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Breeding Model of White Lupine Cultivar

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Abstract

In order to increase the productive potential of plant species, it is necessary to develop models for selection of genetically significant traits. In the present research 23 white lupine cultivars were studied with a purpose to determine the influence of basic traits on their productivity by a regression model and select suitable parental components for the needs of combinative breeding. The results showed that the linear component in the regression of seed productivity in white lupine regarding the studied quantitative traits was statistically significant and considerable. The highest relative share on seed productivity had the growth rate (+ 43.367), the number of seeds per plant (+0.321) and plant weight (+ 0.266). The breeding model of plant in white lupine has the following characteristics: vegetative period ≤ 98 days, growth rate ≥ 0.71, plant height 36-71 cm, aboveground mass ≥ 44 g, number of pods 13-16, number of seeds ≥ 69, number of seeds in a pod 3-4, mass of 1000 seeds ≥ 298 g. From the white lupine cultivars studied in our collection, promising to realize this model are Astra, Tel Keram, Termis Mestnii and Solnechnii that can be included in hybridization schemes in the breeding-improvement work of this crop. Choosing suitable parents in the combined breeding by using the simplex method will allow targeted planning of the breeding process to development of high-productive cultivars in shorter terms.
Keywords: white lupine; Breeding model; Regression; Parental components.

1. Introduction

Scientific researches in the field of breeding of annual leguminous crops, including white lupine, have made significant progress in recent years in the creation of new varieties with high nutritional value, improved environmental plasticity and resistance to unfavorable conditions [1, 2]. Despite the huge success in this direction, the need and possibilities for further improvement and development of new varieties in these crops continue to be a major task due to the constantly changing conditions of cultivation and the lack of suitable varieties for them [1, 2].

To date, the most promising direction in the breeding work in lupine was the application of the complex method based on knowledge of the quantitative genetics of culture in developing models of a modern variety [3].

Plant breeding is a lengthy process dependent on a number of biotic, abiotic and economic factors. The development of the basic principles of selection and a program for the implementation of these principles will allow a purposeful planning and realization of the selection process for the creation of varieties with certain qualities in short deadlines [4].

The ideotypic breeding differed from the traditional one in that the breeders aim to change precisely certain qualities in order to increase the productivity or adaptation of the plant to specific cultivation technologies. This approach has been successfully used in many cultures [5].

Appropriate choice of parents in the selection process is crucial for the successful breeding. When the collection is numerous and the accessions in it are evaluated in terms of many breeding characteristics, the choice becomes very difficult. For this reason, a method is needed to make the right choice for parents in order to achieve the intended objective [6]. In order to increase the productive potential of plant species, it is necessary to develop models for selection of genetically significant traits. Combining them in the breeding process will lead to the development of the desired genotype. Information on the variability and interrelationships of the quantitative traits in the plant population is of particular importance for enhancing the efficiency of selection work [7, 8].

The aim of the study was to determine the influence of basic traits on white lupine productivity by a regression model with a view to select suitable parental components for the needs of combinative breeding.

2. Material and Methods

The study was conducted during the period 2014-2016 at the Institute of Forage Crops, Pleven. The collection included 23 cultivars of white lupine (*Lupine albus* L.): Bezimenii 1, Bezimenii 2, Tel Keram, Horizont, Pflugs Ultra, Solnechnii, Termis Mestnii, Pink Mutant, Barde, Manovitskii, Dega, Desnyanskii (with origin from Russia), Garant (with origin from Ukraine), Amiga, Nahrquell, Astra, Ascar, BGR 6305, WAT, Shienfield Gard, Kijewskij Mutant, Hetman, Start (with origin from Poland). The cultivars were cultivated in a field for organic production after a two-year conversion period. The seeds were sown by hand, in the third decade of March, at a sowing rate of 50

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seeds per m2. A randomized block method was used. Each unit plot (5.50 m width × 2 m length) included 12 rows at a distance of 50 cm apart.

Determination of appropriate parental components was performed by the simplex method using data from the characteristic of the cultivars involved in the study with respect to 9 traits: plant height (cm), pods per plant, seeds per plant, seeds in a pod, 1000 seeds mass (g), seed weight per plant (g), plant weight (g/plant), growth rate (cm day^{-1}), vegetation period (days). Correlation coefficients were calculated with the program product SPSS 13, and Path coefficients – by using GENES 2009.7.0 for Windows XP [9]. The solving of the Simplex task was accomplished with Lp_solve Version 5.6.13 of Michel Berkelaar LpSolve [10].

