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SEED RETAINING MODEL OF NON-DEHISCENCE SESAME (*Sesamum indicum* L.) GENOTYPES AT RIPENING

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Abstract

The retention of seeds in capsules of 25 sesame genotypes intended for mechanized harvesting was investigated. The mentioned share is determined for capsules which when ripe open tops, but retain their seeds because they have attached placenta and narrowing. Before opening, the capsules stay with the tip down to reach 12% humidity of the seeds under natural conditions. A statically adequate regression model for the percentage of seeds retained in the capsules was obtained. The model testifies that the distance of the capsule narrowing relative to its base is most strongly influenced by said percentage, followed by the force by which the placenta retains the seeds. Least but significantly and directly proportional effect on the percentage of retained seed has the average number of branches of a plant. As the number of branches in one plant increases, a greater degree of capsules narrowing are observed. The genetic progress and the opportunities to increase the number of branches in the future sesame crop is shown for breeding improvement.

Key words: *sesame (Sesamum indicum L.), breeding, seed retention, modelling.*

INTRODUCTION

The mechanized harvesting of sesame is an unsolved problem worldwide and is of paramount importance for preserving the culture. Scientists from several countries are working hard on the issue, giving priority to the breeding of varieties suitable for mechanized harvesting (Stamatov et al., 2018). They have to meet three basic requirements:

- Varieties must retain their seeds in the capsules upon ripening until they enter the threshing apparatus. The capsule retains mature seeds by the presence of a placenta attached and due to anatomical features that determine its shape.
- Plants should dry under natural field conditions. If the moisture content of seeds is above 8%, they suffer significant mechanical damage and loss of germination when threshing with a conventional combine. Therefore, inertial threshing is recommended under these conditions (Ishpekov et al., 2016).
- The variety must have high seed yield.

The relatively low yields of sesame globally require directing the selection process towards increasing it (Furat and Uzun, 2010). The wide range of plant gene-plasma provides great possibilities for the genetic improvement of the crop plants. Introduction of gene-plasma allows extension of this range and genetic improvement on valuable economic signs of culture (Zhang et al., 2011).

The purpose of the study is to model the retention of seeds in the capsules when ripening non-dehiscent genotypes of sesame from Bulgarian breeding program.

MATERIALS AND METHODS

Plant material

25 sesame accessions from the national collection in IPGR - Sadovo have been evaluated. Their capsules open the tops but retain their seeds at maturation, because they have a placenta attached and narrowing of the walls. The accessions are the result of eight hybrid combinations, also derived from international exchange and personal correspondence.

Morphological measurements

The accession's indicators of three groups were tested. The first group includes the percentage of retained seeds in the capsules when their tips are turned down under natural conditions. Each accession dries out for a different number of days up to 12% humidity. This position allows the seeds to leave the capsules when they are not attached to the placenta or when their walls do not narrow. During the drying the wind speed changes from 2.0 to 10.3 m/s.

The second group of indicators is related to the yield and includes:

- the seed mass of one plant - ms1, g;
- the height of the central stem - hst, cm;
- the number of branches - Nbr;
- the number of capsules on the central stem - Ncst;
- the number of capsules on the branches - Ncbr.

The third group of indicators characterizes the shape and dimensions of the seminal chamber (carpel) and includes:

- seminal chamber length - lc, mm;
- the width of chamber at the base, middle and top - bb, bm, bt, mm;
- the dimensions of narrowing's the capsule walls - bn, mm and its distance from the base of the capsule - bn in natural (mm) and relative units (%).

The rate of capsule narrowing was calculated constriction - Rn by the expression:

$$R_n = 100\frac{b_b - b_n}{b_b}, \% \qquad (1)$$

All measurements were made in 10 replicates with an electronic micrometer caliper with an accuracy of 0.01 mm.

Statistical methods

The genetic advance of the number of branches in a plant was estimated using the variance analysis. Evaluation of variation components, phenotypic and genotypic variants was performed according to the method proposed by Burton and Devane (1953). The following statistical estimates are used:

1. Environmental variance:

$$\sigma_e^2 = MSE \qquad (2)$$

2. Phenotypic variance:

$$\sigma_p^2 = \sigma_g^2 + \sigma_e^2 \qquad (3)$$

3. Genotypic variance:

$$\sigma_g^2 = MST\text{-}\ MSE \qquad (4)$$

where:

MSE is the mean square error;
MST - the mean square treatment;
r - the replications.

