

Stanisław CEBULA<sup>1</sup>, Stanisław MAZUR<sup>2</sup>  
and Andrzej KALISZ<sup>3</sup>

**EVALUATION OF PRODUCTIVE VALUE  
OF SEVERAL WHITE CABBAGE CULTIVARS  
RESISTANT TO CLUBROOT (*Plasmodiophora brassicae* WOR.)**

**OCENA WARTOŚCI UŻYTKOWEJ  
KILKU ODMIAN KAPUSTY GŁOWIASTEJ BIAŁEJ  
ODPORNYCH NA KIŁĘ (*Plasmodiophora brassicae* WOR.)**

**Abstract:** In a 3-year experiment three late cultivars of clubroot-resistant white cabbage: 'Kilafur F<sub>1</sub>', 'Kilaton F<sub>1</sub>' and 'Kilaxy F<sub>1</sub>' were compared with 3 standard cultivars: 'Blokator F<sub>1</sub>', 'Kingston F<sub>1</sub>' and 'Novator F<sub>1</sub>'. The experiment was located on a stand where in the previous year also cabbage was cultivated. During vegetation the degree of plants affected by clubroot was determined. Yield as well as commercial and nutritional quality of cabbage heads were evaluated.

In all three years of the experiment it was demonstrated that clubroot-resistant cultivars were not at all affected by *Plasmodiophora brassicae* pathogen while other cultivars were affected to a varied degree. High commercial yield of clubroot-resistant cultivars and a very good head quality were obtained. In the same conditions, non-resistant cultivars demonstrated a significantly lower yield level.

**Keywords:** white cabbage, clubroot, resistant cultivars

White cabbage is a basic vegetable species grown in Poland [1]. High concentration of cultivation in certain regions results in a considerable increase of the occurrence of clubroot, the most arduous and difficult to control pathogen for this vegetable group. Among preventive measures against clubroot agrotechnical methods, such as crop rotation or calcium fertilization dominate [2]. Apart from these, fungicides are also used to pickle seedlings or disinfect soil. These methods are not always effective [3, 4]. Thus, since long, scientists have concentrated on searching for such genetic resistance which

<sup>1</sup> Department of Vegetable Crops, University of Agriculture in Krakow, al. 29 Listopada 54, 31-425 Kraków, Poland, phone: +48 12 662 5218, email: scebula@ogr.ar.krakow.pl

<sup>2</sup> Department of Plant Protection, University of Agriculture in Krakow, al. 29 Listopada 54, 31-425 Kraków, Poland, phone: +48 12 662 5254, email: smazur@ogr.ar.krakow.pl

<sup>3</sup> Department of Vegetable Crops, University of Agriculture in Krakow, al. 29 Listopada 54, 31-425 Kraków, Poland, phone: +48 12 662 5214, email: andy@ogr.ar.krakow.pl

would provide full protection against the infection caused by *Plasmodiophora brassicae* fungus. Extensive breeding researches culminated in a spectacular success, namely creating, by Syngenta Seeds Corporation, of several cultivars resistant to most usual on the European continent clubroot races [5]. The introduction of such cultivars to the production of cabbage is the most rational and effective method of protection against clubroot. At the same time, such cultivars should possess important use features, such as good productivity and, in particular, high commercial and nutritional values of the heads [6–8].

In the present experiment the actual susceptibility to clubroot of several such cultivars of white head cabbage was checked in field conditions. At the same time the attempt was made to assess their yielding and quality as compared with other popular cultivars.

## Materials and methods

Field experiment was carried out in the years 2005–2007 on the site where cabbage was grown in a previous year. Three late cultivars of clubroot-resistant white cabbage were compared, ie ‘Kilafur F<sub>1</sub>’, ‘Kilaton F<sub>1</sub>’ and ‘Kilaxy F<sub>1</sub>’ with three standard cultivars having a comparable vegetation period and growth pattern: ‘Blokator F<sub>1</sub>’, ‘Kingston F<sub>1</sub>’ and ‘Novator F<sub>1</sub>’.

