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THE EFFECT OF THE METHOD AND TIME OF SEEDLING PRODUCTION ON RED CABBAGE (*Brassica oleracea* L. ssp. *oleracea* convar. *capitata* (L) Alef. var. *capitata* L. f. *rubra* DC.) YIELD

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Abstract

This study, conducted in the period 2006-2008, involved an evaluation of yield and commercially useful traits of red cabbage grown from seedlings produced from seeds sown at three different times (the second decade of April, the third decade of April, and the first decade of May). Seedlings were produced in multicell trays in an unheated greenhouse and in a nursery bed from seeds sown at the same time. The experiment included 6 red cabbage cultivars ('Huzaro F_1', 'Kalibos', 'Langedijker Polana', 'Rodeo F_1', 'Roxy F_1', 'Zelox F_1'). After cabbage heads were harvested in the second decade of October (in each year), total and marketable yield as well as head weight and the head shape index were determined.

Red cabbage yield was shown to be significantly dependent on the cultivar, time of sowing, and method of seedling production. Among the cultivars studied, the following proved to be the most productive, irrespective of the other experimental factors: 'Zelox F_1' (marketable yield averaged 398.11 kg×100 m^{-2}), 'Roxy F_1' (marketable yield averaged 368.82 kg×100 m^{-2}), and 'Rodeo F_1' (marketable yield averaged 331.59 kg×100 m^{-2}). The cultivar 'Kalibos' was characterized by the lowest marketable yield (on average 257.09 kg×100 m^{-2}). Delayed sowing (to produce seedlings) by 10 and 20 days, compared to the earliest sowing time, had a significant effect on the reduction in total and marketable yield. Irrespective of the time of sowing, the production of seedlings in multicell trays did not have a significant effect on higher head weight. But the influence of the cultivar was significant – heads of the highest weight were found in the yield of the cultivar 'Zelox F_1' (head weight was on average 1.71 kg). The head shape index was more than 1 and on average it did not exceed 1.35. The cultivar 'Kalibos' had the most elongated heads (with a conical shape), while cabbage heads in the cultivar 'Langedijker Polana' were closest to the spherical shape.

Key words: red cabbage, time of sowing, method of seedling production, yield

INTRODUCTION

Head cabbage owes its popularity in Poland to the climatic and soil conditions that are favourable to its growth and development, quite easy cultivation of cabbage, high reliability of yield, and consumption traditions. An additional advantage of late cabbage cultivars is the possibility of long-term storage of cabbage heads or preservation of cabbage by using the popular technology of fermentation.

White cabbage is grown in largest amounts, but red cabbage, which is distinguished by exceptional health-enhancing properties and many beneficial sensory traits, has become more and more important in recent years (Mazza and Miniati, 1993; Bridle and Timberlake, 1997; Verkerek and Dekker, 2004; Wojciechowska et al. 2007; Verkerek and Dekker, 2004). An important advantage of red cabbage is the fact that it is generally consumed raw, which permits the preservation of vitamins sensitive to thermal processing and some polyphenolic compounds (Pliszka et al. 2007; Singh et al. 2007; Ismail et al. 2004; Kisała, 2009). Among cabbages, red cabbage is characterized by the highest richness in chemical compounds considered to be antioxidants and the average weight of red cabbage heads is mostly lower than in white cabbage (Tendaj and Kuzyk, 2001; Chohura and Kołota, 2005; Singh et al. 2006; Posta and Berar, 2006; Franczuk et al, 2010).

In head cabbage, similarly to other vegetable species grown from seedlings, the time of sowing as well as the method of seedling production and planting in the field may determine yield effects and storage life (Sundstrom and Story, 1984; Kleinhenz and Wszelaki, 2003).

The present study was designed to evaluate yield of several red cabbage cultivars depending on the time of starting seedling production using the traditional method of growing seedlings in a nursery bed and in multicell trays with cabbage plants growing in an unheated greenhouse. The scope of this study also included the characteristics of plant growth and heads produced depending on the cultivar and cultivation method.