3. Results

According to Genchev [6] at the initial stage of breeding for achieving a particular target, parents from geographically distant areas are chosen. Ordinarily, between geographic diversity and genetic diversity is placed equality that is not always correct, although accessions with different geographic origin have different genetic components for the same level of a given trait.

In the conditions of the present study, statistically significant positive relationships were found between seed productivity and studied traits (Figure 1). Correlation analysis showed that the individual plant productivity interacted strongly with plant weight (r = 0.955), number of seeds per plant (r = 0.881), number of pods (r = 0.733), 1000 seeds mass= 0.700) and growth rate (r = 0.678). Medium dependencies were established of the productivity with the plant height (r = 0.634), vegetation period (r = 0.547) and number of seeds in a pod (r = 0.517). The obtained values of correlation coefficients gave a basis for estimation, with how many units on average the dependent variable (seed productivity) would change under a unit of alteration of the independent variables (the other quantitative traits), in front of which it (dependent variable) was located in the regression model.

According to the regression analysis, the linear component in the multiple regression of the trait seed weight per plant to the other quantitative traits was considerable and statistically significant (Table 1). As a result of the complex study of the traits, a model (1) was obtained that showed the change in productivity depending on the change of other quantitative traits. The type of the obtained regression equation was the following:

(1) $Y = 3.5786 + 0.0063*X1 + 43.367*X2 + 0.266*X3 -0.446*X4 - 1.033*X5 +0.321*X6 - 2.773*X7 +0.038*X8$

Where:

Y - seed weight per plant (productivity); X1 - vegetation period; X2 - growth rate; X3 - aboveground mass per plant; X4 - plant height; X5 - number of pods per plant; X6 - number of seeds per plant; X7 - number of seeds per pod; X8 - 1000 seeds mass.

According to the applied analysis, the greatest impact on seed productivity formation had the growth rate, followed by number of seeds per plant, plant weight and 1000 seeds mass (Table 2). The influence of vegetation period length and number of seeds per pod/plant was statistically insignificant on the trait seed weight per plant.

Plant height in white lupine had a slightly negative impact on the productivity. The value of the regression coefficient indicated that preferably are cultivars with a middle-high stem. In the obtained regression equation (1), the dependence between seed productivity and plant height was negative, i.e. any increase in plant height reduced seed productivity by 0.446 g. Above certain values, the great height could have a negative impact on the productivity as the maturing period was prolonged.

The rate of growth had the highest relative share on seed yields (R = 43.367) **(1).** Individual productivity is raised by about 43 g if the growth rate increases with a unit. The influence of aboveground mass (R = 0.266) and 1000 seeds mass (R = 0.038) was less pronounced. Positive, but nonsignificant was the impact of the number of seeds (R = 0.321) and vegetation period (R = 0.0063).

The graphical representation of the dependence between grain productivity and the other traits included in the study gave reason with some approximation to obtain theoretical results and to establish the basic regularity between the quantitative traits (Figure 2). The second most significant trait determined in the obtained regression equation was the plant weight. In the figure presented, its parameters ranged from 12.77 g (Hetman) to 46.50 g (Solnechnii), and in this diapason, each raising increased the productivity.

The highest direct effect on plant productivity had the growth rate (18725.60), number of seeds in pod (948.26), number of pods (227.14) and plant weight (220.80) (Table 3). Negative direct effects were reported concerning the plant height (-226.17), number of seeds (-154.12), vegetation period (-1.11) and 1000 seeds mass (-10.19). This negative effect showed that some difficulties would be possible at recombining them with higher yield. The model for development of a high-yielding white lupine cultivar with regard to the vegetation period length and plant height required in the selection process to be involved plants that were medium-high (70-72 cm) and with a medium longevity of the vegetation period (about 98 days). The limitations were imposed because of negative direct effects of these parameters on the seed weight and their low regression coefficients.

According to the results obtained from the solution of the Simplex task (Table 3), the optimum number of seeds in one pod should not be more than four and, unlike the previous trait which acted in the opposite direction, possibly at the expense of the size of seeds. The 1000 seeds mass ranged from 173 to 322 g. The relatively low regression coefficient (R) of this trait and its negative direct effect on seed productivity determined in the model of white lupine a value that was more than 267 g but not greater than 300 g.

In the present study, the average value of aboveground mass per plant was about 31 g. Only two accessions (Termis Mestnii and Solnechnii) corresponded to the cultivar model according to which the plant weight should be over 44 g.

