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Determination of the mechanical properties of blackcurrant shoots

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A b s t r a c t. In this study, the mechanical properties of blackcurrant shoots are expressed by means of shoot rigidity and elasticity coefficients determined in a bending test. The experiment was performed on one-, two- and three-year old shoots of the Titania and Ojebyn varieties. It was found that the determination of the mechanical properties of one-, two- and three-year old shoots contributed to the knowledge of the strength characteristics of shoots of blackcurrant shrubs. The studies also showed the differentiation between the varieties.

K e y w o r d s: rigidity, elasticity coefficient, shoot diameter, shoots of blackcurrant shrubs

INTRODUCTION

During combine harvesting of the blackcurrant, shoot damage is a frequent occurrence. The combine harvesters currently in use operate on the principle of fruit raking or shaking. Of the two, however, the shaking system is more frequently used and constantly improved. In combines of this type, pick-ups lift the shoots to an oblique position and at the same time the separator directs them into slots between the grilles. In the slots, the shoots are vibrated by the vibrating fingers of the shakers, and the fruits drop onto the moving conveyor belts.

The level of fruit loss and shrub damage depends primarily on the operating speed of the combine, on the amplitude at the tips of the shaker fingers, and on the shaking frequency [8]. Increased combine speed reduces harvest accuracy [1,2]. Increased amplitude and shaking frequency, on the other hand, improves the efficiency of shaking, but at the same time causes more extensive damage to the shrubs.

It is commonly known that the level of fruit loss and the extent of damage to the plants in a mechanical harvest depends on the specific properties of currant cultivars. A more accurate harvest is possible in the case of cultivars with stiff and long shoots and with short and medium long bunches. Shoot breaking and bark abrasion is related to the number of shoots in a shrub and to shoot elasticity [1].

The results of the three-year study, conducted in order to determine the effect of blackcurrant shoot damage on the crop yield in subsequent years, indicated significant relations between shoot damage occurring during mechanical harvest and the fruit crop obtained [3].

In this study the authors determined the mechanical properties of shoots of two blackcurrant cultivars, as expressed by the rigidity and coefficients of elasticity determined in the process of bending. They assessed the strength properties of the shoots of the blackcurrant cultivars under study, as well as the effect of shoot geometry, expressed by the cross section diameter, on the mechanical properties of the shoots.

MATERIAL AND METHOD

Methods for the determination of the mechanical properties of blackcurrant shoots have been developed for static tests [6]. To determine the mechanical parameters of blackcurrant shoots, it was necessary to perform tests on characteristic shoots of blackcurrant cultivars. The tests were performed on one-, two- and three-year old shoots of the Titania and Ojebyn cultivars originating from experiments at the Institute of Pomiculture and Floriculture, Skierniewice. In the first year of the experiments, two, one-year old shoots were chosen, characteristically growing out of a two-year old shoot; one was longer from the root (lateral shoot) and the other grew centrally from a two-year old shoot (central shoot). A similar procedure was followed the next year, when three-year old shoots were subjected to

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testing. Characterisation of the mechanical properties of the shoots was obtained in tests performed by means of an Instron strength tester.

It is worth mentioning that in earlier tests, an Instron strength tester was used to determine the mechanical parameters of rape stems, and the experiments helped in the determination of the strength characteristics of the stems of rape varieties grown under varied agrotechnical conditions [5,7].

In this study shoot rigidity (*EI*) and modulus of elasticity (*E*) were determined in the process of bending [6].The strength parameters were determined by bending shoot sections, 8 cm long, supported at both ends, the bending force being applied in the middle of the section length. The results were recorded by means of a computer system, using a program specially developed for the purpose. The moment of inertia (*I*) was determined for the circular section of the shoots. To determine the variability of the mechanical properties on the length of the shoots, measurements were taken at five points on the shoot length, from the base to the tip of the shoots. At the same time, the shoot diameter (d_a) was measured at the point of the application of the bending force, as the geometrical parameter determining the shoot thickness, that being necessary for the determination of the moment of inertia (*I*).