MATERIALS AND METHODS

This study, conducted in the period 2006-2008, involved an evaluation of yield and commercially useful traits of red cabbage grown from seedlings that were planted at different times.

The study included 6 red cabbage cultivars (*Brassica oleracea* L. ssp.*oleracea* convar. c*apitata* (L) Alef. var. *capitata* L. f. *rubra* DC.) differing in morphological and commercially useful traits. These were the following cultivars: 'Huzaro F_1', 'Kalibos', 'Langedijker Polana', 'Rodeo F_1', 'Roxy F_1', 'Zelox F_1'.

Cabbage of the abovementioned cultivars was grown from seedlings produced in the field in a nursery bed and in multicell trays on tables in an unheated greenhouse.

Seeds were sown at three different times: in the second decade of April (19 April 2006, 18 April 2007, 19 April 2008), in the third decade of April (29 April 2006, 28 April 2007, 29 April 2008), and in the first decade of May (9 May 2006, 8 May 2007, 9 May 2008).

In the successive years of the study, seeds were sown on the same day in the nursery bed in the field and in multicell trays (cell capacity – 55,4 cm^3) filled with peat substrate which placed in an unheated greenhouse as well as on the nursery bed prepared under field conditions.

Seedlings (obtained from the successive times of sowing) were transplanted to the field at the following times: 1st decade of May – seedlings produced in multicell trays from the first sowing time; 2nd decade of May – seedlings produced in the nursery bed from the first sowing time and seedlings produced in multicell trays from the second sowing time; 1st decade of June – seedlings produced in the nursery bed from the second sowing time and seedlings produced in multicell trays from the third sowing time; 2nd decade of June – seedlings produced in the nursery bed from the third sowing time.

The three-factor (cultivar, time of sowing, method of seedling production) experiment was set up in a randomized block design in 4 replications.

The smallest experimental unit was a 3 m^2 plot where 10 plants were grown at a spacing of 0.45 x 0.5 m (10 plants). The experiment was established on compact, grey-brown podzolic soil, with a humus content of 1.5% and medium nutrient availability. Depending on the forecrop in the successive years (French bean, tomato, rooted parsley), before planting seedlings mineral fertilization was applied in accordance with the recommendations for this species (S a d y , 2006) at the following rates: 100 kg $N \times ha^{-1}$, 80 kg $P_2O_5 \times ha^{-1}$, 200 kg$\times$ K_2O ha^{-1}.

During the study years, red cabbage heads were harvested once in the second decade of October. After harvest, heads were selected by determining total and marketable yield as well as some head traits (average weight, shape index). Healthy heads, without any damage caused by the presence of pests, with a weight of more than 500 g were included in marketable yield. The head shape index was determined on the basis of the ratio of the height to the largest diameter of a head and it was expressed in a scale from 1 to 1.35.

The results were statistically analysed using analysis of variance and the significance of differences was assessed by Tukey's multiple confidence intervals, at a significance level of α=0.05.

RESULTS

Total and marketable head yield of the red cabbage cultivars studied. On the basis of the red cabbage yield results for the period 2006-2008, both total yield and marketable yield were found to be significantly dependent on the cultivar, time of sowing to produce seedlings, and method of seedling production.

Among the cultivars under investigation, 'Zelox F_1', 'Roxy F_1', and 'Rodeo F_1' proved to be the most productive, irrespective of the other experimental factors. No significant differences were found in total and marketable yield of these cultivars (Table 1 and 2). Total head yield averaged 424.31-496.81 kg$\times$100 m^{-2}, while the average marketable yield was 331.59-398.11 kg$\times$100 m^{-2}. The cultivar 'Kalibos' proved to be the least productive; its average total yield was 382.54 kg$\times$100 m^{-2} , while the average marketable yield 257.09 kg$\times m^{-2}$. However, these were not significant differences in comparison to the yield of the cultivars 'Huzaro F_1' and 'Langedijker Polana'. The cultivar 'Kalibos' was also characterized by the lowest share of marketable yield in total yield, which was 67.2%. Compared to the cultivars 'Zelox F_1' and 'Roxy F_1', this share was lower by 15.4-12.9% (Table 3).

