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DEVELOPMENT AND YIELD OF MORPHOLOGICALLY DIFFERENT GROUPS OF WINTER OILSEED RAPE CANOPY II. THE HARVEST INDEX VALUE DEPENDING ON THE CUTTING HEIGHT

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Abstract. The scientific literature rarely describes the harvest index of winter oilseed rape, most probably due to difficulties in its estimation, resulting from the cracking of siliques. Our work aimed at evaluating the harvest index of winter oilseed rape, depending on the cutting height of plants of different size categories, described in the 1st part of our work. Plants harvested from the field were dried, weighed and then 10 cm sections of the main shoot were cut off, simulating crop cutting during combine harvest. The obtained sections of plant shoots were weighed and a diameter of each was measured individually. Due to the specific distribution of dry mass in the lower section of the main shoot, an improvement of the harvest index value with raising the height of cutting the plants was obtained. Cuts at height of 60 cm increased the harvest index value by 0.08-0.09. Moreover, cutting oilseed rape at height of 60 cm is technically easier and fragments of the main and lateral shoots are left on the field as high stubble of an estimated mass of 1967.5 kg·ha^{-1}. Moreover, this technological solution may optimize harvesting, due to speeding it up.

Keywords: hybrid cultivar, branch of oilseed rape, oilseed rape stubble, shoot diameter

INTRODUCTION

Winter oilseed rape (WOR) is the leading oil species in the cooler climatic zones of Europe. Unfortunately, as evidenced by Kaczmarek *et al*. [2003], a varied genotype--environmental reaction of WOR cultivars depends on the soil and weather conditions

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in a particular location and growing season, which indicates the desirability of determining the productivity of this plant cultivars in several areas.

Harvest index value introduced by Donald and Hamblin [1976] is widely used in breeding and cultivation of agricultural crops, mainly cereals. As compared with cereals, the specification of WOR harvest index value should be evaluated as sparse. Diepenbrock [2000] reports the value of harvest index of WOR crop in the range of 0.25-0.3, that is equal to the above-ground dry matter yield of 20 $t \cdot ha^{-1}$, accompanied by a seed yield of 5 $t \cdot ha^{-1}$. Huehn [1993] estimated harvest index range from 0.22 to 0.34, in conditions of northern Germany (Schleswig-Holstein) for 10 varieties and strains of WOR, whereas individual fluctuations ranged more widely, i.e. from 0.16-0.41. Currently, Scott *et al*. [1999] empirically determined the harvest index of WOR cv. Apex in the conditions of central England, in the range 0.26-0.3. However, it may be presumed that the value of harvest index of WOR cultivars can vary to some extent, depending on the climatic conditions and soil properties in the area of rape growing. Taking into account repeatedly varying heights of rape plants in different years and locations, as well as the degree of plants branching, a diversified harvest index can be also expected. So far, no studies have been undertaken to assess the impact of WOR crop cutting height during combine harvesting on the value of harvest index. It should be noted that under field conditions, the measured height of winter rape plants varies widely. Therefore there are options of varied cutting of plants during harvesting. This may change the value of harvest index within wide limits, which so far have been difficult to estimate. The increased rate of deflection, as well as a strong lodging of WOR canopy, can force a reduction of the cutting height of plants at harvest.

The present study aimed at assessing the harvest index value, depending on the height of plant cutting.

MATERIAL AND METHODS

Localization of experiments, as well as the weather conditions, fertilization and chemical protection of WOR were presented in the 1st part of paper [Zając *et al.* 2013].

The number of plants was determined in two two-meters-long rows to assess the number of plants and their production category: small, medium and large, based on the number of lateral branches: small – 1 to 4, medium – 5 to 7 and large ≥ 8 branches. Plants harvested from the field were dried in a ventilated room for one month. Air-dried oilseed rape plants were weighed and then 10 cm sections of the main shoot and lateral branches were cut off simulating crop cutting during a combined harvest. The obtained sections of plant shoots were weighed and a diameter of each was measured individually by electronic calipers Yato®. Then from each of plant shoot fruiting parts three siliques were selected, one from the lower, middle and upper part, using the procedure described in the paper of Zając *et al*. [2011b]. Collected siliques were placed individually in labeled string bags. Other siliques from the plants were harvested as a bulk sample and collectively weighed, their seeds were collected in a cuvette and also weighed. The vegetative parts of plants, ranging from 60 cm upwards, were weighed as well.