4. Phenotypic coefficient of variation:

$$PCV = 100\frac{\sqrt{\sigma_p^2 x}}{x} \qquad (5)$$

5. Genotypic coefficient of variation:

$$GCV = 100\frac{\sqrt{\sigma_g^2 x}}{x} \qquad (6)$$

where:

σ_p^2 is the phenotypic variance;
σ_g^2 - the genotypic variance;
x - the grand mean of a character.

By Johnson et al (1955) genetic advancement and genetic advancement was determined as a percentage of the mean value:

$$GA = \frac{K\sigma_g^2\sqrt{\sigma_p^2}}{\sigma_p^2} = \frac{K\sigma_g^2}{\sqrt{\sigma_p^2}} \qquad (7)$$

where:

GA is the expected genetic advance;
K - the standardized selection differential at 5% selection intensity (K = 2.063).

$$GAM = 100\frac{GA}{x} \qquad (8)$$

where:

GAM is the genetic advance as percentage of mean, %;
GA - the expected genetic advance.

The analyzed results determine the most important factors that affect seed retention in the capsules. They are included in a regression analysis for obtaining equations in coded and natural form. All statistical analyses are performed at a level of significance α = 0.05.

RESULTS AND DISCUSSIONS

The values obtained for the parameters h_n and R_n show that the capsule walls of all genotypes tested have a narrowing. It is located from the base at a height of 46.0 to 75.4% of its length. In two of the accessions (464 and 361-7-3-2-1) capsule walls have narrowing at the base of the seminal chamber and are located from the base at a height of 24.7 to 27.5% of their length. For this reason, the distance of the capsule narrowing relative to its base and the rate of capsule narrowing are included as factors in regression analysis.

The seed retention in capsules in some varieties is due to the force with which the placenta attached them. That ability is explained by the i_3 index (Ishpekov and Stamatov, 2015) and therefore its value is also included as a factor in the regression analysis.

The dependencies in Table 1 show that there is no connection between the yield elements, the seed chamber sizes, and the ability of the genotype to retain its seeds in the capsules at ripening. Besides, the mass of seeds from a plant is directly related to the elements of the yield. The sizes of the seed chamber have a strong correlation between each other.

The correlation coefficients obtained indicate a direct dependency between the parameters studied. The results of the PATH analysis reveal the existence of an indirect link between them. The retention of seeds is due to the architecture of the capsules that define the shape of seeds chamber (Langham, 2014). Narrowing the capsule walls causes the seeds retaining in the period of maturing. In Table 2 is seen that the ability of capsules to retain seeds decreases when there are no walls narrowing (direct PATH = - 0.547). This ability increases when the narrowing is closer to the tip, as evidenced by the value of the indirect coefficient (0.596). It is obtained from the correlation between the length of the seminal chamber and the distance of the narrowing from the base of the capsule. The width at the base of chamber indirectly affects the retention of the seeds (indirect factor 1.821) by the correlation between it and the width in the middle part. Reducing the width in the middle part of the seminal chamber leads to an increase in seed retention (direct PATH = 2.119). Reducing the tip width also leads to seed retention (indirect coefficient 1.570). This is due to the correlation that exists between the width of both the middle of the seminal chamber and tip. Reducing the width in the middle of the chamber leads to increasing of seed retention (direct PATH = 2.119). The absence of narrowing in the seed chamber leads to an increase in the proportion of released seeds (direct PATH = - 1.966). This lack is a reason for their retention, if any (indirect factor 2.00) and is explained from the correlation existing between the width of the middle part of the chamber and the narrowing of capsule. When the constriction is located near the tip, it retains the seeds in the capsule (direct PATH = 1.260). When it is close to the base, its seed retention effect is greatly reduced (direct PATH = -1.206).

The tested accessions have an average of 2.29 branches. This is a sufficient reason to include the average number of branches in a sesame plant as another factor in the regression analysis.