The effect of the time of sowing and planting of seedlings on red cabbage yield. Delayed sowing (to produce seedlings) by 10 and 20 days, compared to the earliest sowing time, had a significant effect on the reduction in total and marketable yield. In the case of

marketable yield, a significant reduction in yield was shown only between the treatments with the first and third time of sowing (Table 1 and 2). Delayed sowing and, in consequence, delayed planting of seedlings by, on average, 20 days adversely affected total and marketable yield, in particular in the most productive cultivars – 'Zelox F_1' and 'Roxy F_1'. In cv. 'Langedijker Polana', the study found no negative response to delayed sowing by both 10 and 20 days. Total yield of this cultivar obtained from the third sowing time was even slightly higher than that obtained from the second sowing time, while marketable yield was slightly higher compared to the first sowing date. The study did not show any significant interaction of the factors – time of sowing and method of seedling production – on total and marketable head yield of the red cabbage cultivars under study.

The participation of marketable yield in total yield proved to be slightly higher in the treatments with the first and second sowing time in a larger number of the studied cultivars (Table 3). But the study found no such correlation in the cultivars 'Huzaro F_1' and 'Langedijker Polana'.

The effect of the method of seedling production on red cabbage yield. Growing red cabbage from seedlings produced in mullticell trays in an unheated greenhouse, irrespective of the time of sowing, proved to be more beneficial compared to the planting of seedlings produced in the nursery bed under field conditions. The treatment that used seedlings produced in multicell trays was found to give significantly higher total and marketable head yield as well as a higher proportion of marketable yield in total yield (Table 1, 2, 3).

Among the cultivars studied, the following cultivars: 'Zelox F_1', 'Roxy F_1', and 'Rodeo F_1', were found to show the highest reduction in yield in the treatments in which cabbage was grown from seedlings obtained from the nursery bed. These cultivars were characterized by the highest productivity and the highest share of marketable yield in total yield.

In the cultivars 'Huzaro F_1' and 'Kalibos' grown from seedlings produced in multicell trays, slightly smaller total head yield was obtained, but marketable yield and its share in total yield were higher.

The shape index and head weight. In all the cultivars, the head shape index was more than 1 and it was not dependent on the time and place of seedling production. The red cabbage cultivar 'Kalibos' had the most elongated heads that were characterized by a conical shape. In this cultivar, the head shape index was the highest, but it did not exceed 1.35. The cultivar 'Langedijker Polana' had the lowest propensity to form elongated heads (Figs 1-2).

The average head weight was significantly dependent on the cultivar, while the other experimental factors did not have any significant effect on this trait. Among the cultivars under investigation, 'Zelox F_1' was distinguished by the formation of heads of the highest weight (on average 1.71 kg). In the other cultivars, the average head weight was 1.22-1.35 kg and it did not differ significantly (Table 4).

Table 1.
Total yield of red cabbage, mean for 2006-2008, depending on the cultivar, time of sowing, and method of seedling production (kg×100 m^{-2})

Cultivar	Time of sowing to produce seedlings, irrespective of method of seedling production			Method of seedling production, irrespective of time of sowing		Mean
	I	II	III	in multicell trays	in nursery bed	
Huzaro F_1	488.46	356.17	370.39	398.77	411.31	405.04
Kalibos	379.69	395.28	372.67	378.25	386.84	382.54
Langedijker Polana	421.98	395.08	400.96	419.79	392.23	406.01
Rodeo F_1	444.68	417.02	411.22	443.28	405.33	424.31
Roxy F_1	506.70	411.74	417.04	492.89	399.44	446.16
Zelox F_1	587.10	489.35	413.98	544.99	448.63	496.81
Mean	470.46	410.77	397.64	446.32	407.29	426.81
$LSD_{0.05}$						
cultivar (A)						96.589
time of sowing (B)						58.821
method of seedling production (C)						37.937
interaction (A x B)						n.s.
interaction (A x C)						n.s.
interaction (B x C)						n.s.

