characters with large variations are the number of pods per plant, the grain number in the pod and the grain size. Therefore, the improve these characters can lead to an increase of grain production. For a more in-depth study of these characters, is required the molecular analysis of germplasm [2].

The manifestation of pod productivity elements depends also on applied technology, in particular the density of culture. The plant production depends on the density in the crop by the number of pods per plant, being less affected the number of grains in the pod and their weight [6].

The number of grains in the pod is also dependent on the cultivar type. In the case of hybrids, the greatest contribution over genetic variation it has the number of berries in the pod and their size. In hybrids, these characters may have higher values due to the genetic progression resulting from hybridization. It supports the replacement of varieties with hybrids to beans, but should be considered the difficulty of hybrids multiplying [10].

The studies on bean germplasm are very mach. The studied biological materials are very diverse. This is due to the extremely pronounced variability of this species. The evaluation of a collection of 300 genotypes, show that from the total variance, the size of the grain and the grain number in the pod, are basic characters that can be considered when applying selection [11].

The character variability in beans is very high, especially in the case of the plant productivity component. The number of pods per plant is an important character which along with the number of grains in the pods and their weight, contributes decisively to the production of the plant. Between the plant production and these characters is a linear relationship [7].

The climbing bean is less studied as a crop for grain. However, the grain yields of this variety may be very high. The evaluation of some landraces shows that the improving of grain weight in the pod can also lead to a simultaneous improvement of grain quality, as protein content or culinary qualities (boiling capacity and percentage of shells). Knowing these links between

characters will increase the amount of genetic progress achieved by simultaneous selection for multiple characters [8].

Studies on the manifestation of plant productivity elements were also made on dwarf beans. From the study of some landraces collections it has been found that plant productivity depends on the number of pods per plant and the weight of grain in the pod. The correlations between characters and the extent to which they influence one another serve to establish the selection strategy for the creation of varieties of beans [9].

Material and Method

The study aimed to evaluate a collection of climbing bean genotypes with regard to the manifestation of some component characters of the grain production: the grain number in the pod and the grain weight in the pod.

The experimentation was carried out in field conditions, on plots that included a plant number necessary for the collection of experimental data through biometric measurements. The experimental duration was three years. Climate conditions were normal, with short periods with insufficient rainfall.

The biological material consisted of 57 climbing beans landraces collected from the west and southwest of Romania. Their comparison was done with Aurie de Bacau variety, used as a control. The experimental data was collected by biometric measurements on two morphological characters: the grain number in the pod and their weight. The analyzed samples were representative, being analyzed 25 plants, in three repetitions.

The processing of the experimental data was done by determining the indices of intrapopulation variability, variance analysis, test F and test t to establish the differences between populations. We have also determined the correlations between the studied characters and other components of plant productivity, using correlation coefficients and "path" coefficients, which provides information on dependency between characters and the proportion in which a character is influenced directly or indirectly by other characters [5].

Results and Discussions

The two characters studied, the grain number in the pod and their weight, presented very varied values in the collection. The averages of grains number in the pod for the experimental period were influenced both by the genotype value, but also by the specific conditions of the experimental year. Applying the F test points out that variation is due to both factors, highlights that the variation is due to both factors, for both, the F values being distinctly significant (table 1)

Table 1

Variance analysis for grain number/pod in common bean landraces studied

Source of variation	SS	DF	MS	F test
The total	3035.67	173		
Years	12.82	2	6.41	F = 12.90**
Populations	2966.17	57	52.04	F = 104.67**
Error	56.68	114	0.50	

The averages of experimental cycles of three years, highlight the variants with stability for the grain number in the pod. The extreme variants, highlighted in each of the three experimental years, are not those that are present at extreme extremes according to the average of the experimental cycle. This is due to the instability of this character. Taking into account the three-year averages, the minimum value for the grain number in the pod was 2.85 grains / pod to the Târcaia 1 landrace, and the maximum value was 7.20 grains / pod to the Julița 3 landrace. An average of over 7 grains / pods has also presented and Olari landrace, but most average values are between 5 and 6 grains / pods (Table 2)

Variability from year to year has been moderated for most variants. But there are some

situations where the variability is very high, the variability coefficients presenting values up to 52.47. Large variations from one year to the next occurred in the Vinga 1, Pietrani, Buteni 2 landraces.

Compared to the Aurie de Bacau variety, only the Julita 3 landrace, with an average of 7.20 grains in the pod, has a positive difference. Landraces inferior to the control, they are few, negative differences are statistically assured for 12 variants. From these data it can be concluded that the populations collected are at the level of the control variety in terms of the grain number in the pods. Their use in the breeding process is possible by applying the selection, choosing and pursuing the very valuable forms, and as genitors, only after a prior uniformization, because the intrapopulation variability is high.

