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CHEMICAL PREPARATIONS AFFECTING THE RESISTANCE OF RAPE SILIQUES TO CRACKING*

T. Rudko

Institute of Agrophysics, Polish Academy of Sciences, Doświadczalna 4, 20-236 Lublin, P.O. Box 121, Poland

A b s t r a c t. In the study the author presents the problem of winter rape silique cracking and seed shedding. In a three-year experiment (1992-1994), using two winter rape varieties - Ceres and Bolko, an assessment was made of the effect of four chemical preparations (Spodnam DC, Reglone, urea, starch) on the resistance of siliques to cracking. This unfavourable feature of rape can be either enhanced or weakened through the application of suitable preparations. An improvement in the resistance of siliques to cracking was observed after the application of Spodnam DC and urea (as additional nitrogen fertilization in the form of sprinkling with 10 % water solution). Desiccation of plants with Reglone had a negative effect on the strength properties of siliques, lowering their resistance to cracking. In comparison to the control, the effect of starch on the strength properties of siliques was statistically insignificant.

K e y w o r d s: winter rape, silique cracking, chemical preparations

INTRODUCTION AND REVIEW OF LITERATURE

Over the last decades, rape has become a plant of special interest. The reason for this is the constantly increasing demand for the seeds and products of oil-bearing plants. Among such plants, the production of rape has been expanding in the most dynamic manner. With a potential yearly production of 1.3 million t of seeds, Poland is one of the leading countries in the world as a rape producer.

The obtaining of erucic acid-less (single zero) rape varieties has been an enormous success of the breeders, followed in the next stage by doubly improved varieties (double-zero) which can be used to produce high quality consumption oil and middlings (thanks to the lowering of the content of erucic acid and glucosinolans). In this country, the transition to '00' varieties took place in 1985, when the Jantar variety was registered, characterized by a low content of glucosinolans. By 1994 nine varieties of this type were cultivated [3].

Rape seeds are produced primarily because of their high content of oil (40-45 %) and protein (18-22 %).

The phenomenon of pod cracking and seed shedding is determined genetically, as well as affected by environmental conditions. This phenomenon, unfavourable from the viewpoint of economy, applies to many species of the family of cruciferous and papilionaceous plants [1,4,12] as well as weeds [8].

The mechanism of silique cracking is explained by Garlicka and Tomaszewska [1,12] by means of an analysis of the morphological and anatomical structure of fruits cracking easily and not. The anatomical structure determines

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most of the internal stress within the silique. Non-uniform lignification and the different cellular wall thickness of inner parenchyma cause, in ripening, non-uniform drying of cells. The result of this are differences in stress which cause silique cracking.

The fruit of rape is the pod. It is a two-chamber, multi-seed fruit formed from two carpels, divided by a central septum to which the seeds are attached. During ripening, the fruit cracks along the seams; the two husks fall away, and the joined edges of the two carpels remain as a frame with a 'false' septum.

In rape cultivation, the tendency of the pods to crack is the source of seed losses, both spontaneous and resulting from the contact of the plant with the working elements of harvesting machinery. Multi-year studies conducted at the Institute of Agrophysics, Polish Academy of Sciences, showed that such losses can be from 3 to 20 % of the crop yield, depending on the variety, method and time of harvest, operating parameters of the harvesting machines, as well as other factors [9,11].

The need for a total, or at least a partial solution to the problem is also indicated by the fact that the double-zero varieties currently grown are characterized by an increased susceptibility to pod cracking, as compared to the single-zero or the traditional varieties of rape. Methods developed so far for the limitation of seed losses through the improvement of varieties, cultivation measures and harvest technology have eliminated the problem of seed losses only to a degree [9].

Studies showed that further limitation or prevention of the tendency of pods to crack can be achieved also through the application of various preparations in the form of plant spraying [10].

OBJECTIVE OF THE STUDY

The feature of fruit cracking and seed shedding applies to many plant species. This is especially notable among plants important for humanity, of the cruciferous family and the papilionaceous, highly numerous in the plant world, as well as among weeds. This phenomenon causes irreversible losses of the seeds of crop plants, and in the case of weeds - their proliferation.

The improvement of plant varieties, cultivation measures and harvest technology brought effects limiting the scale of the problem, though to various degrees with respect to various plant species.

A new direction in the research on the limitation of rape pod cracking is the application of chemicals reducing the tendency to pod cracking and seed shedding.

The objective of the present study was to determine the effect of selected chemical preparations on the strength properties of winter rape pods. Apart from the cognitive aspect, this is also of considerable practical significance.