Seeds were sown to multipots (palettes of 96 cells each) filled with peat substrate in the first half of April (11, 6 and 12, respectively in consecutive years) and cabbage seedlings were planted out to the field in the first half of May (12, 8 and 9, respectively in consecutive years). The experiment was established in randomized blocks with four replications. Plants were planted in 67.5 × 40 cm distance into plots of the area of 10.8 m<sup>2</sup> (40 plants). Measurements were carried out on 32 plants of each plot, excluding side rows.

During the growth period plants were weeded and they were fertilized with nitrogen. When necessary plants were watered and protected against diseases and insect pests.

During vegetation, the percentage of plants affected with clubroot was assessed using a 6-point scale, ie: 0 – healthy plant; 1 – first symptoms of disease, wilting; 2 – more noticeable symptoms, wilting and yellowing of leaves; 3 – clearly noticeable symptoms, delayed growth, wilted or yellowed leaves; 4 – strong symptoms, inhibited growth, yellowed or lacking leaves; 5 – plant completely diseased, dried or lacking.

Heads were harvested in mid-October (between 8 and 18 in individual years). At harvesting yield was assessed by determining the mass and number of cabbage heads as per quality grades (I, II and unmarketable). Commercial quality (mean weight, yield structure) and consumption quality (dry matter, sugars, L-ascorbic acid, chlorophylls and carotenoids content) of cabbage heads were an important element in assessment process. Dry matter was determined using hair-dryer method at 95 °C, sugars after inversion with Luff-Schoorl method, L-ascorbic acid with Tillmans method, and chlorophylls and carotenoids with Lichtenthaler method.

The obtained results were compared as averages from three years of the experiment and subjected to statistic analysis with variation method at  $p = 0.05$ .

## Results and discussion

The most important result obtained in this study was the finding that in all the years of the experiment cultivars 'Kilafur F<sub>1</sub>', 'Kilaton F<sub>1</sub>' and 'Kilaxy F<sub>1</sub>' were not, even to the smallest degree, affected by clubroot. Not a single plant of clubroot-resistant cultivars was infected by *Plasmodiophora brassicae* pathogen, whereas the remaining cultivars were affected to a varied degree.

Most attacked plants (Fig. 1) were found for 'Kingston F<sub>1</sub>' cultivar (86.0 %) with affection degree varying from first symptoms (8.5 %) to total disease (25.0 % of the whole population). 'Blokto F<sub>1</sub>' cultivar was affected to the smallest extent, however also in this case as many as 55.4 % of plants were diseased. Complete lack of affection of clubroot-resistant cultivars in three consecutive years of the experiment at varied weather conditions and in the direct vicinity of standard cultivars, which showed strong clubroot symptoms, confirms the success of resistant cultivar breeding.

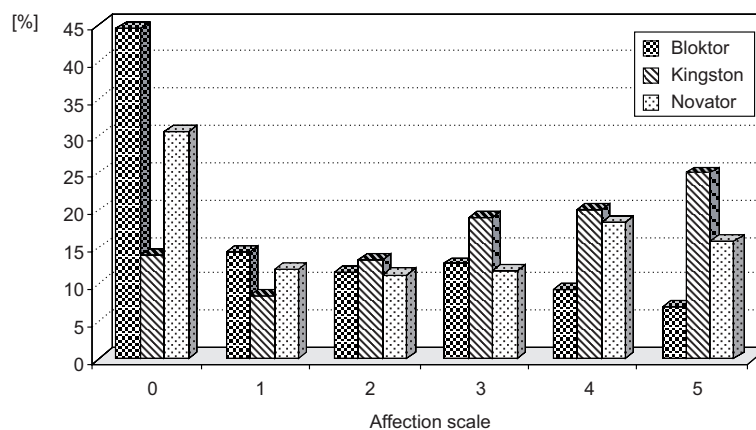


Fig. 1. Percentage of non-resistant cultivar plants affected by clubroot; 0–5: affection scale, for description see Materials and methods

In effect, clubroot-resistant cultivars generated almost twice as big commercial yield, determined in mass units, than non-resistant ones (Table 1).