The value of harvest index was calculated for each single WOR plant using the formula given by Donald and Hamblin [1976] and Huehn [1993].

The obtained data were statistically analyzed, using three way ANOVA, Statistica® 9.0 [StatSoft 2009]. Tables and figures in the text present the main effects and chosen, significant interactions. The significance of differences was determined by Tukey's test.

RESULTS

Harvest index value in the range of compared factors (Table 1) was not significantly diversified, especially the inter-varietal differences were slight and not directed. Obtained values of this index referring to new WOR cultivars, i.e. Poznaniak and Adam, should be regarded as interesting. The above mentioned harvest index for the whole plants oscillated about 0.4, i.e. a desired value. Interesting arrangement of harvest index results was revealed for the localities. Higher rapeseed plants in Głubczyce were characterized by a higher harvest index value in comparison with lower plants grown in Prusy, which, at the same time, were more bulky, however these were statistically non--significant differences (Table 1). Such a configuration of values evidences that developing adaptation of a cultivar to a given locality changes harvest index value. Direct comparison of cutting heights assumed for oilseed rape plants during harvest was unable to markedly change harvest index assessed at determined cutting heights.

Table 1. Winter rapeseed harvest index depending on assumed cutting height, considering cultivar, locality and identified plant groups

Factor	Treatment	Height of plant cutting, cm							$LSD_{0.05}$
		0	10	20	30	40	50	60	
Cultivar	Poznaniak	0.41	0.43	0.44	0.45	0.46	0.47	0.49	0.033***
	Adam	0.39	0.41	0.42	0.44	0.45	0.46	0.47	0.050*
	$LSD_{0.05}$	ns	ns	ns	ns	ns	ns	ns	–
Localities	Głubczyce	0.43	0.45	0.46	0.47	0.48	0.50	0.51	0.038**
	Pawłowice	0.40	0.41	0.43	0.44	0.45	0.46	0.48	ns
	Prusy	0.38	0.39	0.41	0.42	0.43	0.44	0.46	0.036**
	$LSD_{0.05}$	ns	ns	ns	ns	ns	ns	ns	–
Plant groups	small	0.37	0.38	0.40	0.41	0.43	0.44	0.46	0.054*
	medium	0.42	0.44	0.45	0.46	0.48	0.49	0.50	0.034***
	large	0.42	0.43	0.44	0.45	0.46	0.48	0.49	ns
	$LSD_{0.05}$	ns	ns	ns	ns	ns	ns	ns	–

significance levels: * 0.05, ** 0.01, *** 0.001
ns – non-significant differences

However, systematic increasing WOR plant cutting height led to optimization of harvest index (Table 1). In all the localities cutting WOR plant at the height of 60 cm improved harvest index value by between 0.08 and 0.09. Systematic growth of this index value indicates that technical conditions of winter oilseed rape harvest are an important correcting factor. The obtained results clearly show the advantages of increasing WOR canopy cutting height leading to an increasingly higher stubble mass left on the field, which most probably facilitates and accelerates combine harvesting of this oil plant, currently so important for Europe. In Głubczyce winter oilseed rape plant cutting on the height of 50 or 60 cm allowed to obtain harvest index on the level of 0.5 and 0.51, which is important for precise harvest and proper understanding of it consequences (Table 1).

Diversification of WOR plant cutting height during harvest caused that various amounts of aboveground biomass were left on the field as stubble (Table 2). Lower parts of the main shoot had the main share in the stubble mass, whereas the share of lateral branches was low. Cutting heights of 10, 20, 30, 40, 50 and 60 cm assumed during harvest caused that following amounts of air-dried dry mass were left on the field, respectively: 387, 752, 1092, 1697 and 1968 kg·ha^{-1}.