RESULTS AND DISCUSSION

The study permitted the characterisation of the mechanical parameters for two varieties of blackcurrant. The mean values of the parameters studied for one-year old shoots, two-year old shoots and tree-year old shoots are presented in Table 1, while the variability of the parameters along the length of the shoots is shown in Figs 1 and 2.

Table 1. Mean values of mechanical parameters of Titania and Ojebyn varieties: $\bar{x}$, median , W - coefficient of variability (%)

Measurements points on the length	Mechanical parameter								
	Shoots	One-year shoots (lateral)		Two-year shoots (central)		Two-year shoots (lateral)		Three-year shoots	
	Statistic parameter	$EI \times 10^5$ (N mm^2)	E (GPa)	$EI \times 10^5$ (N mm^2)	E (GPa)	$EI \times 10^5$ (N mm^2)	E (GPa)	$EI \times 10^5$ (N mm^2)	E (GPa)
					Titania				
1	$\bar{x}$	4.41	2.18	1.70	1.39	4.92	0.31	6.89	0.17
	median	4.31	2.00	1.80	1.33	4.11	0.24	6.94	0.15
	W	49	42	54	58	28	64	24	43
2	$\bar{x}$	3.29	2.21	1.76	1.66	3.91	0.66	7.86	0.25
	median	3.32	2.18	1.65	1.49	3.66	0.40	8.21	0.21
	W	53	28	55	33	19	98	25	48
3	$\bar{x}$	4.31	5.12	1.71	1.71	3.85	0.97	7.13	0.34
	median	3.51	5.04	1.27	1.81	3.63	0.56	6.83	0.29
	W	59	51	73	26	18	96	22	49
4	$\bar{x}$	3.99	7.08	1.24	1.83	3.56	1.06	6.88	0.69
	median	3.33	8.29	1.07	1.82	2.89	1.47	6.71	0.68
	W	66	45	65	40	34	62	19	45
5	$\bar{x}$	2.26	7.33	0.59	1.59	2.53	2.03	4.79	0.81
	median	2.28	6.91	0.53	1.27	2.58	1.93	4.98	0.76
	W	64	50	86	71	31	41	40	63
					Ojebyn				
1	$\bar{x}$	3.66	3.71	1.57	0.10	8.48	0.43	7.53	0.36
	median	3.78	3.88	1.82	0.12	8.23	0.42	7.05	4.21
	W	23	25	38	38	13	51	16	45
2	$\bar{x}$	3.07	4.25	1.10	0.15	11.03	0.86	11.02	0.67
	median	2.94	4.27	0.76	0.16	9.15	0.80	9.42	0.60
	W	35	27	57	27	61	75	42	57
3	$\bar{x}$	2.08	4.24	0.97	0.13	7.10	0.76	6.54	0.90
	median	2.10	4.10	0.78	0.12	7.46	0.61	6.73	0.76
	W	35	16	67	23	26	65	25	74
4	$\bar{x}$	1.19	3.79	0.71	0.13	4.61	0.92	4.77	1.10
	median	1.25	3.86	0.44	0.14	4.50	0.73	4.88	1.05
	W	38	22	69	27	28	56	39	43
5	$\bar{x}$	0.39	2.21	0.55	0.18	3.21	1.03	2.84	1.22
	median	0.34	2.14	0.40	0.20	3.01	0.92	2.61	1.18
	W	48	36	74	32	27	63	44	46