MATERIAL AND METHODS

The susceptibility of pods to cracking was determined according to a number of methods:

- through analysis of the morphological and anatomical structure of fruits [1,12],
- on the basis of the number of seeds shed onto the soil surface or the number of young plants grown from shed seeds [7],
- by keeping the plants in the field even after full ripeness and then visually assessing the number of cracked pods [5],
- by subjecting the plants to the effect of the centrifuge [2],
- by determining the force causing pod cracking by bending the pod in a strength apparatus [6].

To determine the effect of chemical preparations on the strength properties of rape pods a plot experiment was set up. The experiment was localized at the Experimental Variety Evaluation Station in Zadąbrowie, Przemyśl Voivodship. The experiment was run for three years (1992-1994). The localization of the experiment was determined by the following factors: the soil - degraded chernozem developed from loess, classified in the very good wheat class, and very mild climatic conditions permitting multi-year experiments (reducing the problem of plant freezing).

The experiment was based on two varieties of winter rape:

- Ceres - a German '00' variety, grown in this country in the years of 1987-1993. This is an early variety,
- Bolko - a Polish '00' variety, registered in 1989. This is a late variety. Its distinguishing feature is the lowest content of glucosinolans among the European varieties [13].

Seeds were row-sown at a rate of about 90 seeds per m^2, which gave a sowing density at harvest of about 50 plants per m^2. The surface area of a single plot was 15 m^2 (10 m x 1.5 m). The rows were sown at a spacing of 30 cm, giving 5 rows per plot. A block system of experiment was applied - 5 blocks.

From the sowing through the whole period of vegetation typical cultivation measures were applied in the plots, special attention being paid to the protection of the plants from weeds and diseases.

Plant sprinkling with the Spodnam DC (1.25 dm^3/ha) and Reglone (2 dm^3/ha) preparations was performed at times recommended by the manufacturers. Urea, in the form of a 10 % water solution, was applied twice - after blooming and in the phase of formed green pods. Sprinkling with starch was applied at the beginning of technical ripeness. The above applications were performed using a back-strapped turbine-type sprinkler.

In full ripeness, pods were collected from the particular combinations of the experiment to determine their strength parameters. The pods were collected from the main stems and the upper branchings of the first row, at about 200 pods per combination.

Characterization of the preparations used

Spodnam DC

Active component - di-p-menthene [polymer of cyclohexane; 1-methyl-4-(1-methylethyl)]. A growth regulator, produced by Mandops Europa S.A., Belgium. It forms a semipermeable film inhibiting water intake from the outside. It prevents the cracking of siliques and pods of cruciferous and papilionaceous plants and the shedding of grass seeds. In Poland used only sporadically.

Urea - 10 % water solution

Carbonic acid diamide - $CO(NH_2)_2$. It is an organic compound well soluble in water. A popular nitrogen fertilizer. In the experiment used as additional nitrogen fertilization applied to the leaves.

Reglone

Active component - diquat dibromide (N N'-ethylene-2,2'- bipyridynum dibromide). Polish-produced, by Sarzyna-Organika (on a licence from J.C.J. Agrochemicals, Great Britain). Widely used for plant desiccation and defoliation. The preparation acts by damaging the cellular walls of the plant, the result of which is the dehydration of the cells and their withering.

Starch

Polysaccharide, main component of the endosperm, perisperm, and cotyledon of many crop plants. In the experiment starch was used in the form of sprinkling, at technical ripeness, as an impregnating-adhesive medium.

In the particular plots of the experiment, each of the preparations was applied separately, while in the control plots no measures were applied that would change the properties of the pods.

Strength test

The strength tests of the rape siliques were conducted according to a method developed at the Institute of Agrophysics, Polish Academy of Sciences [11], with modifications [9]. The method consists in torsional tests of the siliques and determining their strength parameters. The torsional tests were performed using a specially designed strength tester coupled to a computer.

The apparatus permitted the recording of the process of torsional tests and the calculation of the values of the parameters studied. Graphs and sets of data were obtained for each individual silique and for the particular

combinations of the experiment. A sample was constituted by 50 siliques selected at random. Five most extreme results were left out.

The method permitted the determination of the resistance of siliques to cracking with relation to the preparations applied and to the varieties tested, in the particular years of the experiment.