The highest yields were obtained from 'Kilafur F<sub>1</sub>' cultivar (116.8 Mg · ha<sup>-1</sup>) and slightly lower from 'Kilaxy F<sub>1</sub>' and 'Kilaton F<sub>1</sub>' cultivars (90.9–99.3 Mg · ha<sup>-1</sup>). Such a high yield is the best proof of a high production potential of these cultivars and is comparable with the productivity of best world cultivars, grown on clubroot-free sites [9]. In the same conditions, from non-resistant cultivars significantly lower yields were obtained (51.3–65.1 Mg · ha<sup>-1</sup>) with no significant statistical differences observed between individual cultivars. Such a significant reduction in yield regarding sensitive cultivars shows how economically important and serious disease leading to considerable loss is clubroot. However, it is worth mentioning that a group of such cultivars, despite evident infection, was not totally destroyed, the fact which may prove lower genetic susceptibility of such cultivars to clubroot pathogen. Studies conducted by some authors

demonstrate variations in sensitivity of cultivars or production lines of white head cabbage [2, 10].

Table 1

Marketable yield and mean weight of heads

Cultivars	Marketable yield				Mean weight of heads [kg]	
	[Mg · ha <sup>-1</sup> ]		[number · ha <sup>-1</sup> ]		for cultivar	mean for group
	for cultivar	mean for group	for cultivar	mean for group		
Resistant:						
Kilafur F <sub>1</sub>	116.8 c		32 790 d		3.56 ab	
Kilaton F <sub>1</sub>	99.3 b	102.3	24 305 bc	28 517	4.09 b	3.61
Kilaxy F <sub>1</sub>	90.9 b		28 455 cd		3.19 a	
Non-resistant:						
Bloktor F <sub>1</sub>	65.1 a		21 025 b		3.10 a	
Kingston F <sub>1</sub>	51.3 a	57.7	14 180 a	16 943	3.62 ab	3.45
Novator F <sub>1</sub>	56.8 a		15 625 a		3.64 ab	

a, b – means in the columns marked with different letters differ significantly at  $p = 0.05$ ; 1 Mg = 1 ton.

Mean head weight of clubroot-resistant and non-resistant cultivars was comparable (3.61 and 3.45 kg, respectively for each group). The highest one was characteristic for ‘Kilaton F<sub>1</sub>’ (4.09 kg) cultivar only. On the other hand, the analysis of total yield structure (Fig. 2) demonstrates a high share of 1<sup>st</sup> grade heads for ‘Kilafur F<sub>1</sub>’ (87.8 %) and ‘Novator F<sub>1</sub>’ (90.8 %) cultivars and relatively low one for 2<sup>nd</sup> grade and unmarketable cabbage heads. In the case of other cultivars the number of highest quality heads collected was slightly lower and the number of lower quality ones relatively higher. The lack of significant differences regarding this aspect may seem surprising but it is a direct consequence of including these heads of sensitive cabbage cultivars which

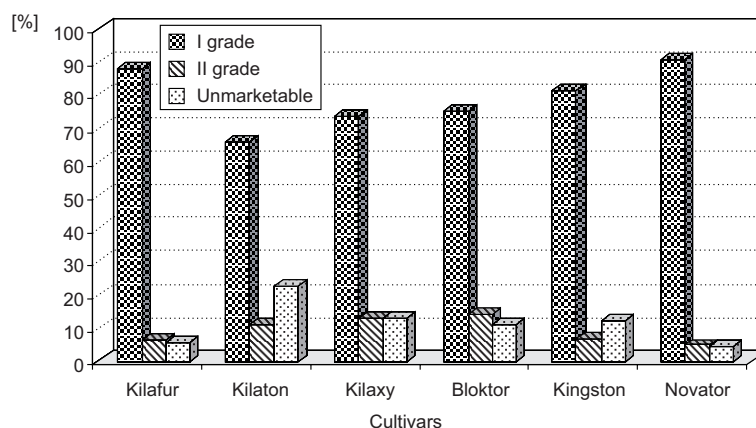


Fig. 2. Structure of total cabbage yield

had not been destroyed by clubroot in the above classification. The presented data are a proof of full commercial values of new cultivars which are comparable with the commonly cultivated ones [7, 9].