Table 2

The significance of differences between studied common bean landraces concerning grain number/pod

No	Genotype	Grain number/pod		Relative value (%)	Difference significance	No	Genotype	Grain number/pod		Relative value (%)	Difference significance
		$\bar{x} \pm s_x$	$s_{\%}$					$\bar{x} \pm s_x$	$s_{\%}$		
1	Aurie de Bacău (Ct)	5.63±0.09	2.71	100.00	Martor	31	Ioniș 2	5.90±0.21	6.11	104.73	0.27
2	Târcaia 1	2.85±0.18	10.75	50.53	-2.79 ⁰⁰⁰	32	Beiuș	5.80±0.50	15.03	102.96	0.17
3	Târcaia 2	6.07±0.27	7.61	107.69	0.43	33	Fiziș 1	6.15±0.39	11.00	109.17	0.52
4	Julița 1	6.18±0.12	3.30	109.64	0.54	34	Fiziș 2	6.05±0.20	7.35	107.40	0.42
5	Julița 2	6.70±0.70	18.10	118.93	1.07	35	Pocola 1	5.65±0.14	5.80	100.30	0.02
6	Julița 3	7.20±0.53	12.73	127.81	1.57**	36	Pocola 2	6.28±0.12	4.52	111.54	0.65
7	Vinga 1	4.47±1.35	52.47	79.29	-1.17 ⁰	37	Pietrani	3.50±0.55	36.48	62.13	-2.13 ⁰⁰⁰
8	Vinga 2	5.75±0.58	17.37	102.07	0.12	38	Vânători	3.13±0.17	13.29	55.62	-2.50 ⁰⁰⁰
9	Secusigiu	6.17±0.74	20.91	109.47	0.53	39	Buteni 2	4.22±0.85	44.56	74.85	-1.42 ⁰
10	Buteni 1	5.92±0.28	8.12	105.03	0.28	40	Buteni 3	4.34±0.51	22.32	77.10	-1.29 ⁰
11	Păulean 1	5.75±0.62	18.71	102.07	0.12	41	Bârsa	5.02±0.38	10.75	89.05	-0.62
12	Păulean 2	5.30±0.38	12.37	94.08	-0.33	42	Cornereva	3.27±0.23	12.74	57.99	-2.37 ⁰⁰⁰
13	Sebiș 1	6.72±0.25	6.33	119.23	1.08	43	Bolvașnița	4.30±0.33	17.56	76.33	-1.33 ⁰
14	Olari 1	6.17±0.32	8.93	109.47	0.53	44	Svinița	5.87±0.56	16.11	104.14	0.23
15	Olari 2	7.05±0.87	21.31	125.15	1.42	45	Begheiu Mic	4.67±0.73	29.17	82.84	-0.97
16	Bata	5.95±0.45	13.21	105.62	0.32	46	Carășova	4.13±0.11	5.59	73.37	-1.50
17	Birchiș 1	5.62±0.40	12.47	99.70	-0.02	47	Joia Mare 1	6.42±0.07	2.74	113.91	0.78
18	Birchiș 2	5.58±0.63	19.46	99.11	-0.05	48	Joia Mare 2	3.95±0.22	11.12	70.06	-1.69 ⁰⁰
19	Oțelu Roșu 1	5.63±0.39	12.08	100.00	0.00	49	Vinga 3	4.55±0.09	4.85	80.71	-1.09
20	Oțelu Roșu 2	5.40±0.23	7.41	95.86	-0.23	50	Nădab	5.24±0.04	1.43	93.08	-0.39
21	Oțelu Roșu 3	5.12±0.16	5.56	90.83	-0.52	51	Sebiș 2	6.70±0.13	3.95	118.93	1.07
22	Caransebeș 3	4.92±0.19	8.88	87.28	-0.72	52	Vălișoara 1	4.22±0.09	4.79	74.85	-1.42 ⁰
23	Orțișoara	5.03±0.32	10.94	89.35	-0.60	53	Vălișoara 2	4.89±0.04	2.06	86.86	-0.74
24	Semlac	5.08±0.52	21.82	90.24	-0.55	54	Caransebeș 1	5.35±0.11	4.07	94.97	-0.28
25	Târcaia 3	5.95±0.29	11.37	105.62	0.32	55	Caransebeș 2	6.05±0.15	5.42	107.40	0.42