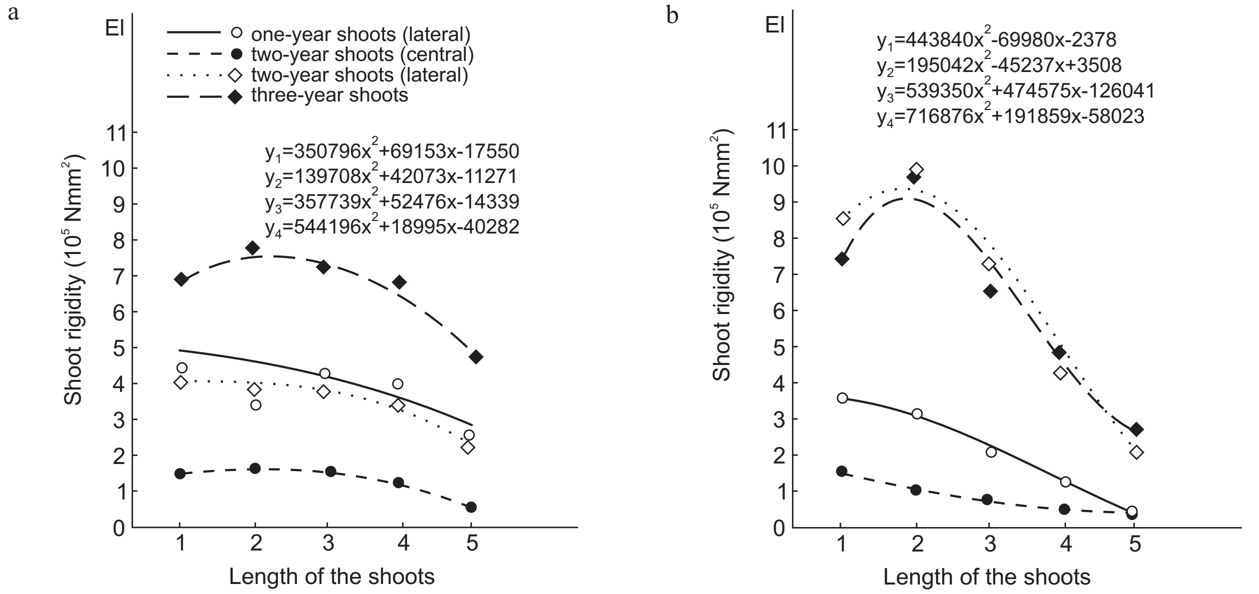

Fig. 1. Rigidity (*EI*) of the Titania (a) and Ojebyn (b) varieties at different parts of shoot (1...5 points on the length of shoots from the base to the tip).