Eight strength parameters were determined:

- α - silique twist angle (rad),
- M_{max} - maximum torque at which the first crack of the silique occurred (Nmm),
- M_k - final torque at silique twist angle equal Π rad (Nmm),
- A - energy causing full cracking (opening) of the silique (mJ),
- A' - energy overcoming the elastic resistance of silique already cracked (mJ),
- A'' - energy of the first crack of the silique (mJ),
- ΔA - energy necessary to overcome the adhesion of the seams of the silique (mJ),
- R - index of silique resistance to cracking, calculated from the formula:

$$R = -0.42 + 0.21A' + 1.64\,A'' + 0.38\Delta A + 0.3\,M_{max} + 2.91\alpha$$

where the figures are values of the particular indices calculated according to the method of multiple linear regression.

RESULTS AND DISCUSSION

To investigate the effect of the preparations, the varieties and the years on the values of the strength parameters characterizing the resistance of the siliques to cracking, a three-factor analysis of variance was performed for each of the strength parameters. Prior to that, it had been checked that the parameters had distributions close to normal and their variances in samples for the particular combinations of the experiment did not show any strong differentiation. Each of the combinations of the experiment (preparations x varieties x years) was represented by the same number of measurements (r=45). In the assessment of differences between the mean values, Tukey's intervals of credibility were used.

The assessment of the strength parameters was performed to find out which one, or which ones best describe the chemical parameters and how strong are the relationships between the parameters. The author tried to eliminate parameters of low significance (poorly describing the preparations) and to isolate those parameters which were strongly correlated, and to select from among those one or two most important in the assessment of the resistance of siliques to cracking.

The results of the analyses of variance are presented in Table 1. The calculated coefficients of correlations were used to draw Fig. 1.

In the columns, the top line shows the level of significance of the given source of variability, and the bottom line the corresponding value of Tukey's semi-interval of credibility (95 %).

The graph presented in Fig. 1 has the following features:

1) All the ties in the graph (symbols of parameters) are connected (correlated);
2) Of special importance in the 'chain' seem to be those ties which correspond to parameters A and R as they join three ties each. It is known, however, that in fact parameter R is an index calculated on the basis of measured parameters, while parameter A is a sum of energies A', A'' and ΔA, and hence this apparent 'importance' of the ties.

The author adopted A' and M_{max} as the basic parameters describing the resistance of rape siliques to cracking. This was due to the fact that parameter A', i.e., the energy necessary to overcome the elasticity of the silique, is responsible for as much as 54 % of the total variability, and that the elasticity of plant materials was emphasized by other authors in studies on rape [6], lupine [4], or soya [14]. M_{max}, i.e., the maximum torque twisting a silique, is responsible for the total variability to a lesser degree - only 31 %. This parameter is determined at the moment of the first crack of the silique, which is why it is important from

Table 1. Results of the analyses of variance for the particular strength parameters of winter rape siliques

Strength parameters	M_{max}	α	M_k	A	A'	A''	ΔD	R
Part of total variability covered by the analysis of variance (%)	31	24	52	55	54	29	35	39
Varieties	—	***	***	***	***	***	***	***
	0.01	0.16	0.20	0.20	0.26	0.06	0.14	0.13
Years	***	***	***	***	***	***	***	***
	0.02	0.23	0.29	0.30	0.38	0.09	0.21	0.19
Preparations	***	***	***	***	***	***	***	***
	0.03	0.35	0.44	0.45	0.58	0.13	0.31	0.28
Var. x Years	***	***	—	***	*	***	***	—
	0.03	0.40	0.50	0.51	0.66	0.15	0.36	0.32
Var. x Prep.	***	—	***	**	***	**	***	***
	0.05	0.57	0.71	0.74	0.94	0.21	0.51	0.46
Years x Prep.	***	***	***	***	***	***	***	***
	0.06	0.75	0.94	0.97	1.24	0.28	0.67	0.60
Var. x Years x Prep.	***	***	***	***	***	***	***	***
	0.10	1.14	1.42	1.46	1.88	0.42	1.01	0.91

***- significance at the level of α = 0.001, ** - significance at the level of α = 0.01, * - significance at the level of α = 0.05, — no significance.