26	Voiteg 1	5.97±0.38	12.35	105.92	0.33	56	Sacu	5.85±0.14	5.34	103.85	0.22
27	Voiteg 2	4.82±0.16	7.51	85.50	-0.82	57	Juliska	3.96±0.09	5.34	70.30	-1.67 ⁰⁰
28	Ioniș 1	6.32±0.13	4.77	112.13	0.68	58	Făget	5.51±0.14	6.24	97.81	-0.12
29	Becicherecu Mic	4.28±0.42	17.01	76.04	-1.35 ⁰	Media experientei		5.35±0.98	18.41		
30	Bobda	5.55±0.28	8.59	98.52	-0.08						
		DL _{5%} = 1.14 grains/pod			DL _{1%} = 1.51 grains/pod			DL _{0,1%} = 1.95 grains/pod			

The variants grouping according to the average values of the pods from the experimental period, highlights that there is variability in the collection for this character. Almost half of the variants of the experience shows averages of 5 to 6 grains per pod. Big values, over 7 grains occur only in 2 variants Julieta 3 and Olari 2 (3.44%). Can be considered valuable also the

12 landraces (20.68%) at which the averages are between 6 and 7 grains / pods. For the breeding process, the collection is useful, the landraces can be processed directly through selection, because variability within the populations is very high. Some of the landraces can also be used as genitors (figure 1).

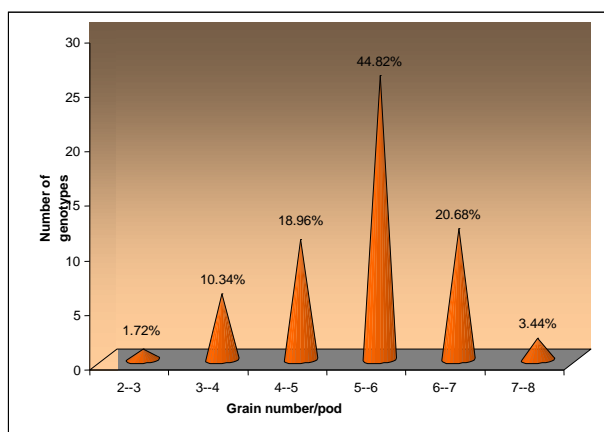


Fig. 1. Results regarding number of grains/pod for climbing bean landrace collection

The weight of the berry pods varied under the influence of the genetic dowry of the populations, but also due to the experimental years. Applying the F test shows the

existence of meanings both for character interaction with experimental years, and because of the value of populations. (table 3).

Table 3

Variance analysis for grain weight/pod in common bean landraces

Source of variation	SS	DF	MS	F test
The total	770.57	173		
Years	2.34	2	1.17	F = 4.37*
Populations	737.61	57	12.94	F = 48.27**
Error	30.56	114	0.27	

The average for grain weights for the experimentation period show that the most variants have values above 2 g. The average of experience for the experimental cycle was 2.47 g. The highest weight of pod grains was presented by the Juliska variety (5.79 g), variety that every year was first. This is the only character for which the Juliska variety is remarkable being valuable (table 4).

The variability of grain weights from one year to another is rather low. There are only a few variants

where the variability coefficients are high. The maximum value was shown by the Vinga 1 landrace (58.35 g), but a large variations from year to year have also been presented by Otelul Roșu 2, Oțelu Roșu 3 and Vânători landraces.

The Aurie de Bacau variety has an average of 2.75 g. This value was exceeded by three other genotypes. The value of the Julita 3 landrace is significantly higher, and of the Sebiș 2 landrace and Juliska variety, are significantly superior. The lower

variants are ranked as follows: 5 are significantly inferior, 3 are distinctly significant and 3 others are very significantly inferior. From this situation it can be concluded that many of the surveyed landraces are at

the control level with regard to the weight of grain in the pod. Also, the two genotypes that are superior, can help the increase values for this character if used in breeding programs.