The pod numbers in the studied cultivars varied in a relatively wide range (from 8 to 18). Despite the high positive correlation and considerable direct effect on productivity, the obtained negative regression coefficient gave reason to believe that the increased number of pods per plant over a certain optimum would result in a reverse effect i.e. to a decrease of the plant productivity. Therefore, the breeding model limited the number of pods between 13 and 16.

4. Discussion

In genetic-selection investigations for analyzing causation in systems with correlating values are used various criteria and analyses: correlation coefficients, multiple regression, Path-analysis, etc. Togay, *et al.* [11] recommended using such criteria in choosing genotypes at a breeding process of the relevant culture in order to increase efficiency. According to these authors, correlation coefficients can be used to evaluate the relationship between yield and yield components and are more effective than other methods.

Zakharova, *et al.* [12] when analyzing basic quantitative parameters in white lupine by correlation analysis concluded that the most stable elements of productivity were pod weight, total plant biomass, seed and pod numbers.These parameters can be used in the breeding process in the selection of individual plants.

Kosev [13] and Nawab, *et al.* [14] reported a maximum direct effect on pea grain yield of the 1000 seeds mass, number of pods and seeds per plant. The plant height had an indirect effect on yield by means of the number of fertile nodes and seeds per plant.

Kalapchieva [15] found that the highest direct effect on plant productivity was due to the length of internodes (16.7) and the number of pods (16.0). Their indirect effect was positive and high, both by the number of pods and grains per plant, and by the plant height.

According to Misnikova [16], modern principles of modeling of lupine cultivar should be applied differentiated and adjusted to the specific soil-climatic conditions.

Creation of model in white lupine required a study of the morpho-physiological nature of parameters affecting the productivity and resistance to stress factors. The correlation analysis performed by the author showed that plant productivity depended to the greatest extent on the number of seeds and pods per plant.

5. Conclusions

The results obtained from the conducted analysis showed that the linear component in the regression of seed productivity in white lupine regarding the studied quantitative traits was statistically significant and considerable. The highest relative share on seed productivity had the growth rate (+ 43.367), the number of seeds per plant (+0.321) and plant weight (+ 0.266).

The breeding model of plant in white lupine has the following characteristics: vegetative period ≤ 98 days, growth rate ≥ 0.71, plant height 36-71 cm, aboveground mass ≥ 44 g, number of pods 13-16, number of seeds ≥ 69, number of seeds in a pod 3-4, mass of 1000 seeds ≥ 298 g. From the white lupine cultivars studied in our collection, promising to realize this model are Astra, Tel Keram, Termis Mestnii and Solnechnii that can be included in hybridization schemes in the breeding-improvement work of this crop.

Choosing suitable parents in the combined breeding by using the simplex method will allow targeted planning of the breeding process to development of high-productive cultivars in shorter terms.

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Appendix

Table-1. Regression analysis of white lupine productivity regarding the other quantitative traits

	df	*SS*	*MS*	*F*	*Signif. F*
Regression	8	275.7267721	34.46584651	108.519507	2.9177E-11
Residual	14	4.446406595	0.317600471		
Total	22	280.1731787			

Table-2. Regression coefficients of productivity with respect to other quantitative traits in white lupine

	Coefficients (R)	**Standard Error**	**t Stat**	**P-value**
Intercept	3.5786	13.136073	0.670632	0.513367
Vegetation period	0.0063	0.080650	-0.210921	0.835988
Growth rate	43.367	15.154911	2.789216	0.014484
Aboveground mass	0.266	0.097558	2.924850	0.011084
Plant height	-0.446	0.148418	-2.886685	0.011952
Pods per plant	-1.033	0.763579	-1.629467	0.125500
Seeds per plant	0.321	0.192931	1.890198	0.079614
Seeds per pod	-2.773	2.403027	-1.503071	0.155040
1000 seeds mass	0.038	0.006668	5.495949	0.000079

Table-3. Direct effect of the traits on white lupine productivity: limitations and breeding model