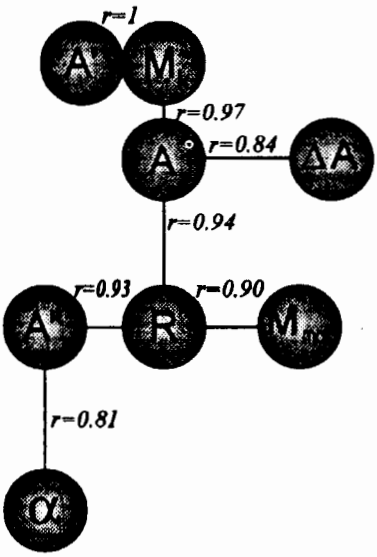

Fig. 1. The strongest relationships (correlations) between the strength parameters of rape siliques: r - coefficient of correlation, A', M_k, ... - symbols of the strength parameters.

the viewpoint of fruit cracking. A cracked silique is usually lost for the producer at the moment of harvest, and especially in the case of delayed harvest [9].

It should be added that the value of the twist angle α is a reference to the values of all the parameters and can be adopted as one of the parameters describing the resistance of the silique. However, it is not a substitute for M_{max} and A', as an interaction was observed between the preparations and varieties, which shows that it is not really suitable to describe the effect of the preparations.

The above supports the adoption of the two parameters (M_{max} and A') for the assessment of the effect of the particular preparations on rape siliques, with respect to varieties as well as years.

Table 2 presents the mean values and the standard deviations of M_{max} for the particular combinations of the experiment, and Table 3 the mean values and the standard deviations of A'.

Table 2. Mean values and standard deviations of the maximum silique twisting torque M_{max} [Nmm] for the particular combinations of the experiment

Variety	Year		Preparation				
			Control	Spodnam	Urea	Reglone	Starch
Bolko	1992	$\bar{x}$	4.07	6.99	4.51	3.54	3.75
		s	1.13	2.39	1.42	1.16	1.12
	1993	$\bar{x}$	4.58	4.59	5.20	3.72	4.85
		s	1.39	1.41	1.35	0.92	1.35
	1994	$\bar{x}$	3.77	4.90	4.65	3.59	4.65
		s	1.18	1.78	1.64	0.92	1.54
Ceres	1992	$\bar{x}$	4.10	5.95	4.27	3.71	5.05
		s	1.24	1.90	1.07	1.10	1.20
	1993	$\bar{x}$	6.36	6.24	6.84	5.16	5.36
		s	1.91	2.23	1.87	1.84	1.51
	1994	$\bar{x}$	4.08	5.27	5.57	3.37	4.03
		s	1.41	1.26	1.63	1.18	1.20

$\bar{x}$ - mean value, s - standard deviation. Values of the maximum twisting torque M_{max} for the preparations studied, in increasing order: Reglone - 3.85*, Control - 4.49, Starch - 4.61, Urea - 5.18**, Spodnam - 5.66**, * - significant decrease with relation to the control, ** - significant increase with relation to the control.

Table 3. Mean values and standard deviations of the energy of elasticity *A'* [mJ]

Variety	Year		Preparation				
			Control	Spodnam	Urea	Reglone	Starch
Bolko	1992	$\bar{x}$	3.59	8.20	5.25	3.02	3.52
		s	1.33	2.61	1.37	1.37	0.96
	1993	$\bar{x}$	6.31	6.94	8.83	5.45	9.25
		s	1.24	1.46	1.98	1.20	2.05
	1994	$\bar{x}$	7.54	8.95	8.46	6.65	8.55
		s	2.09	2.46	2.20	2.07	1.50
Ceres	1992	$\bar{x}$	4.40	7.50	4.85	3.60	6.23
		s	1.35	2.04	1.15	1.32	1.31
	1993	$\bar{x}$	8.44	7.40	9.74	7.51	8.42
		s	2.19	2.94	2.31	1.88	1.99
	1994	$\bar{x}$	9.32	8.62	8.01	9.66	8.02
		s	1.92	1.64	1.92	2.04	1.80

$\bar{x}$ - mean value, s - standard deviation. Values of energy necessary to overcome the elasticity of the silique *A'* [mJ] for the preparations studied, in increasing order: Reglone - 6.0*, Control - 6.6, Starch - 7.3**, Urea - 7.5**, Spodnam - 7.9**, * - significant decrease with relation to the control, ** - significant increase with relation to the control.

The values of M_{max} for Reglone are significantly lower than the control, and the values for urea and Spodnam are significantly higher than the mean value for the control. The starch preparation had an insignificant effect on that parameter as compared to the control. Therefore,

Table 4. Score points of the effectiveness of the preparations with respect to the resistance of siliques to cracking (parameter *A'*)

Preparation	Variety	Year			Effectiveness for varieties	Effectiveness of preparations
		1992	1993	1994		
Spodnam	Bolko	+5	+1	+1	+7	+8
	Ceres	+1	+1	-1	+1	
Urea	Bolko	+5	+5	+1	+11	+12
	Ceres	+1	+1	-1	+1	
Reglone	Bolko	-1	-5	-1	-7	-8
	Ceres	-1	-5	+1	-1	
Starch	Bolko	-1	+5	+1	+5	+8
	Ceres	+5	-1	-1	+3	

Where score of +5 or -5 signifies a significant increase or a significant decrease with relation to the control, respectively, while score of +1 or -1 signifies an insignificant increase or an insignificant decrease.