Table 1. Correlation between the surveyed signs

	Ds	ms1	hst	Nbr	Ncst	Ncbr	lc	bb	bm	bt	bn	hn	hn (%)
	%	g	cm	number	number	number	mm	mm	mm	mm	mm	mm	
Ds	1	-.339	-.338	-.208	-.374	-.269	.184	-.098	.170	.049	-.054	-.143	-.258
ms1		1	.753**	.615**	.510**	.817**	-.350	.037	-.100	.199	.024	-.142	-.021
hst			1	.706	.363	.677**	-.338	-.074	-.101	.195	.058	-.381	-.297
Nbr				1	.301	.783**	-.200	-.354	-.430*	-.212	-.299	-.149	-.081
Ncst					1	.674**	.301	-.051	-.206	-.020	-.161	.273	.137
Ncbr						1	-.059	-.157	-.309	-.148	-.221	.103	.120
lc							1	-.058	-.016	-.162	-.134	.473*	.072
bb								1	.859**	.633**	.881**	.406*	.457*
bm									1	.741**	.944**	.104	.086
bt										1	.791**	-.241	-.231
bn											1	.066	.096
hn												1	.908*
hn (%)													1

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

Table 2. Direct and indirect connections between the structural elements of the yield with the anatomical characteristics of the seminal chamber

	lc	bb	bm	bt	bn	hn	hn (%)	Phenotypic correlation
	mm	mm	mm	mm	mm	mm		
lc	-0.547	0.014	-0.034	-0.025	0.267	0.596	-0.087	0.184
bb	0.032	-0.250	1.821	0.097	-1.758	0.511	-0.551	-0.098
bm	0.009	-0.215	2.119	0.114	-1.884	0.131	-0.104	0.170
bt	0.089	-0.158	1.570	0.153	-1.580	-0.303	0.278	0.049
bn	0.073	-0.220	2.000	0.121	-1.996	0.083	-0.116	-0.054
hn	-0.258	-0.101	0.221	-0.037	-0.132	1.260	-1.095	-0.143
hn (%)	-0.040	-0.114	0.183	-0.035	-0.191	1.144	-1.206	-0.258

Dependent variant: % retained of seeds

The relationship between the number of branches in a plant and the width of the chamber is presented in Table 1 (r = - 0.430). The increase in the number of branches is accompanied by contraction of the walls of the seed chamber. This is the reason for including the average number of branches in one sesame plant as a factor in the regression analysis. The accessions studied formed an average of 2.29 branches.

The analysis of genetic progress for the number of branches in a plant is presented in Table 2. It shows that the phenotypic coefficient of variation (PCV) is 98.2% and significantly higher than the genotypic (GCV) with a value of 8.1%.

PCV and GCV values greater than 20% are considered high, whereas values of less than 10% are considered low and values between 10 and 20% are average (Deshmukh et al., 1986). Based on this argument, the number of branches in a plant is strongly influenced by growing conditions.

In the accessions examined, the low GCV value refers to the conservative nature of the sign and the genes expressing it are in the homozygous state. Johnson et al. (1955) classify the values of genetic advance as a percentage of the mean (GAM) in the following way: values of 0-10% are low, 10-20% is moderate and over 20% are high.

The resulting GAM for our collection has a value of 27.7% (Table 3).

Table 3. The genetic advance of number branches in a plant

	Mean	σ_e^2	σ_g^2	σ_p^2	GCV, %	PCV, %	GA	GAM, %
Nbr	2.29 ± 0.144	2.00	2.21	0.21	8.1	98.2	0.64	27.7

This fact, separately from genetic advance, also points to the possibility of genetic improvement of the indicator in future breeding-improvement work.

A regression analysis was carried out in which the response variable was the percentage of seed retained in the capsules - Ds, % and the following factors:

- The distance from seminal chamber narrowing to the base of the capsule - hn, %;
- The degree of capsules narrowing - Rn, %;
- The value of the index i3 for each tested genotype;
- The average number of branches per plant - Nbr;

The following regression equations were obtained:

In coded form:

$$D_s = 0.1636.N_{br} + 1.2691.h_n - 0.6984.h_n^2 + 0.2931.i_3 \quad (9)$$

In natural form:

$$D_s = 4.5241.N_{br} + 1.4657.h_n - 0.0120.h_n^2 + 41.8993.i_3 \quad (10)$$

The equations have coefficient of determination R2 = 0.936 and probability pF = 0.00001 < 0.05. These values testify that regression models include all significant factors that affect the percentage of retained seeds in capsules.