Table 4

The significance of differences between studied common bean landraces concerning grain weight/pod

No	Genotype	Grain weight/pod (g)		Relative value (%)	Difference significance	No	Genotipul	Grain weight/pod (g)		Relative value (%)	Difference significance
		$\bar{x} \pm s_x$	$s_{\%}$					$\bar{x} \pm s_x$	$s_{\%}$		
1	Aurie de Bacău (Ct)	2.75±0.04	3.71	100.00	Martor	31	Ioniș 2	2.55±0.32	21.69	92.73	-0.20
2	Târcaia 1	1.36±0.04	5.09	49.45	-1.39 ⁰⁰	32	Beiuș	2.33±0.12	9.12	84.73	-0.42
3	Târcaia 2	2.26±0.56	43.09	82.18	-0.49	33	Fiziș 1	2.97±0.21	12.32	108.00	0.22
4	Julița 1	3.33±0.08	4.34	121.09	0.58	34	Fiziș 2	3.06±0.15	8.39	111.27	0.31
5	Julița 2	3.35±0.33	17.31	121.82	0.60	35	Pocola 1	3.04±0.09	5.44	110.54	0.29
6	Julița 3	3.64±0.37	17.74	132.36	0.89*	36	Pocola 2	2.72±0.37	24.79	98.91	-0.03
7	Vinga 1	2.57±0.87	58.35	93.45	-0.18	37	Pietrani	2.48±0.16	11.16	90.18	-0.27
8	Vinga 2	2.55±0.14	9.39	92.73	-0.20	38	Vânători	3.25±0.97	55.78	118.18	0.50
9	Secusigiu	3.38±0.38	19.39	122.91	0.63	39	Buteni 2	2.41±0.32	21.88	87.63	-0.34
10	Buteni 1	2.25±0.40	30.57	81.82	-0.50	40	Buteni 3	1.54±0.12	17.87	56.00	-1.21
11	Păulean 1	2.21±0.11	8.68	80.36	-0.54	41	Bârșa	2.93±0.18	8.40	106.54	0.18
12	Păulean 2	2.80±0.40	24.47	101.82	0.05	42	Cornereva	2.11±0.53	28.42	76.72	-0.64
13	Sebiș 2	3.09±0.16	9.22	112.36	0.34	43	Bolvașnița	2.32±0.17	12.76	84.36	-0.43
14	Olari 1	2.62±0.32	21.38	95.27	-0.13	44	Svinița	3.47±0.36	12.55	126.18	0.72
15	Olari 2	2.76±0.18	11.40	100.36	0.01	45	Begheiu Mic	1.99±0.58	47.01	72.36	-0.76
16	Bata	2.78±0.16	9.94	101.09	0.03	46	Carașova	0.86±0.18	36.80	31.27	-1.89 ⁰⁰⁰
17	Birchiș 1	2.49±0.10	7.11	90.54	-0.26	47	Joia Mare 1	1.76±0.03	2.87	64.00	-0.99 ⁰
18	Birchiș 2	2.93±0.12	7.25	106.54	0.18	48	Joia Mare 2	0.90±0.13	12.28	32.72	-1.85 ⁰⁰⁰
19	Oțelu Roșu 1	1.89±0.30	27.32	68.72	-0.86 ⁰	49	Vinga 3	1.48±0.10	8.78	53.82	-1.27 ⁰⁰
20	Oțelu Roșu 2	1.44±0.46	56.05	52.36	-1.31 ⁰⁰	50	Nădab	2.00±0.07	3.28	72.73	-0.75
21	Oțelu Roșu 3	1.73±0.56	55.99	62.91	-1.02	51	Sebiș 2	4.35±0.10	2.74	158.18	1.60 ^{***}
22	Caransebeș 3	2.57±0.07	4.94	93.45	-0.18	52	Vălișoara 1	1.26±0.07	8.46	45.82	-1.49 ⁰⁰⁰
23	Orțișoara	3.03±0.26	14.20	110.18	0.28	53	Vălișoara 2	1.80±0.04	4.84	65.45	-0.95 ⁰
24	Semlac	2.15±0.16	13.25	78.18	-0.60	54	Caransebeș 1	1.93±0.11	6.49	70.18	-0.82
25	Târcaia 3	2.64±0.23	16.27	96.00	-0.11	55	Caransebeș 2	1.91±0.08	5.49	69.45	-0.84 ⁰
26	Voiteg 1	3.08±0.22	10.14	112.00	0.33	56	Sacu	1.29±0.12	12.81	46.91	-1.46
27	Voiteg 2	2.01±0.45	33.33	73.09	-0.74	57	Juliska	5.79±0.20	4.84	210.54	3.04 ^{***}
28	Ioniș 1	1.99±0.48	43.81	72.36	-0.76	58	Făget	2.76±0.13	5.44	100.36	0.01
29	Becicherecu Mic	1.76±0.18	16.68	64.00	-0.99 ⁰	Media experientei		2.47±0.83	33.59		
30	Bobda	2.55±0.03	1.94	92.73	-0.20						
		DL _{5%} = 0.84 g		DL _{1%} = 1.11 g		DL _{0.1%} = 1.43 g					

In the collection, the grain weight in the pod showed high variability, but the very valuable forms are few. Most of the variants of the collection (48.27%) have had the grains of medium weight between 2 and 3 g, and only two showed weights of over 4 g (Sebiș 2 landrace and Juliska variety). Most of the collected populations are at the level of the Aurie de Bacău variety. For the grain weight of the pod is

recommended a very careful pursuit of plants in populations with higher average values, among them can be found very valuable plants. In the favorable years, the averages do not grow much, but the intrapopulation variability is lower. This means that some individuals, who under stressed conditions showed high values, remain constant, and those with low levels achieved something more (figure 2).

