

Model of forage pea (*Pisum sativum* L.) cultivar in conditions of organic production

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Abstract

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The requirements which the production systems with reduced levels of inputs and, in particular, organic production, impose on the cultivars, present a new challenge in the pea breeding. In the present study a linear regression equation was obtained defining the main traits which should be taken into account when choosing the source material for hybridization and their optimal matching would result in a forage pea cultivar with increased productivity. The results showed that the model for pea plant suitable for organic production conditions was characterized by the following parameters: stem with a height of 75-85 cm, forming 6-7 pods with a total number of seeds 20-25, length and width of the pod respectively 5 cm and 1 cm, and a mass of 1000 seeds in the range of 200-230 g. The cultivars Svit and Kamerton could be recommended as suitable parental components, combining high ecological stability with productivity.

Keywords: pea breeding; regression model; traits; productivity

Introduction

Scientific researches in the field of pea breeding have progressed significantly in creating new cultivars with high nutritional value, improved ecological plasticity and sustainability (Pratap & Kumar, 2011). Despite the great success in this direction, the necessity and possibilities for further improvement and development of new pea cultivars continue to be a priority because of the ever-changing conditions for growth (Sood & Kalia, 2006). A new challenge are the requirements that impose on varieties production systems with reduced levels of investments, in particular, the organic production system and the main problem with these systems – the low productivity of the crops.

The development of high yielding varieties with a high realization of its potential is among the main aims of the breeders. A wide range of morpho-biological parameters that

determine plant productivity conditions genotyped differences between pea varieties. The value of realizing the potential of genetically determined traits is subjected to strong phenotypic variability and defines the ability of the individual to resist the impact of the external factors (Fadeeva et al., 2010; Schulpekov et al., 2014).

The interaction of genotype with growing conditions has an important share in crop cultivation. The differentiation of varieties, breeding lines or hybrid populations regarding different traits, qualities or characteristics is a constant process in the breeding of each crop. Evaluations are carried out by a number of methods and approaches depending on the purposes of the breeding (Tsenov et al., 2014). For enhancing the productive potential of the pea plant, it is necessary to be developed models for selection for genetically significant characteristics which combining in the breeding process will lead to creation of desired genotype (Bilgil et al., 2010; Tan et al., 2012).

Information on variability and interdependencies of quantitative traits in the plant population is of particular importance for increasing the efficiency of the breeding work. One of the popular methods for clarifying the particular type of the studied interdependencies is carried out using methods of the regression analysis, which enables for prognosis when working with them (Penchev, 2009; Kalapchieva, 2013).

The aim of the present study was to determine the impact of the quantitative traits on the seed productivity in spring forage peas (*Pisum sativum* L.) in conditions of organic production by creating a regression model for the needs of the breeding.

Materials and Methods

The experimental activity was carried out during the period 2012-2014 at the Institute of Forage Crops (Pleven, Bulgaria). The objects of the study were five cultivars (Glyans, Svit, Kamerton, Modus, Pleven 4) of spring forage pea (*Pisum sativum* L.) cultivated in conditions of organic farming (Ordinance №1/2013), without use of fertilizers and pesticides. The soil type was leached chernozem, poorly supplied with nitrogen and phosphorus, and well-supplied with potassium. Sowing was manual, with a rate of 120 seeds/m². The experiments were arranged according to the block method, in three replicates. Biometric measurements included the following characteristics: plant height (cm), number of pods per plant, number of seeds per plant, pod length (cm), pod width (cm), seed productivity per (g).

The data were processed statistically by analysis of variance (ANOVA) by using the software product Statgraphics

Plus for Windows Version 2.1. Phenotypic stability was assessed by the nonparametric method of Kang (1993), and the total adaptability (A) of the cultivars was calculated using the method proposed by Valchinkov (1990).

Results and Discussion

Regression analysis

The results of the analysis revealed that the linear component in the regression of seed productivity regarding the studied traits was significant and essential (Table 1).

After a complex investigation of the traits, we received a model (1) that demonstrated the complicated character in formatting the productivity, depending on the values of the studied quantitative characteristics. The general type of the obtained regression equation was the following:

$$Y = -1.813 - 0.008X_1 + 0.253X_2 + 0.163X_3 - 0.919X_4 + 1.996X_5 + 0.128X_6^* + 0.021X_7^* \quad (1)$$

where: Y – seed productivity per plant; X₁ – plant height; X₂ – number of pods per plant; X₃ – length of pods stem; X₄ – pod length; X₅ – pod width; X₆ – seeds per plant; X₇ – mass of 1000 seeds.