Table 2. Mass of 10 cm long sections of main shoot and lateral branches on individual cutting levels depending of cultivar, locality and identified plant groups

Factor	Treatment	0-10	10-20	20-30	30-40	40-50	50-60	$LSD_{0.05}$
				Main shoot, g				
Cultivars	Poznaniak	1.50	1.08	0.93	0.82	0.66	0.57	0.473**
	Adam	1.72	1.22	1.01	0.86	0.74	0.59	0.633*
	$LSD_{0.05}$	ns	ns	ns	ns	ns	ns	–
Localities	Głubczyce	1.06	0.83	0.74	0.66	0.59	0.52	ns
	Pawłowice	1.58	1.30	1.10	0.96	0.83	0.71	ns
	Prusy	2.19	1.34	1.07	0.89	0.68	0.50	0.835**
	$LSD_{0.05}$	ns	ns	ns	ns	ns	1.695	–
Plant groups	small	0.79	0.58	0.51	0.46	0.44	0.39	0.107***
	medium	1.47	1.04	0.88	0.81	0.63	0.51	0.239***
	large	2.57	1.84	1.53	1.24	1.02	0.83	0.709***
	$LSD_{0.05}$	0.875	0.459	0.321	0.279	0.217	0.213	–
				Lateral branches, g				
Cultivars	Poznaniak	0.050	0.178	0.173	0.163	0.137	0.348	ns
	Adam	0.300	0.243	0.234	0.199	0.179	0.482	ns
	$LSD_{0.05}$	ns	ns	ns	ns	ns	ns	–
Localities	Głubczyce	0.050	0.065	0.095	0.080	0.098	0.193	ns
	Pawłowice	–	0.120	0.126	0.157	0.141	0.278	ns
	Prusy	0.300	0.268	0.283	0.235	0.206	0.665	0.5820
	$LSD_{0.05}$	–	ns	ns	ns	ns	0.3614	–
Plant groups	small	–	0.030	0.060	0.082	0.064	0.144	ns
	medium	–	0.100	0.090	0.095	0.097	0.196	0.103**
	large	0.175	0.272	0.289	0.264	0.231	0.657	0.315**
	$LSD_{0.05}$	–	ns	ns	0.1412	0.1037	0.3841	–

explanations under Table 1

Mass of the main shoot and lateral branches sections is presented in Table 2. According to expectations, 10 cm-long stem sections in the lower parts of plants had the largest mass. Moving upwards along the stems, the mass of section was decreasing systematically. Compared cultivars of winter oilseed rape did not differ with the mass of main and lateral shoots. Rape plats in Głubczyce had a significantly higher mass of the main shoot in the 50-60 cm range. This arrangement referring to the mass of 10 cm-long sections was most probably due to a bigger plant height in this locality, which led to a lower decrease in diameter and consequently mass. On the other hand, oilseed rape plants in Prusy, although lower, still formed lateral branches of a bigger mass. A similar regularity was observed also for the total mass of a single silique. It should be emphasized that although large plants developed about 4 times more siliques than the small ones, the mass of 10 cm-long sections of the main shoot above 30 cm was not analogous. Sections of lateral branches above 30 cm from the soil surface did not differ significantly. Large oilseed rape plants produced more bulky lateral branches which gave a bigger mass of the 10cm long sections of lateral branches (Table 2).

Table 3 presents diameters of main shoot sections starting from the soil surface to 60 cm of its length, which was systematically diminishing towards the stem top. Cv. Adam had a bigger diameter of the main shoot and lateral branches in comparison with cv. Poznaniak, which resulted from a specific character of its development. Large WOR plants had main shoot diameters significantly higher in comparison with the other groups identified with the agrophytocenosis of this species.

Table 3. Diameter of main shoot and lateral branches sections on individual cutting levels depending on cultivar, locality and identified plant groups, mm