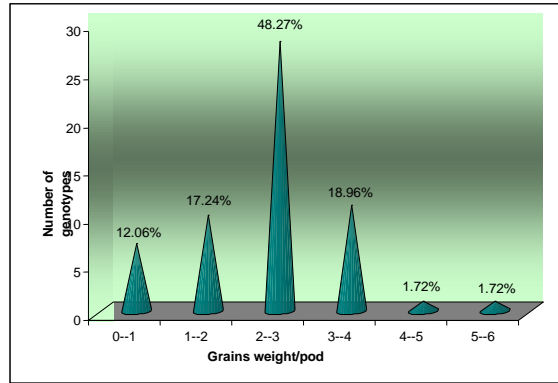


Fig. 2. Results regarding grain weight/pod for climbing bean landrace collection

According to the data presented in Table 5 we can observe the existence of very close and statistically assured correlations between the majority of the studied quantitative characters, with the exception of

the link between the diameter and the number of grains in the pod. As such, apply of selection to increase the value of these characters has a direct and significant impact on the increase of grain weight of the pods.

Table 5

Covariance values and correlation coefficients between quantitative traits analyzed in the common bean landraces

Character	Pod lenght ($s^2=5,63$)	Pod diameter ($s^2=0,06$)	Grains number/pod ($s^2=0,89$)	Grains weight/pod ($s^2=0,66$)
Pod lenght		$r = 0,421^{**}$ $S^2_{XY} = 0,23$	$r = 0,715^{***}$ $S^2_{XY} = 1,58$	$r = 0,354^{**}$ $S^2_{XY} = 0,67$
Pod diameter			$r = -0,084$ $S^2_{XY} = -0,02$	$r = 0,372^{**}$ $S^2_{XY} = 0,07$
Grains number/pod				$r = 0,261^*$ $S^2_{XY} = 0,20$

Given the results of the analysis of the "path" coefficients, from table 6 it is noted that the highest direct contribution on the grain weight of pods they had the pods diameter ($P=0.441$) and the grains number from pods ($P=0.364$). In the case of the

correlation between the pods length and the grains weight of the pods, a major influence on these characters has the indirect effect of the pods diameter and the grains number in the pod (table 6).

Table 6

"Path" coefficients analysis for grain weight / pod in the common bean landraces

Correlative links	Path coefficients
Grains weight/pod – Pod lenght	
The direct effect of pods length	0,092
The indirect effect, through the pod diameter through grains number/pod	0,186 0,260
Total correlation	0,354
Grains weight/pod – Pods diameter	
The direct effect of pods diameter	0,441
The indirect effect, through pods lenght through grains number/pod	-0,039 -0,031
Total correlation	0,372
Grains weight/pod – Grains number/pod	
The direct effect of grains number/pod	0,364
The indirect effect, through pods lenght through pods diameter	-0,066 -0,037
Total correlation	0,261

Conclusions

In the collection, the grains weight of the pod showed high variability, but the landraces with high average values are few. In most genotypes (48.27%) the grains of pod had an average weight of 2-3 g, only two of them exceeded 4 g (Sebiş 2 landrace and Juliska variety). In the favorable years, the averages do not grow much, but the intrapopulation variability is lower.

The collection contains variability also for the number of beans in the pod. Almost half of the genotypes have the average 5-6 grains in the pod. High values, over 7 grains occur only in 2 genotypes (Julita 3 and Olari 2 populations). For the breeding process, the collection is valuable. Because within populations the variability is very high, they can be processed directly by selection

Among the studied characters there are very close correlations and statistically ensured. The exception is the connection between the pods diameter and the grains number in the pod. Applying the selection to increase the value of these characters has a direct impact and significant to increase of the grains weight in the pod.

The analysis of the "path" coefficients shows that the highest direct contribution to the grain weight of the pod has the pods diameter ($P=0.441$) and the grains number from pod ($P=0.364$). For the link between the pods length and the grains weight in the pod, a major influence is due to the indirect effect of the pods diameter and of the grains number in the pod.

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