The applied regression analysis showed that the formation of seed productivity was influenced to the greatest extent by the pod width (R = 1.996) and the number of pods per plant (R = 0.253), followed by the number of seeds per plant (R = 0.128). The productivity was significantly related only to the number of seeds per plant and mass of 1000 seeds (R = 0.021).

Table 1. Regression analysis (ANOVA) of the seed productivity per plant in regard to the other traits

ANOVA	df	SS	MS	F	Significance F
Regression	7	21.35422	3.050602	34.40484	5.14E-07
Residual	12	1.064014	0.088668		
Total	19	22.41823			

Table 2. Regression coefficients of the seed productivity per plant in regard to the other traits

	Coefficients	Standard error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	-1.813	2.400	-0.756	0.464	-7.043	3.416
B	-0.008	0.016	-0.484	0.637	-0.042	0.027
C	0.253	0.215	1.175	0.263	-0.216	0.722
D	0.163	0.193	0.841	0.417	-0.259	0.584
E	-0.919	0.634	-1.449	0.173	-2.301	0.463
F	1.996	1.552	1.287	0.223	-1.384	5.377
G	0.128	0.053	2.442	0.031	0.014	0.243
H	0.021	0.009	2.370	0.035	0.002	0.040

A – seed weight per plant; B – plant height; C – number of pods per plant; D – length of pod stem; E – pod length; F – pod width; G – number of seeds per plant; H – mass of 1000 seeds

The plant height in spring forage pea grown for grain is important for mechanized harvesting, for which reason, preferable varieties are those with medium-high and non-lodging stems. Above determined values, too great height has a negative impact on the productivity – it prolongs the maturing, which results in difficulties in mechanized harvesting. In the regression, equation obtained (1), the relationship between productivity and plant height, as a value was insignificant and had a negative sign, indicating that every increase in plant height would lead to productivity decrease. Contrary to the first trait, the increment of pod numbers, length of pod stem and seeds per

plant increased the productivity by 0.253 g, 0.163 g and 0.128 g, respectively (Table 2).

A high relative share on the productivity had the trait of pod width (1). The individual productivity would increase by about 2 g if the value of the trait under consideration increased by a unit. The influence of mass of 1000 seeds ($R = 0.021$) and pod length was less pronounced, as in the last trait the coefficient of regression had a negative sign ($R = -0.919$).

The obtained data confirmed dependencies established by Kalapchieva (2013) in garden pea. Positive, but insignificant, was the influence of characteristics as pod numbers; length of pod stem and pod width.

