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Bean pod areas most susceptible to cracking

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A b s t r a c t. The paper contains the results of research to determine those areas of the bean pod which are most susceptible to cracking. Measurements were taken on pods of five bean cultivars grown for dry seeds, at five levels of moisture content. The 'abdominal' seam near the pod end and in the middle section and the dorsal seam near the stalk and near the pod end were the bean-pod areas most resistant to cracking for all cultivars tested. In the case of the Aura, Bor, Igołomska and Prosna cultivars, the abdominal seam near the stalk side cracked most often, whereas the pods of the Nida cultivar cracked most often in the middle of their dorsal seam. The moisture content had a significant effect on the location of the cracking in the bean pod. In all cultivars tested, the increased moisture content caused a drop in the frequency of the complete splitting of the abdominal seam and the splitting of the abdominal seam in the middle of the pod and the increased frequency of the cracking of the abdominal seam near the stalk end for the Aura, Nida and Prosna cultivars, as well as that of the dorsal seam near the pod end in the Aura, Bor and Igołomska cultivars.

K e y w o r d s: bean pod, cracking, moisture content

INTRODUCTION

Mechanically harvesting beans, grown for dry seeds, is particularly difficult compared to harvesting grain or harvesting other leguminous plants. This is a direct result of the unfavourable agrophysical and biological characteristics of this plant. One such characteristic of beans which materially affects the scale of loss is the high susceptibility of mature pods to cracking and the subsequent shedding of their seeds. Learning about this characteristic of the bean and the factors governing it may significantly contribute to a reduction in seed loss during the harvest.

The internal structure of shells and of the seams joining them is considered a characteristic facilitating cracking in the pods. The pod shell is built essentially of two layers: the external parenchyma and the internal sclerenchyma (a parchment-like substrate) composed of strongly thickened and elongated sclerenchymatic cells of a relatively small diameter. The axes of those cells are usually crosswise or oblique to the longitudinal axis of the pod. In the latter case, the parchment substrate frequently consists of two layers, the cells of which (oblique to the pod axis) cross each other at nearly right angles. As a result of the varied arrangements of microfibrils in the cell walls, these two parts of the thick-walled parchment substrate shrink in various directions during drying and the pod cracks along its abdominal seam (at carpel fusion) and dorsal seam (main vain/rib). The oblique arrangement of the elongated sclerenchymatic cells in the parchment substrate and in other parts of the percarp causes the split pod halves to curl. There is one conductive xylem fascicle on the dorsal side of the pod and two – on the abdominal side. Branch fascicles leading to the seeds come off alternately from the abdominal fascicle. Two sclerenchymatic fascicles, joined to each other in non-splitting cultivars, or separated by a strip of thin-walled crack-facilitating parenchyma cells [1, 2, 7] are arranged over the conductive fascicles.

According to Szwed [5, 6], the crack begins in the middle part of the seam, because here the twisting stresses and forces acting on the pod halves at the seam are the highest.

The aim of the paper was to determine the bean pod area most susceptible to cracking.

MATERIALS AND METHODS

The research was performed on the following bean cultivars grown for dry seed: Aura, Bor, Igołomska, Nida and Prosna. The above mentioned cultivars were characterised by varied seed and pod sizes, a contributory factor

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in their selection for research. These cultivars were grown on experimental plots at the Mechanization of Agriculture Department in the University of Rzeszów. The basic characteristics of the pods of bean cultivars studied are presented in Table 1.

The study was conducted for five levels of moisture content (Table 2) with a replication of 100 pods. In order to obtain a suitable moisture content in the pod samples they were moistened in a foil tunnel to about 28–30% moisture and then dried at approx. 20°C to reach the required value.

The frequency of a pod's splitting in a specific location was assumed as the measure of the susceptibility of a pod's area to cracking. Research was conducted using the pressure method in which the pod was burst by the introduction of compressed air [3, 4].

The following ways to split the pods were classified:

- the total splitting of the pod – (all along its dorsal and abdominal seam) (D-A),
- all along the dorsal seam (D),
- the dorsal seam near the stalk (DS),
- the dorsal seam in the middle part of the pod (DM),
- the dorsal seam near the pod end (DE),
- all along the abdominal seam (A),
- the abdominal seam near the stalk (AS),
- the abdominal seam in the middle part of the pod (AM),
- the abdominal seam near the pod end (AE).

RESULTS

At the first level of the moisture content of the pod (Table 3) the majority of pods which split completely were of the Bor cultivar – 52%, and the least for – for the Prosna and Igołomska cultivars, 11 and 12%, respectively. With a rise in pod moisture content, the share of completely split (D-A) pods decreased steadily until it reached zero. Pods of the Nida cultivar were the first to stop opening completely (at the third level of moisture content). Further rises in the moisture content of the pods produced no further completely split pods in the Prosna and Igołomska cultivars, and then none – at the highest pod moisture content – in the Aura and Bor varieties. Such differences in the cultivars studied in respect of the number of completely splitting pods may indicate the occurrence of inner stresses at various levels or a different structure in the seams which join the two pod shell halves together.