Table 2.
Marketable yield of red cabbage, mean for 2006-2008, depending on the cultivar, time of sowing, and method of seedling production (kg×100 m^{-2})

Cultivar	Time of sowing to produce seedlings, irrespective of method of seedling production			Method of seedling production, irrespective of time of sowing		Mean
	I	II	III	in multicell trays	in nursery bed	
Huzaro F_1	319.27	293.60	265.72	298.30	290.42	292.86
Kalibos	269.73	259.56	241.98	279.85	234.33	257.09
Langedijker Polana	278.01	306.10	296.09	321.42	265.38	293.40
Rodeo F_1	361.40	323.70	309.66	387.47	275.61	331.59
Roxy F_1	416.50	359.89	330.06	418.76	318.88	368.82
Zelox F_1	494.75	384.34	315.23	446.22	349.98	398.11
Mean	356.61	321.19	293.12	358.67	289.10	323.64
$LSD_{0.05:}$						
cultivar (A)						96.638
time of sowing (B)						57.000
method of seedlings production (C))						38.742
interaction (A × B)						n.s.
interaction (A x C)						n.s.
interaction (B x C)						n.s.

Table 3.
Share of marketable yield in total yield of red cabbage for 2006-2008, depending on the cultivar, time of sowing, and method of seedling production (%)

Cultivar	Time of sowing to produce seedlings, irrespective of method of seedling production			Method of seedling production, irrespective of time of sowing		Mean
	I	II	III	in multicell trays	in nursery bed	
Huzaro F_1	65.3	82.4	71.7	74.8	70.6	72.3
Kalibos	71.0	65.6	64.9	78.9	60.5	67.2
Langedijker Polana	65.8	77.4	73.8	76.5	67.6	72.2
Rodeo F_1	81.2	77.6	75.3	87.4	67.9	78.1
Roxy F_1	82.2	87.4	79.1	84.9	79.8	82.6
Zelox F_1	84.2	78.5	76.1	81.8	78.0	80.1
Mean	75.6	78.2	73.7	80.3	70.9	75.8

Table 4.
Average head weight of red cabbage for 2006-2008, depending on the cultivar, time of sowing, and method of seedling production (kg)

Cultivar	Time of sowing to produce seedlings, irrespective of method of seedling production			Method of seedling production, irrespective of time of sowing		Mean
	I	II	III	in multicell trays	in nursery bed	
Huzaro F_1	4.40	1.19	1.13	1.23	1.26	1.22
Kalibos	1.35	1.14	1.25	1.21	1.28	1.27
Langedijker Polana	1.30	1.41	1.35	1.34	1.37	1.35
Rodeo F_1	1.27	1.33	1.28	1.26	1.31	1.26
Roxy F_1	1.39	1.31	1.31	1.34	1.33	1.34
Zelox F_1	1.77	1.69	1.65	1.71	1.70	1.71
Mean	1.41	1.34	1.33	1.34	1.38	
$LSD_{0.05}$						
cultivar (A)						0.268
time of sowing (B)						n.s.
method of seedling production (C)						n.s.
cultivar x time of sowing (A x B)						n.s.
cultivar x method of seedling production (A x C)						n.s.
time of sowing x method of seedling production (B x C)						n.s.