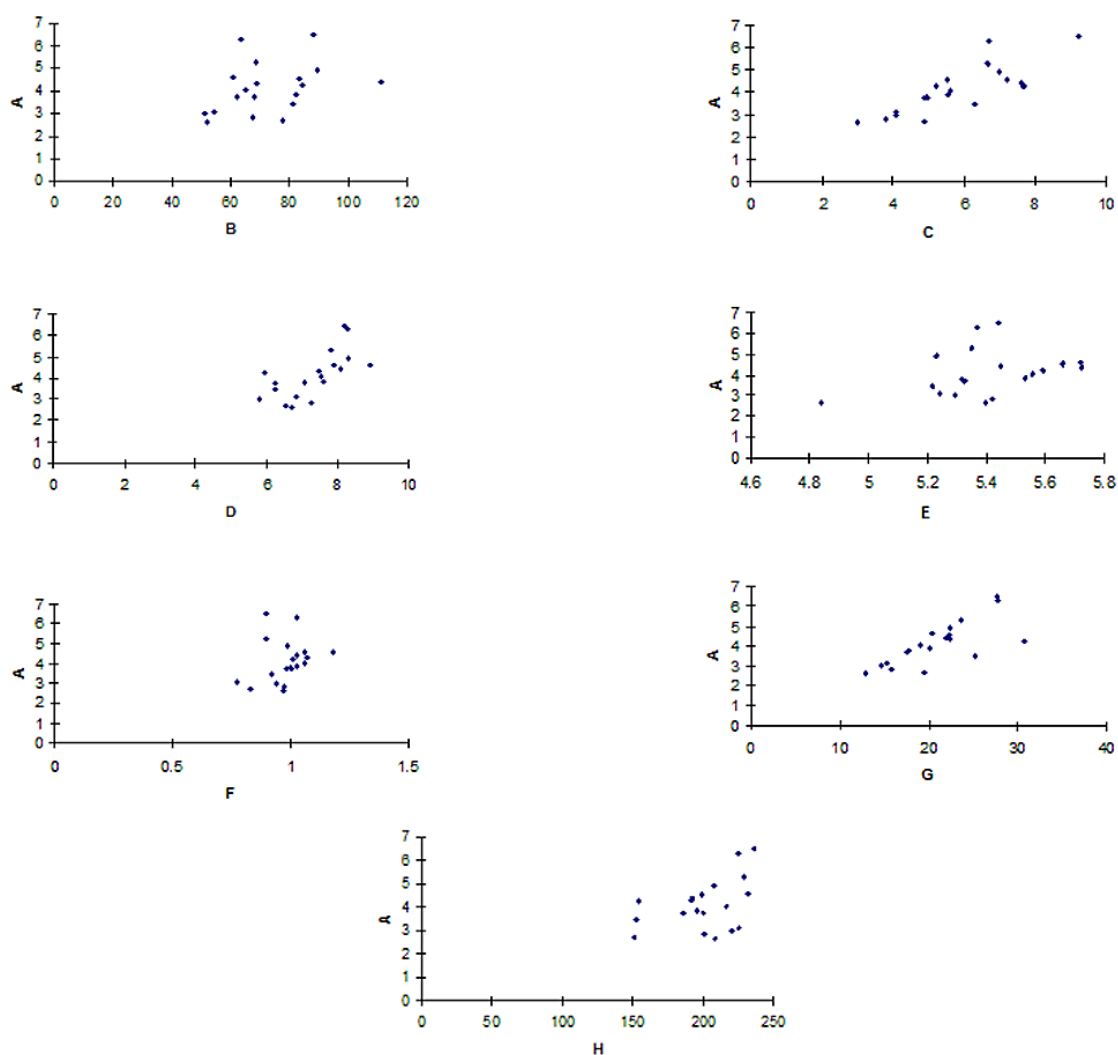


Fig 1. Dependences between seed productivity per plant and quantitative traits

A – seed weight per plant; *B* – plant height; *C* – number of pods per plant; *D* – length of pod stem; *E* – pod length; *F* – pod width; *G* – number of seeds per plant; *H* – mass of 1000 seeds

Dependencies between productivity and quantified traits

The graphical representation of the dependencies between productivity and the studied quantitative components allows with a sufficient approximation to be received theoretical results and to determine the basic dependencies between the studied characteristics (Fig. 1). The seed productivity per plant decreased at a plant height of over 85-90 cm. The optimal pod width and length of pod stem were 1-1.2 cm and 7-8 cm, respectively. While analyzing parental components, Sharma et al. (2000) and Srivastava et al. (2000) indicated the number of pods per plant, the seeds per pod, and the size of one seed as the main components of pea yield. In our model, the traits of seed numbers per plant and mass of 1000 seeds were of less importance. The variant, at which the highest productivity would be obtained, was a plant forming 20 to 25 seeds, with mass of 1000 seeds in the ranges of 200 to 230 g.

The second most important trait determined by the regression equation (1) was the number of pods per plant. In the graph presented, its parameters varied from 6 to 7 and in this range, each rise would increase the productivity. The average length of the pods was 5.3-5.6 cm, and above these values, the productivity decreased. This trait, similar to the plant height, acted in the opposite direction, which probably affects the size of the seeds in a pod. The parameters of the model obtained for a pea cultivar suitable for organic production conditions differed and had lower values (with the exception of plant height) compared to those established by Kosev (2015) for the model pea but under conventional conditions. The author has pointed the following characteristics for a “conventional” cultivar of forage pea: 60-70 cm height, 8-10 pods, 30-40 seeds per plant and mass of 1000 seeds in the range 160-260 g. The greater height of the pea plant received in organic farming is explicable and desirable to a certain extent, as according to some researchers (Moudry, 2003; Uhr et al., 2014), it gives a considerable advantage in the competition with weeds.