Factor	Treatment	0-10	10-20	20-30	30-40	40-50	50-60	$LSD_{0.05}$
Main shoot								
Cultivars	Poznaniak	9.69	9.20	8.53	7.85	7.06	6.41	0.619***
	Adam	9.11	8.46	7.91	7.35	7.00	6.14	0.859***
	$LSD_{0.05}$	ns	ns	ns	ns	ns	ns	–
Localities	Głubczyce	8.55	8.20	7.69	7.89	7.45	7.08	0.679***
	Pawłowice	10.20	9.40	8.93	7.92	7.23	6.44	1.068***
	Prusy	9.46	8.89	8.03	6.97	6.41	5.31	0.868***
	$LSD_{0.05}$	1.242	ns	0.859	0.812	0.644	0.536	–
Plant groups	small	7.12	6.70	6.54	5.99	5.84	5.46	0.380***
	medium	8.67	8.44	8.07	7.53	7.01	5.95	0.333***
	large	12.42	11.34	10.05	9.27	8.24	7.42	0.692***
	$LSD_{0.05}$	0.564	0.516	0.498	0.476	0.456	0.493	–
Lateral branches								
Cultivars	Poznaniak	3.90	4.51	4.23	4.02	3.73	3.66	ns
	Adam	5.00	4.61	4.77	4.53	4.36	4.46	ns
	$LSD_{0.05}$	ns	ns	ns	ns	ns	0.698	–
Localities	Głubczyce	3.90	3.96	3.87	3.95	3.86	3.78	ns
	Pawłowice	–	5.01	4.41	4.31	4.01	3.96	ns
	Prusy	5.00	4.67	4.78	4.37	4.12	4.24	ns
	$LSD_{0.05}$	ns	ns	ns	ns	ns	ns	–
Plant groups	small	–	1.86	2.05	2.45	2.70	3.05	ns
	medium	–	4.31	4.35	4.22	3.92	3.86	ns
	large	4.45	5.08	5.01	4.87	4.52	4.47	ns
	$LSD_{0.05}$	–	ns	1.663	1.044	0.903	0.935	–

explanations under Table 1

Interdependences of variable strength occurred between the mass of the main shoot or lateral branches sections (Fig. 1). Considering the main shoot, the interdependence of a pair of correlated features remained on a satisfactory level, because R^2 values computed for determined WOR cutting heights were higher than 0.6. For the main shoot the mass and diameter of shoot sections were linearly, powerfully or exponentially interdependent. Considering the lateral branches, the connection of these features was satisfactory for the low cutting. When the cutting height was exceeded on the level of 30 cm, the interdependence of this pair was moderate, whereas the causative agent was increasing the number of sections in this shoot category of different mass but constant length of 10 cm.