The factors take values from -1 to +1 in the coded regression equation (9). This allows an assessment of the influence power of each factor on the dependant variable by the value of the regression coefficient in front of it. The highest value has the coefficient in front of hn followed by the one in front of i_3 which testify that their influence on the change of the response - Ds is the strongest and most proportionate due to the equal signs in front of the factors. The least impact on the percentage of retained seeds in the capsules - Ds has the number of branches - Nbr. The degree of narrowing of the capsule walls - Rn is not included as a predictor in the above equations because it does not significantly affect the response - Ds. Obviously no matter how much narrow the capsules are. It is important to have a narrowing and be closer to the top of capsules to prevent the seeds from releasing. The natural form of regression equation (10) is used to visualize the results of the regression analysis.

The statistical significance of the number of branches in a plant as a factor affecting the proportion of retained seeds in the capsules is confirmed by two different statistical criteria. One is PATH coefficient analysis, and the second one is the Student criterion for evaluating the significance of coefficients in the regression equation. In the Figure 1 is shown the effect of the morphological sign - Nbr on the response - Ds. It is clear that the proportion of retained seeds in the capsules increases proportionally to the average number of branches in a plant. If the average number of branches in a plant is greater than 3, can be expected larger proportion of retained seed in capsules.

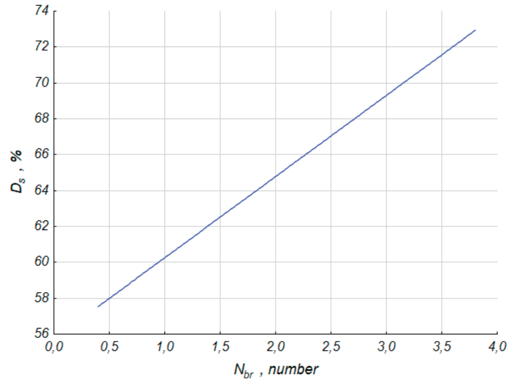

Figure 1. The percentage of retained seeds in the capsules - Ds depending on the number of number of branches in a plant - Nbr when the distance of narrowing from the base of capsule is hn = 54.7% and the index i_3 = 0.345

The effect of the two factors characterizing the shape of the capsules on the response - D_s is presented in Figure 2. Obviously the position of the narrowing relative to the base of the capsule and its second degree influences significantly and positively the percentage of retained seeds in the capsules. The response - Ds grows steeply with the increase in the index i_3 because the strength of the placenta attachment greatly affects the percentage of seeds remaining in the capsules. This percentage reaches to 100% when the genotype had an index $i_3 \geq 1.5$ and its capsules have a narrowing spaced at a distance $h_n \geq 60\%$ relative to the base (Figure 2).

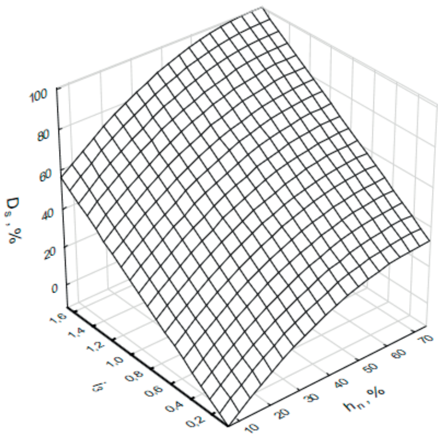

Figure 2. The percentage of retained seeds in the capsules - Ds, depending on the distance of the narrowing from the base - hn and the index i_3 at an average number of branching from one plant Nbr = 2.2

The results obtained may be implemented in the breeding program associated with the preparation of sesame forms suitable for mechanized harvesting. The justification of a morphological sign that significantly influences seed retention in capsules in the maturation of sesame genotypes can be used to select parent pairs and to provide an additional express method in creating future progenies.

CONCLUSION

A statistically adequate regression model was obtained that included all factors that significantly affect the percentage of seeds that are retained in the capsules when their tips are upside down when drying to 12% humidity in natural conditions. The model testifies that the distance of the capsule's narrowing relative to its base influences the strongest to the seed retention, followed by the strength with which the placenta retains the seeds. Less, but significant and proportional impact on the proportion of retained seeds in the capsules is the average number of branches per plant.

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