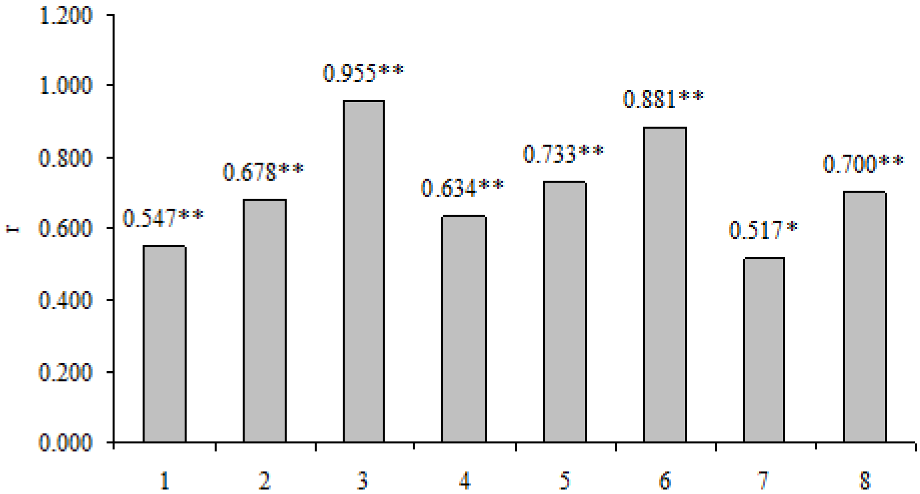
Breeding traits	**Limitations of breeding model**	**Direct effect on productivity**	**Breeding model**
Vegetation period	98.65	-1.11	98.13
Growth rate	0.62	18725.60	0.71
Aboveground mass	31.49	220.80	44.17
Plant height	63.39	-226.17	71.65
Pods per plant	13.24	227.14	16.66
Seeds per plant	52.84	-154.12	69.17
Seeds per pod	3.98	948.26	3.98
1000 seeds mass	267.50	-10.19	298.96

Table-4. Original simplex table for optimal slection of parents for breeding of white lupine cultivar with maximum productivity

Cultivars	**Target function (L) - max**	**Traits**							
	Plant productivity	T1	T2	T3	T4	T5	T6	T7	T8
Astra	16.96	101	0.69	37.75	72.32	13.29	56.38	4.24	317.06
Nahrquell	11.28	107	0.73	31.00	75.85	12.47	41.09	3.29	281.55
Ascar	14.18	99	0.68	33.41	71.31	13.42	50.79	3.79	279.32
BGR 6305	14.91	101	0.67	35.85	69.86	13.5	53.89	3.99	298.81
Shienfield Gard	12.77	107	0.84	34.39	87.13	11.27	47.56	4.22	266.45
WAT	12.37	95	0.58	27.64	57.66	14.63	52.96	3.62	231.54
Kijewskij Mutant	9.38	95	0.57	21.68	57.18	9.73	37.37	3.84	246.64
Hetman	4.89	95	0.42	12.77	41.73	7.87	27.17	3.45	173.14
Start	11.93	95	0.48	28.35	48.23	13.65	51.63	3.78	246.84
Amiga	10.16	95	0.51	23.48	51.35	9.67	41.62	4.31	241.83
Garant	13.82	95	0.51	26.1	51.08	13.1	49.58	3.78	308.12
Tel Keram	16.21	101	0.68	41.68	70.9	17.05	74.88	4.39	239.35
Bezimenii 1	14.32	107	0.72	35.9	75.17	11.49	50.38	4.39	290.8
Bezimenii 2	14.46	101	0.74	35.06	76.78	12.73	55.75	4.38	281.88
Pflugs Ultra	15.26	101	0.68	36.08	70.93	14.57	55.31	3.8	304.29
Termis Mestnii	21.55	106	0.75	46.00	76.1	16.7	70.46	4.22	322.18
Horizont	13.58	101	0.67	31.66	70.19	12.48	50.59	4.05	291.15
Solnechnii	20.51	98	0.74	46.5	72.89	18.67	75.58	4.05	295.69
Pink Mutant	16.66	98	0.66	36.63	65.88	15.33	65.00	4.24	271.92
Manovitskii	10.95	95	0.52	23.8	52.25	12.33	46.58	3.78	232.89
Barde	12.49	92	0.57	28.82	55.38	16.11	64.58	4.01	222.17
Dega	11.89	93	0.45	25.31	45.3	12.08	48.83	4.04	262.6
Desnyanskii	10.64	93	0.42	24.42	42.46	12.33	47.29	3.83	246.19