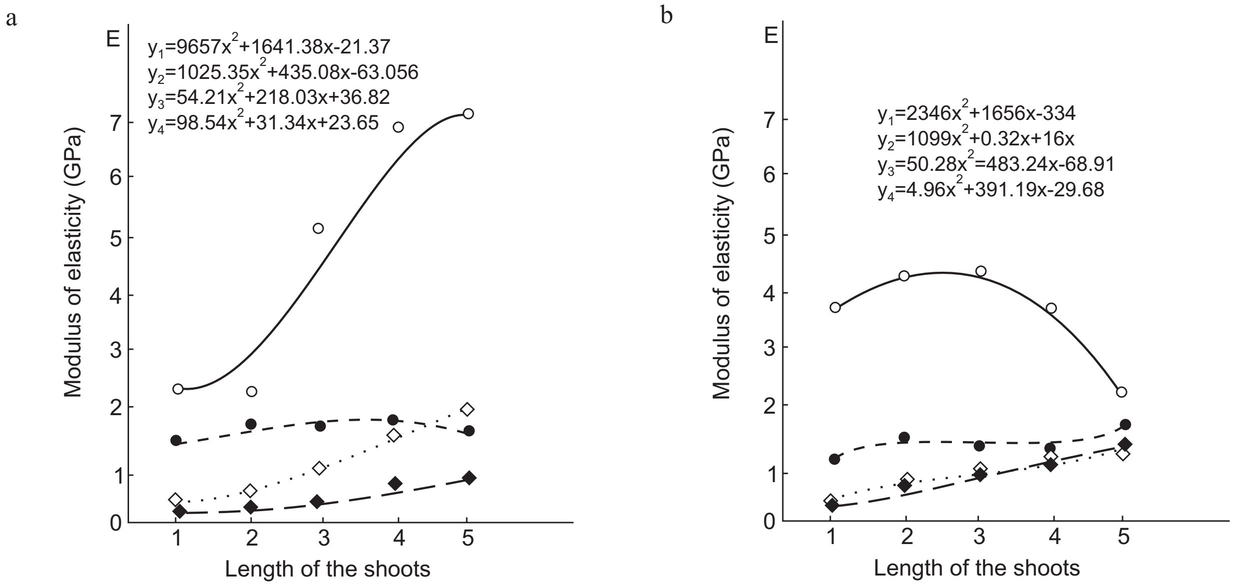

Fig. 2. Modulus of elasticity (*E*) of the Titania (a) and Ojebyn (b) varieties at different parts of shoot. Explanations as in Fig. 1.

Shoot rigidity was highest at the shoot base, and its values decreased in the direction from the base to the tip of the shoot (Fig. 1).

It was found that the shoot rigidity of the Titania cultivar, characterised by much thicker shoots, was much higher than the shoot rigidity of the Ojebyn cultivar. The shoot diameters of the blackcurrant cultivars under study fell within the following ranges for: Titania 4.7-17.3 mm, and Ojebyn 4.3-14.8 mm (Fig. 3). The study showed also a significant directly proportional correlation between shoot rigidity and diameter, particularly strong for one-year old shoots ($r_{0.05} = 0.58 – 0.93$).

It was found that the modulus of elasticity of the Ojebyn cultivar, as compared to that of Titania, was greater at the shoot bases (Fig. 2). Varied courses of variability were observed for the elasticity of one-year old shoots of the blackcurrant cultivars under study. The modulus of

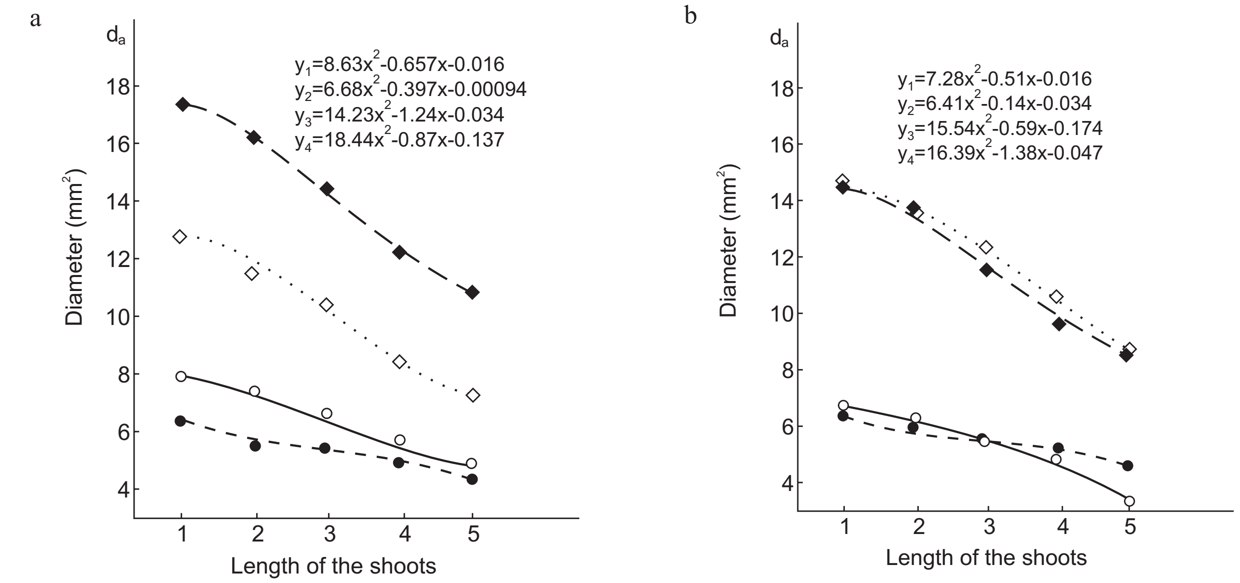

Fig. 3. Diameters (d_a) of the Titania (a) and Ojebyn (b) varieties at different parts of shoot. Explanations as in Fig. 1.