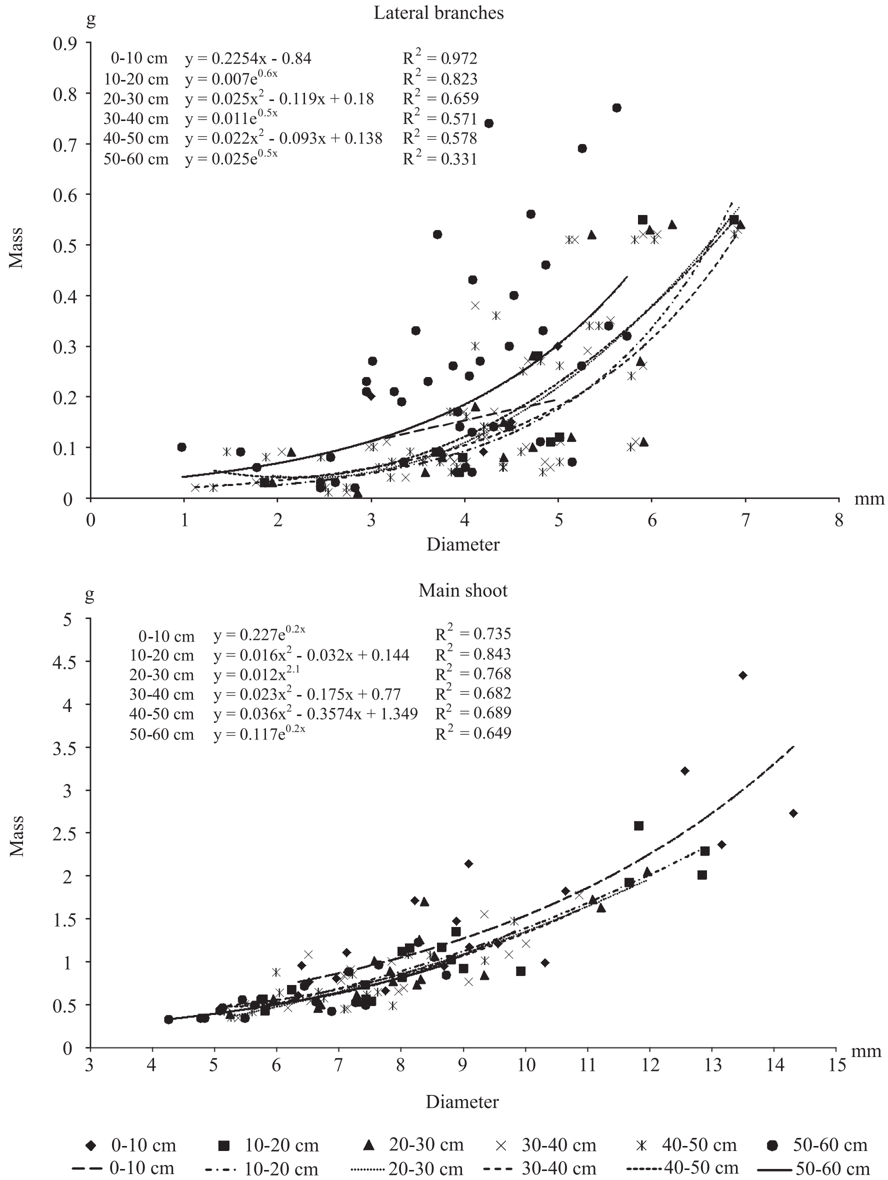

Fig. 1. Interdependences between the mass of 10 cm long sections of the main shoot and lateral branches and their diameter

DISCUSSION

Presentation of a different productive potential of separated oilseed rape plant groups was justified, because they significantly determined the values of harvest index. Empirically established harvest index values for Adam and Poznaniak oilseed rape cultivars were, respectively: 0.41 and 0.39 $g \cdot g^{-1}$ of air-dried mass. In confrontation with the subject data, they may be regarded as astonishingly high. Previous data reported by Huehn [1993] and Diepenbrock [2000] show harvest index values between 0.25 and 0.3. Scott *et al*. [1999] registered harvest index values in a similar range: 0.26-0.3 for winter oilseed rape, cv. Capricorn cultivated under conditions of central England; it was accompanied by the number of siliques, respectively 6800-8400 pieces per $1 m^2$. In the above research, components of the aboveground rape dry mass yield were as follows: stems 5-6, seeds and siliques c.a. 4.5 $t \cdot ha^{-1}$. Under sub-arid conditions of Iran, Siadat and Hemayati [2009] obtained lower values of harvest index for rape, on the level of 0.2 and the compared cultivars did not differ significantly. Increasing cutting height of rape plants led to an improvement of harvest index for plants. In Głubczyce at the cutting height on the level of 50-60 cm it was 0.50 and 0.51.This range of WOR values is identical with harvest index characteristic for currently cultivated short straw cereal cultivars [Zając *et al*. 2013]. Medium and large WOR plants revealed a tendency for a better harvest index than small plants. This arrangement of harvest index values on the agrobiology level indicates less dense winter oilseed rape sowing (optimal level), corresponding to the 40-50 plants per 1 m^2. Zając *et al*. [2011a] state a similar trend of relations, which revealed itself in the plant population of low-morphine poppy canopy differing in the number of formed poppy-heads from 1-6. It was empirically demonstrated that few very large and large plants in the canopy, developing respectively 5 and 4 poppy heads, had a slightly better index in comparison with plants having 1 poppy head and constituting a majority, 70% of the phytocenosis. Intensity of separating plant groups in poppy canopy, diversified as to their development and productivity, depended on the date of sowing and year of growth. Separating plant groups from the population of winter oilseed rape and poppy, representing taxa from various botanical families, points to a certain development universalism, so far disregarded in scientific research.

Elevating the cutting heights of WOR led to cutting plants of an increasingly smaller diameter of the main shoot. Also lower sections, particularly of the main shoot of large plants, were of a considerable diameter and high mass per length unit, therefore leaving them on the field as stubble undoubtedly diminished the time and labour outlays on the technological operation, i.e. combine harvest.

CONCLUSIONS

Due to the specific distribution of dry mass in the lower sections of the main shoot an increasing height of plant cutting during harvest led to improvement of harvest index value. Elevating the height of winter oilseed rape plant cutting to 60 cm improved harvest index value by between 0.08 and 0.09. Moreover, cutting oilseed rape plants on the level of 60 cm is easier due to leaving on the field thicker fragments of the main shoots and lateral branches as high stubble with an estimated mass of 1967.5 $kg \cdot ha^{-1}$. Such a technological solution may optimize harvest facilitating and accelerate this activity.