With rises in the moisture content of the pods, the number of abdominal seams cracking completely (A), decreased steadily and, at the fourth and fifth moisture content level of the pods, this seam no longer split completely in the Nida and Prosna cultivars. In the case of the dorsal seam (D) the reverse tendency was observed, i.e. more often splitting at higher moisture levels. It was also found that the abdominal seam (A) cracked completely more often in the dry pods, with the single exception of the Nida cultivar, where the dorsal pod cracked more often.

Confirmation of the effect of the moisture content of the pod on the location of the crack may be seen in the correlation coefficients specified in Table 4. They indicate the existence of a very strong negative relationship between the moisture content of the pods of all the cultivars studied and the complete splitting of pods (D-A) and abdominal seam (A), as well as the splitting of the abdominal seam in the middle part (AM). An equally strong, but positive relationship to

Table 1. Characteristics of pods of the bean cultivars studied

Specification	Cultivar				
	Aura	Bor	Igo^{3}omska	Nida	Prosna
Length (mm)	104.27	93.05	117.37	102.10	114.47
Width (mm)	10.42	6.56	7.69	10.74	9.48
Thickness (mm)	8.35	6.68	7.77	9.02	8.33
Number of seeds in pod	4.20	4.50	4.10	4.40	4.40
Mass of 1000 seeds (g)	434.40	173.60	340.20	430.00	389.80

Table 2. Average moisture content (%) for the pods of the bean cultivars studied

Cultivar	Moisture content level				
	I	II	III	IV	V
Aura	11.0	14.0	18.1	20.0	26.8
Bor	10.2	14.2	17.7	21.5	25.1
Igo^{3}omska	12.2	13.9	17.3	20.3	26.7
Nida	11.7	14.0	17.9	21.9	25.0
Prosna	12.5	14.9	17.7	20.9	26.1
Average	11.5	14.2	17.7	20.9	25.9

T a b l e 4. Coefficients of the correlation between the cracking of the bean pods and their moisture content

Pod cracking location	Cultivar				
	Aura	Bor	Igo³omska	Nida	Prosna
D-A	-0.9499*	-0.9127*	-0.9604*	-0.8216*	-0.9297*
D	-0.9441*	-0.7833*	-0.9628*	-0.7071	-0.9001*
DS	0.9280*	-0.0240	0.5636	0.7580*	0.9115*
DM	-0.9504*	-0.8778*	-0.9667*	-0.9701*	-0.9258*
DE	-0.6708*	0.1768	-0.3536	0.2236	-0.7271*
A	0.7735*	0.8807*	0.9163*	0.0822	0.8544*
AS	0.5774*	0.3536	0.9481*	-	-
AM	0.7526*	0.8575*	0.6934*	0.1213	0.8321*
AE	0.9125*	0.9090*	0.8868*	0.1971	0.4753

*significance level of $\alpha = 0.05$.

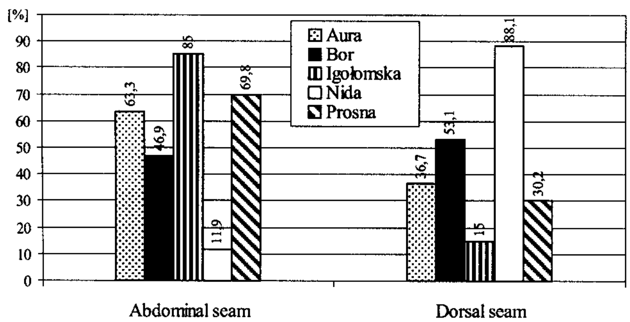

Fig. 1. Average frequency (%) of pod splitting in specific locations.

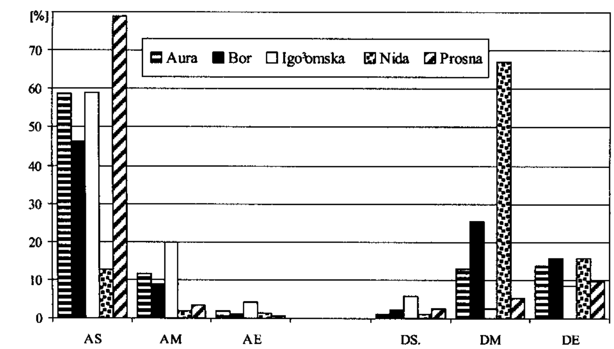

Fig. 2. Frequency (%) of abdominal and dorsal seam splitting near stalk, pod end and in the pod middle. Marking of the location of the cracking in the pods as in the text.

in the middle of their dorsal seam. This seam cracked more often near the pod end (DE) and in the middle part (DM) than nearer the stalk (DS). Thus, Szwed's presumption that the beginning of a crack is to be expected in the middle part of the pod's length has been confirmed for pods of the Nida cultivar only. The more frequent splitting of the pods near the stalk or near the pod end in the remaining bean varieties indicates that their structure is much weaker in those areas.