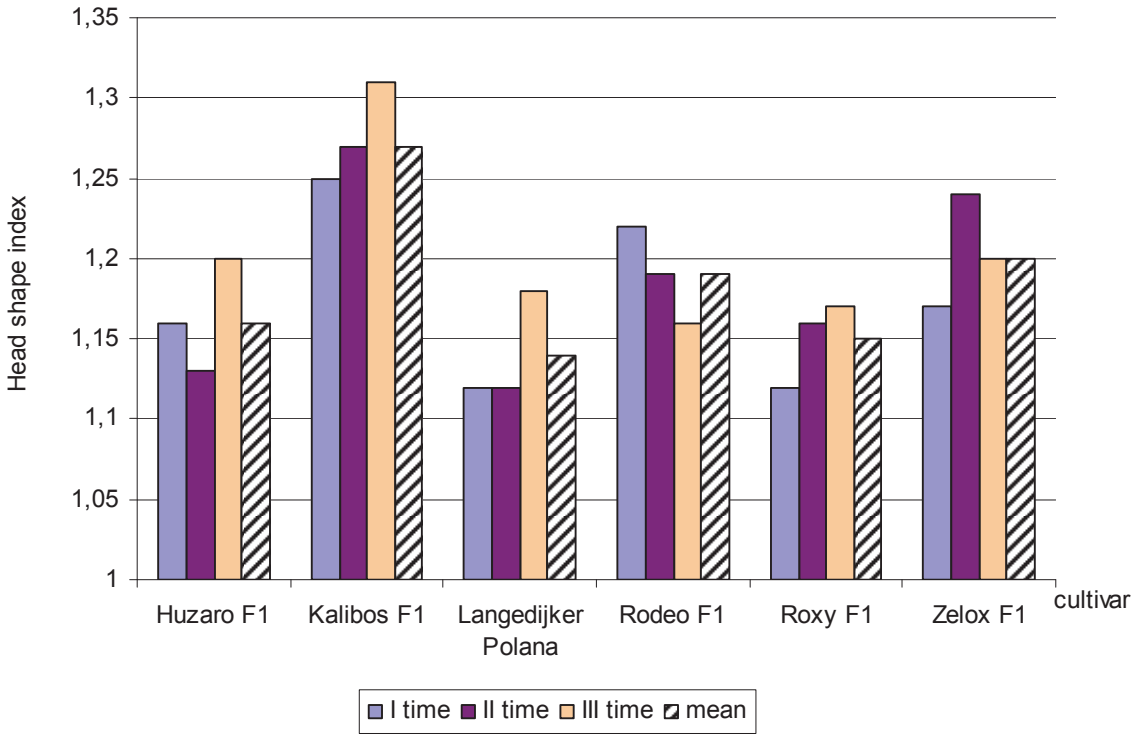

Fig. 1. The head shape index of red cabbage depending on the time of sowing (mean for 2006-2008).