Acknowledgements

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REFERENCES

Diepenbrock W., 2000. Yield analysis of winter rape (*Brassica napus* L.): a review. Field Crops Res. 67, 35-49.

Donald C.M., Hamblin J., 1976. The biological yield and harvest index of cereals as agronomic and plant breeding criteria. Adv. Agron. 28, 361-405.
Huehn M., 1993. Harvest index versus grain/straw ratio. Theoretical comments and experimental results on the comparison of variation. Euphytica 68, 27-32.
Kaczmarek J., Kotecki A., Kotowicz L., Weber L., 2003. Genotype – environmental interaction in yield of winter rape in post registration variety trials. Biul. IHAR 226/227, 395-403.
Scott R.K., Stokes D.T., McWilliam S.C., Spink J.H., Clare R.W., 1999. Yield improvement through canopy management. Proc. 10th Int. Rapeseed Congress, Canberra, Australia.
Siadat S.A., Hemayati S.S., 2009. Effect of sowing date on yield and yield components of three oilseed rape varieties. Plant Ecophysiol. 1, 31-35.
StatSoft Inc., 2009. STATISTICA (data analysis software system), ver. 9. www.statsoft.com
Zając T., Kulig B., Oleksy A., Stokłosa A., Styrc N., Pyziak K., 2013. Development and yield of morphologically different groups of winter oilseed rape canopy. I. Productivity and morphology of plants. Acta Sci. Pol., Agricultura 12(1), 45-56, www. agricultura.acta.utp.edu.pl
Zając T., Oleksy A., Klimek-Kopyra A., 2011a. Comparison of growth and productivity of the low morphine poppy *Papaver somniferum* L. cv. 'Mieszko' depending on the sowing date. Acta Agrobot. 64, 67-78.
Zając T., Oleksy A., Stokłosa A., Klimek-Kopyra A., 2011b. Comparison of morphological traits, productivity and canopy architecture of winter oilseed rape (*Brassica napus* L.) and white mustard (*Sinapsis alba* L.). J. Appl. Bot. & Food Qual. 84, 183-191.
Zając T., Oleksy A., Stokłosa A., Klimek-Kopyra A., Macuda J., 2013. Vertical distribution of dry mass in cereals straw and its loss during harvesting. Int. Agroph. 27(1), 89-95.

ROZWÓJ I PLONOWANIE ZRÓŻNICOWANEGO MORFOLOGICZNIE ŁANU RZEPAKU OZIMEGO II. KSZTAŁTOWANIE SIĘ INDEKSU ŻNIWNEGO W ZALEŻNOŚCI OD WYSOKOŚCI KOSZENIA

Streszczenie. W dostępnej literaturze związanej z rzepakiem ozimym niezbyt często określano wartość wskaźnika plonowania rolniczego (harvest index), zapewne ze względu na utrudnienia wywołane wielką łatwością pękania łuszczyn. Celem badań była ocena kształtowania się wartości wskaźnika plonowania rolniczego w zależności od wysokości cięcia różnych kategorii produkcyjnych roślin rzepaku ozimego, które omówiono w I części pracy. Rośliny zebrane z pól produkcyjnych suszono, ważono, a następnie odcinano 10-centymetrowe fragmenty pędów, symulując różne wysokości cięcia kombajnowego. Odcięte fragmenty ważono i mierzono ich średnicę. Ze względu na specyficzne rozłożenie suchej masy w dolnych odcinkach pędu głównego rzepaku, podwyższanie wysokości cięcia roślin w czasie zbioru żniwnego wpływało na poprawę wartości indeksu żniwnego. Cięcie roślin rzepaku ozimego na poziomie 60 cm podniosło wartości indeksu żniwnego o 0,08-0,09. Cięcie roślin rzepaku na poziomie 60 cm wydaje się technicznie łatwiejsze, z uwagi na fakt pozostawienia na polu grubszych fragmentów pędów – głównego i bocznych, w formie wysokiej ścierni, o szacunkowej masie 1967,5 $kg \cdot ha^{-1}$, a takie rozwiązanie technologiczne może optymalizować zbiór w czasie żniw poprzez przyspieszenie wykonalności tej czynności.

Słowa kluczowe: odmiana mieszańcowa, pęd rzepaku, ścierń rzepaku, średnica pędu

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