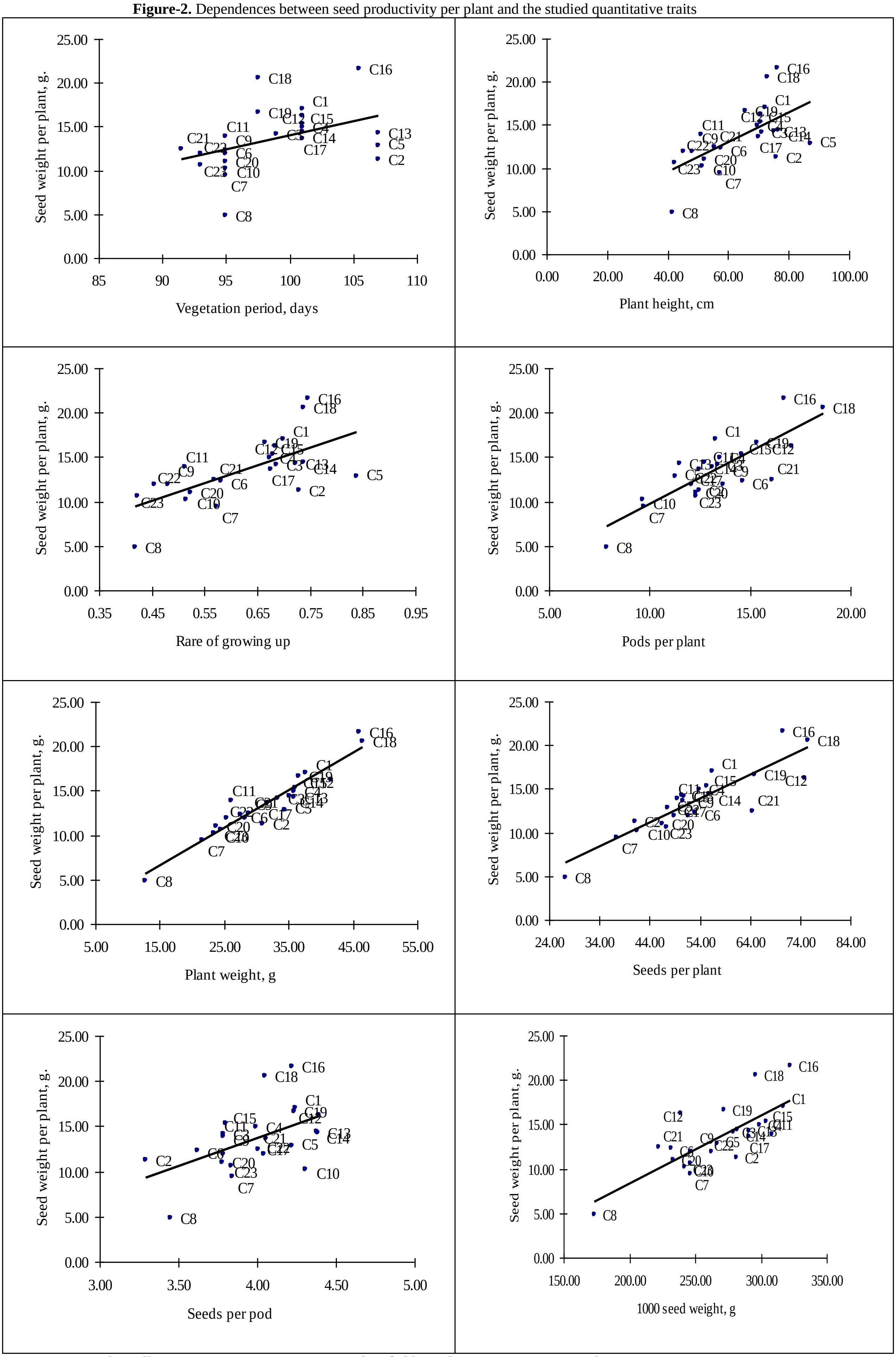
T1-vegetation period; T2- growth rate; T3-aboveground mass; T4-plant height; T5- pods per plant; T6- seeds per plant; T7-seeds per pod; T8-1000 seeds mass

Figure-1. Correlations of the quantitative traits with seed productivity



1-vegetation period; 2- growth rate; 3-aboveground mass; 4-plant height; 5- pods per plant; 6- seeds per plant; 7-seeds per pod; 8-1000 seeds mass
*, ** - significance at $P_{5\%}$ and $P_{1\%}$,

Figure-2. Dependences between seed productivity per plant and the studied quantitative traits



C1-Astra; C2-Nahrquell; C3-Ascar; C4-BGR 6305; C5-Shienfield Gard; C6-WAT; C7-Kijewskij; Mutant; C8-Hetman; C9-Start; C10-Amiga; C11-Garant; C12-Tel Keram; C13-Bezimenii 1; C14-Bezimenii 2;C15-Pflugs Ultra; C16-Termis Mestnii; C17-Horizont; C18-Solnechnii;C19-Pink Mutant; C20-Manovitskii; C21-Barde; C22-Dega; C33-Desnyanskii