Table 5. Score points of the effectiveness of the preparations with relation to the control (parameter M_{max})

Preparation	Variety	Year			Effectiveness for varieties	Effectiveness of preparations
		1992	1993	1994		
Spodnam	Bolko	+5	+1	+1	+7	+16
	Ceres	+5	-1	+5	+9	
Urea	Bolko	+1	+1	+1	+3	+10
	Ceres	+1	+1	+5	+7	
Reglone	Bolko	-1	-1	-1	-3	-10
	Ceres	-1	-5	-1	-7	
Starch	Bolko	-1	+1	+1	+2	+1
	Ceres	+1	-1	-1	-2	

Where explanations as in Table 4.

Spodnam and urea are preparations effectively improving the resistance of siliques to cracking.

The adoption of parameter *A'* (Table 4) as an index of the effectiveness of the chemical preparation in their effect on the strength properties of siliques confirms that both Spodnam and urea effectively improve the resistance of siliques to cracking. Starch is less effective, while Reglone causes a significant deterioration in this respect. These results are similar to those obtained in the assessment of M_{max}.

As can be seen from Table 5, Spodnam has the strongest effect on the increase in the values of M_{max}. Urea is less effective, both of these preparations being more effective with respect to the Ceres variety. Reglone proved to have a markedly negative effect on the value of M_{max}. The starch preparation can be said to practically have zero effect.

Preparations most effectively improving the resistance of siliques to cracking were urea (especially with relation to the Bolko variety) and Spodnam. Similarly effective was starch, its effectiveness with relation to the two rape varieties being comparable. Reglone turned out to have a negative effect on the resistance of siliques to cracking, especially with relation to the Bolko variety.

CONCLUSIONS

The resistance of the siliques of winter rape plants (*Brassica napus* L.) to silique cracking and seed shedding can be enhanced or weakened through the application of suitable chemical preparations as follows:

1) An improvement in the resistance of rape siliques to cracking was observed after the

application of Spodnam DC. The increase in the values of the silique strength parameters measured, with relation to the control, was approximately 22 %.

2) The application of additional nitrogen fertilization by means of plant sprinkling with 10 % water solution of urea caused an 11 % to 20 % increase in the silique resistance to cracking, depending on the plant variety and the year of observation.

3) Rape plant desiccation with Reglone had a negative effect on the strength properties of siliques, causing a 13 % to 34 % decrease in their resistance to cracking in the particular years.

4) Starch, used in the experiment as an agent with an impregnating and adhesive effect on the silique, did not cause any statistically significant differences in the resistance of siliques to cracking.

5) It was found that the main strength parameters of the silique which describe its resistance to cracking are the maximum torque causing its first cracking and the value of energy necessary to overcome its elasticity.

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PREPARATY CHEMICZNE KSZTAŁTUJĄCE ODPORNOŚĆ ŁUSZCZYN NA PĘKANIE

W pracy niniejszej przedstawiono problem pękania łuszczyn i osypywania nasion rzepaku ozimego. W trzyletnim doświadczeniu (1992-1994) na dwóch odmianach - Ceres i Bolko, oceniano wpływ czterech preparatów chemicznych (Spodnam DC, Reglone, mocznik, skrobia) na odpomość łuszczyn na pękanie. Tę niekorzystną cechę rzepaku można wzmocnić lub osłabić przez zastosowanie odpowiednich preparatów. Stwierdzono poprawę odporności łuszczyn po zastosowaniu preparatu Spodnam DC oraz mocznika (jako dodatkowego nawożenia azotowego w postaci oprysku 10 % roztworem wodnym). Desykacja roślin rzepaku preparatem Reglone wpłynęła ujemnie na cechy wytrzymałościowe łuszczyn, obniżając ich odporność na pękanie. W porównaniu do kombinacji kontrolnej wpływ skrobi był statystycznie nieistotny na badane cechy wytrzymałościowe łuszczyn.

S ł o w a k l u c z o w e: rzepak ozimy, pękanie łuszczyn, preparaty chemiczne.