Adaptive ability and environmental stability

Among the characterizations of the many morphological features and biological properties of peas as well as other crops, during the breeding process, the plant genetic resources should be assessed in regard to their adaptability and stability, which gives an important information for the genotypes (Shurkaeva & Fadeeva, 2010; Abrosimova & Fadeeva, 2015). In order to receive objective information on the adaptability of pea cultivars, the total adaptability coefficient (A) (Fig. 2) was calculated, according to which the production potential of the tested accessions can be estimated. For the studied period, all cultivars had positive coefficients of adaptation, over 2. With the lowest values were Glyans (2.29) and Plevan 4 (2.83). The most adaptive

cultivar was Svit (3.76), followed by Kamerton and Modus (3.42-3.14).

The calculated values of the stability parameter “YSi” showed essential differences between cultivars in terms of the stability demonstrated. According to the results, Svit appeared as the most valuable cultivar, combining ecological stability and high productivity in terms of organic production, and can be considered as close to the ideal cultivar. Of particular interest was also Kamerton, which is suitable for cultivation in a wider range of environmental conditions, although it was less productive. These varieties may be recommended as proper parental components. Modus was relatively stable with a low positive value (1) of the YSi parameter, but it was weakly productive, and Glyans had the highest productivity but high instability (-1). This cultivar, as well as Plevan 4, showed very good responsiveness in improving environmental conditions.

According to Lukashevich & Kovaleva (2012), the most important tasks in pea breeding were related to selection and cultivation of high yielding and stable, early and late-ripening varieties with high seed productivity and good resistance to disease and unfavorable environmental conditions. Halipsky (2006) considered that the development of breeding models in cultivated plants is an important task accompanying the development of new cultivars in different soil-climatic regions of the world. The author found that for Ukraine and the southern regions of Russia, the pea cultivar model should meet the following characteristics: grain yield 400-450 kg/da; plant height 75-80 cm; number of beans 7-8, number of seeds per plant 30-35, weight of 1000 seeds in the range 190-220 g, and the ratio of seed weight to the rest of the dry plant – 50:50 (%).

As a result of long-standing researches in Finland, Hovin-en (1988) proposed an ideotype of a high-protein pea cultivar whose seed yield was 450 kg/da in a pure stand, at plant height of 61-94 cm, with vegetation period of 91-101 days and the flowering period within 19-28 days.

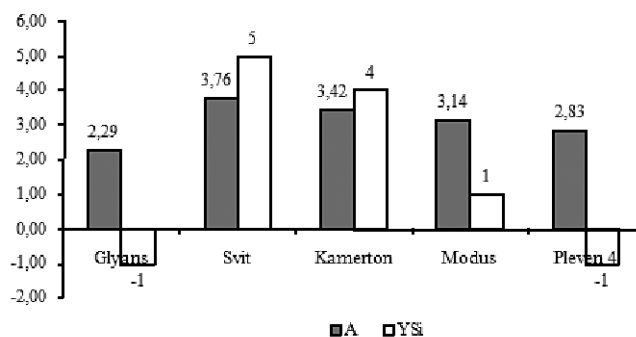


Fig. 2. Adaptive ability (A) (Valchinkov, 1990) and yield stability index (YSi) (Kang, 1993) in forage pea cultivars regarding seed productivity

Katyuk et al. (2014) presented the results of studies of pea accessions with a different morphotype regarding grain yield and stability. They stated that over the last 20 years, grain yield in modern varieties (afila and heterophilic type) has increased between 12 and 28%. The adaptability of these morphotypes to changing environmental conditions has increased. The authors consider that the main trend in pea breeding will be in the direction of restructuring the plant morphology, paying attention to the smaller height, a heterophilic arrangement of the petals of the complex leaf and compact pod formation.

Conclusions

A linear regression equation was obtained defining the main traits (number of pods per plant, number of seeds per plant and mass of 1000 seeds) which should be taken into account when choosing the source material for hybridization and their optimal matching would result in a forage pea cultivar with increased productivity.

The obtained results showed that the model for pea plant suitable for organic production conditions was characterized by the following parameters: stem with a height of 75-85 cm, forming 6-7 pods with a total number of seeds 20-25, length and width of the pod respectively 5 cm and 1 cm, and a mass of 1000 seeds in the range of 200-230 g. From the cultivars that are the subjects of the present study, Svit and Kamerton could be recommended as suitable parental components, combining high ecological stability with productivity.

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