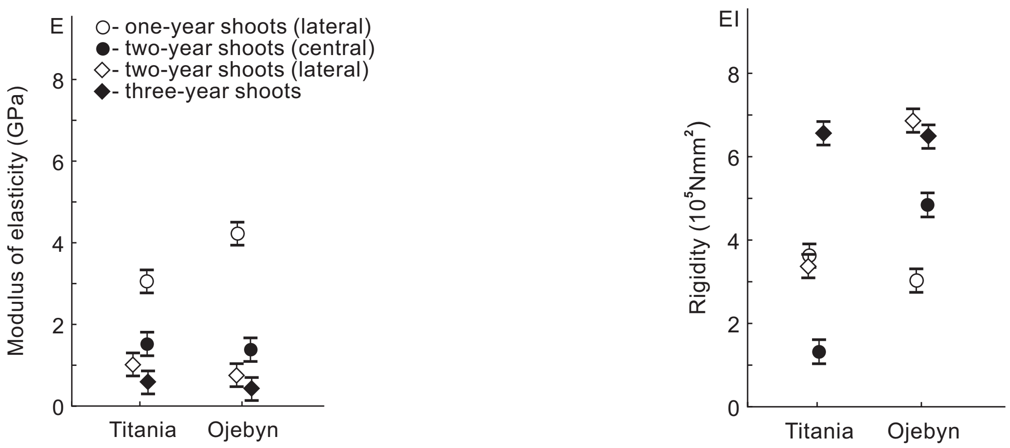

Fig. 4. Mean values and the 95% Tukey HSD intervals of the modulus of elasticity (*E*) and rigidity (*EI*) of shoots for varieties of the blackcurrant.

elasticity of Titania shoots was characterised by a strong increase in elasticity from the shoot base towards its tip, while the Ojebyn shoots showed a parabolic change in the values of the modulus of elasticity. A negative correlation was observed between the modulus of elasticity and the shoot diameter, particularly strong for the lateral two-year old shoots and for the three-year old shoots ($r_{0.05}$ = from –0.71 to –0.87).

Earlier studies showed that the mechanical behaviour of the plant stem as a whole can be explained almost entirely by means of its geometrical characteristics. It was found that rigidity at various points on the rape stem is related to the stem cross section surface area [4], and the variability of the modulus of elasticity on the length of winter wheat stalk is strongly related to the outer diameter of the stalk [7].

This study showed significant differences, confirmed statistically, between the mechanical properties of the shoots of two blackcurrant varieties (Fig. 4). This statement concerns the summary assessment for the three-year old shoots, and most of the shoots and mechanical parameters under analysis. The only exception is the varietal assessment conducted on the basis of the rigidity of three-year old shoots.

The study showed the existence of differentiation in the mechanical properties of the shoots of blackcurrant cultivars.

CONCLUSIONS

1. It was found that rigidity was characterised by values decreasing on the length of the shoots, while the modulus of elasticity increased in the direction from the base towards the tip of the shoot.

2. A significant relationship was observed between the rigidity and modulus of elasticity of shoots, and their thickness. The modulus of elasticity of one-year old shoots varied in a manner characteristic for the variety. A parabolic course of changes in elasticity on the length of the shoots was observed in the variety Titania.

3. Intervarietal differences between the blackcurrant cultivars were found especially in the rigidity and the modulus of elasticity on one- and two-year old shoots.

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