To sum up, it should be stressed that the area most susceptible to cracking is affected not only by the internal structure of its seams but also by the pod shell geometry near those seams.

CONCLUSIONS

1. The pod areas most resistant to cracking in all the cultivars tested were: the abdominal seam near the pod end and in the middle of the pod, as well as the dorsal seam near the stalk and near the pod end.

2. The area most susceptible to cracking varied from one location on the pod to another for various bean cultivars. In the Aura, Bor, Igołomska and Prosna varieties, the abdominal seam cracked most often near the stalk, whereas the pods of the Nida cultivar cracked most often in the middle of their dorsal seams.

3. The moisture content affected cracking significantly. A rising moisture content in the pods caused a decrease in the frequency of the total splitting of the pods and the abdominal-seam, as well as in the frequency of the cracking in the middle of the abdominal seam.

4. With a rising moisture content in the pods, the highest frequency for the cracking of the abdominal seam near the stalk was recorded for the Aura, Nida and Prosna cultivars, as well as for the cracking of the dorsal seam near the pod end in the Aura, Bor and Igołomska cultivars.

5. The area of the pod most susceptible to cracking is affected not only by the internal structure of its seams but also by the geometry of the pods' shells near the seams.

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Table 3. Frequency (%) of pod splitting in various locations in the bean cultivars studied

Cultivar	Moisture content level	Pod cracking location								
		D-A	D	DS	DM	DE	A	AS	AM	AE
Aura	I	23	27	24	13	1	7	0	3	2
	II	22	18	28	8	2	12	1	5	4
	III	7	13	35	6	1	23	0	10	5
	IV	2	10	33	3	1	25	1	11	14
	V	0	9	46	3	0	19	1	8	14
	Average	10.8	15.4	33.2	6.6	1.0	17.2	0.6	7.4	7.8
Bor	I	52	10	29	7	0	2	0	0	0
	II	47	9	14	6	1	12	0	8	3
	III	6	10	32	5	0	22	2	16	7
	IV	7	7	10	5	2	33	4	24	8
	V	0	1	34	0	0	25	0	17	23
	Average	22.4	7.4	23.8	4.6	0.6	18.8	1.2	13.0	8.2
Igo³omska	I	12	43	21	17	2	2	1	1	1
	II	11	42	22	16	4	1	2	0	2
	III	6	37	31	10	2	4	3	1	6
	IV	0	24	45	8	2	6	5	3	7
	V	0	18	50	6	2	7	6	2	9
	Average	5.8	32.8	33.8	11.4	2.4	4.0	3.4	1.4	5.0
Nida	I	16	1	4	3	1	27	0	44	4
	II	4	2	2	2	1	30	1	48	10
	III	0	0	11	1	0	25	2	42	19
	IV	0	0	6	0	2	29	1	48	14
	V	0	0	20	0	1	28	0	45	6
	Average	4.0	0.6	8.6	1.2	1.0	27.8	0.8	45.4	10.6
Prosna	I	11	24	34	4	1	14	3	3	6
	II	9	22	43	4	1	15	1	2	3
	III	6	13	53	3	0	17	1	3	4
	IV	0	0	68	0	0	16	0	4	12
	V	0	0	62	0	0	23	3	5	7
	Average	5.2	11.8	52.0	2.2	0.4	17.0	1.6	3.4	6.4

Marking of the location of the pod's cracking as in the text.

moisture content occurred for those abdominal seams cracking near the stalk end (AS) for the Aura, Nida and Prosny cultivars, as well as for the dorsal seam cracking near the pod end for the Aura, Bor and Igołomska cultivars. No relationship between the pod splitting area and the moisture content was found for the dorsal seam cracking near the pod stalk for Nida and Prosna or for abdominal seam cracking near the pod stalk for the Bor cultivar.

A comparison of the frequency of the splitting of the individual seams (Fig. 1) leads to the conclusion that the abdominal seam of the pods of the Igołomska, Prosna and Aura cultivars was clearly more susceptible to cracking. It split at first in 85, 69.8 and 63.3% of pods, respectively. The dorsal seam, on the other hand, split over seven times more frequently in the Nida cultivar but insignificantly more often in the Bor cultivar. As first mentioned by Szwed [6], the frequent splitting of the abdominal seam may result from its geometry, as this seam is concave, and therefore a lower bending moment is able to split it. The dorsal seam on the other hand, is convex and is therefore less at risk of splitting by the inner stresses generated in the pod's shell during drying. The more frequent splitting of the dorsal seam in the Nida and Bor cultivars is indicative of its weaker internal structure.

In respect of the pod area (Table 3, Fig. 2) it was found that for the Aura, Igołomska and Prosna cultivars, the abdominal seam near the stalk (AS) cracked far more frequently than in the middle of the pod; (AM) cracked several times less frequently, and that near the pod end (AE) cracked least frequently. Pods of the Nida cultivar cracked most frequently

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