As it can be seen from the data presented in Table 2, nutritional value of the compared cultivars was pretty similar, although, in certain cases, statistically differentiated.

Table 2

Content of some compounds in cabbage heads

Cultivars	Dry matter	Total sugars	L-ascorbic acid [mg · 100 g <sup>-1</sup> f.m.]	Chlorophyll <i>a</i>	Chlorophyll <i>b</i>	Carotenoids
	[g · 100 g <sup>-1</sup> f.m.]			[mg · g <sup>-1</sup> f.m.]		
Resistant:						
Kilafur F <sub>1</sub>	8.87 d	4.47 a	24.92 a	0.015 c	0.008 a	0.006 a
Kilaton F <sub>1</sub>	8.29 a	4.77 b	24.66 a	0.011 ab	0.007 a	0.006 a
Kilaxy F <sub>1</sub>	8.73 cd	4.79 b	25.39 a	0.012 b	0.006 a	0.006 a
Non-resistant:						
Bloktor F <sub>1</sub>	8.57 bc	4.47 a	26.43 a	0.012 b	0.008 a	0.007 a
Kingston F <sub>1</sub>	8.63 bc	4.52 a	65.44 b	0.011 ab	0.008 a	0.006 a
Novator F <sub>1</sub>	8.45 ab	4.58 a	23.33 a	0.009 a	0.006 a	0.005 a

a, b – means in the columns marked with different letters differ significantly at  $p = 0.05$ .

From all cultivars, ‘Kingston F<sub>1</sub>’ distinguished with a very high L-ascorbic acid content (65.44 mg in 100 g of fresh matter), whereas for all other cultivars the value ranged from 23.33 to 26.43 mg. Dry matter content for all cultivars ranged from 8.29–8.87, and total sugars content from 4.47–4.79 g · 100 g<sup>-1</sup> f.m. Chlorophyll *a* level ranged from 0.009 to 0.015, chlorophyll *b* from 0.006 to 0.008, and caretonoid level from 0.005 to 0.007 mg in 1 g of fresh mass. These values, except for the above-mentioned case of vitamin C fall into limits of standard element content determined for white head cabbage [8, 11, 12].

Summarizing, clubroot-resistant cultivars under investigation remained unaffected by the disease in the conditions of the experiment and gave good quality, high yield, proving suitable for commercial production.

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Katedra Warzywnictwa z Ekonomiką Ogrodnictwa  
Katedra Ochrony Roślin  
Uniwersytet Przyrodniczy im. Hugona Hołłątaja w Krakowie

**Abstrakt:** W trzyletnich badaniach porównywano 3 późne odmiany kapusty głowiastej białej odporne na kiłę: 'Kilafur F<sub>1</sub>', 'Kilaton F<sub>1</sub>' i 'Kilaxy F<sub>1</sub>' oraz 3 standardowe: 'Blokator F<sub>1</sub>', 'Kingston F<sub>1</sub>' i 'Novator F<sub>1</sub>'. Doświadczenie zlokalizowano na stanowisku, na którym w poprzednim roku była również uprawiana kapusta. W czasie wegetacji szacowano stopień porażenia roślin przez kiłę. Oceniano plonowanie oraz jakość handlową i odżywczą główek kapusty.

We wszystkich latach prowadzenia badań wykazano brak jakiegokolwiek porażenia odmian odpornych przez patogena *Plasmodiophora brassicae*, podczas gdy pozostałe uległy w różnym stopniu infekcji. Uzyskano duży plon handlowy odmian odpornych oraz bardzo dobrą jakość ich główek. W tych samych warunkach uzyskano znacząco niższe plony odmian nieodpornych.

**Słowa kluczowe:** kapusta głowiasta biała, kiła, odmiany odporne