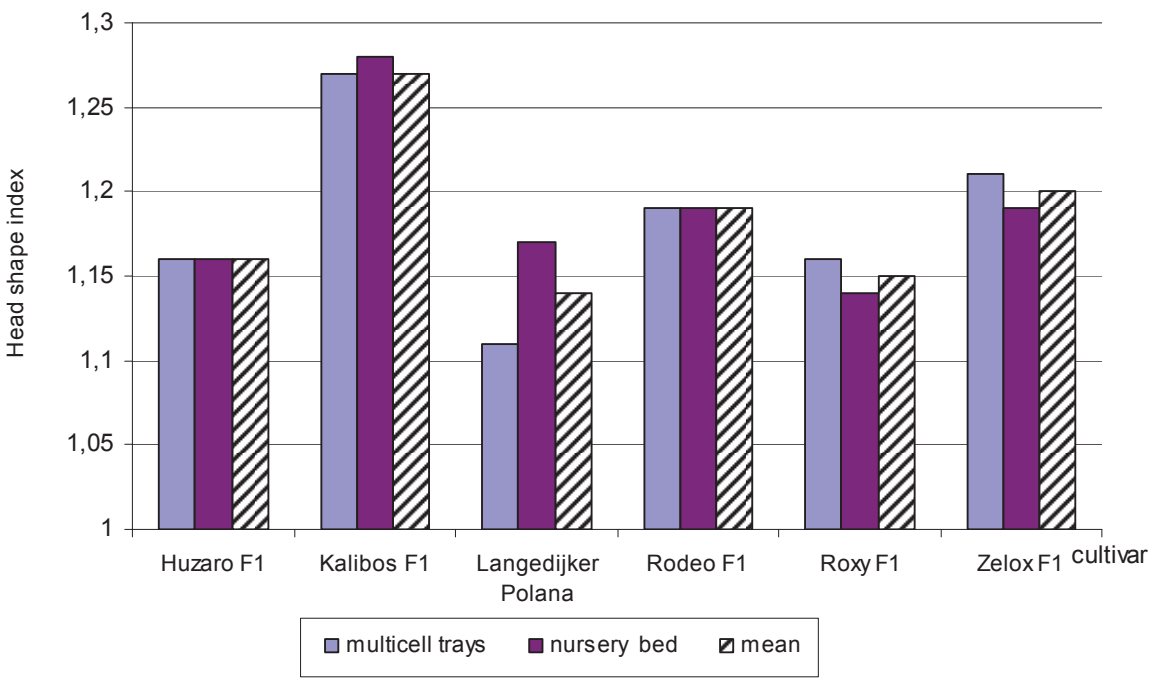

Fig. 2. The head shape index of red cabbage depending on the method of seedling production (mean for 2006-2008).

DISCUSSION

The experiment whose results are presented in this paper proved that the method of seedling production and an appropriately early start of seedling preparation might be of significant importance for the amount of yield obtained. Irrespective of these factors, the cultivar traits significantly influenced the weight of heads formed, their shape, and yield per unit area.

S a d y and S m o l e ń (2007) showed head yield of the red cabbage cultivar 'Langedijker Polana' to average 65.3-68.5 t×ha^{-1} in their study in which dif-

ferent nitrogen fertilization was applied. According to the study presented in this paper, the average yield of this cultivar was 40.6 t×ha^{-1}. These differences in the yield of this cultivar can be explained by the fact that in the study of the above-cited authors increased nitrogen fertilization could have resulted in increased yield (the yield from the control treatments was lower and it was on average 55.6 t×ha^{-1}). However, Biesiada et al. (2010) give yield results for this cultivar comparable to the results obtained in the present study.

In the study of Franczuk et al. (2010), conducted under conditions similar to those prevailing in the Lublin region, the average marketable yield of red cabbage was 41.29 t×ha^{-1}. Thus, it was higher than in the present study (it averaged 32.36 t×ha^{-1}). The differences in the yield of this cabbage probably resulted from different growing conditions and genetic characters of the cultivars under study.

Growing red cabbage from seedlings produced in multicell trays in an unheated greenhouse proved to be more beneficial compared to the planting of seedlings produced in the nursery bed under field conditions. An earlier study of Kossowski et al. (1980) showed that red cabbage produced better yields from direct sowing in the field compared to the planting of seedlings produced in a nursery bed and that the transplant of seedlings, involving damage to the root system, might have no effect on the reduction in yield.

The proper time for sowing cabbage seeds and for planting seedlings in the field is an important issue in many climatic zones. Kleinenz and Wszelaki (2003) report that, under the conditions of North America (Ohio, USA), planting cabbage in the second and third decade of June had a significant effect on the reduction in yield compared to planting seedlings in the second decade of May. This is in agreement with the results of the present study, since this study found a significant reduction in the yield obtained from the third sowing time – the latest date of sowing cabbage seeds to produce seedlings. Under the conditions of sub-mountainous areas of Poland (the Sub-Carpathian region), delayed planting of seedlings of 4 white cabbage cultivars also resulted in a significant decrease in white cabbage yield. But in the case of the cultivar 'Kamienna Głowa', the yield obtained was not significantly dependent on the time of planting (Cebula et al. 1996).

The size of heads formed and their shape are an important cultivar trait in cabbage, but this trait can be greatly affected by cultivation conditions (Acer and Paksoy, 2006; Cervenski et al. 2011). The present study proved that delayed sowing by 10-20 days and, in consequence, delayed planting of seedlings as well as the method of seedling production did not have a significant influence on the weight and shape of heads in the cultivars studied. Information about the negative effect of delayed planting of seedlings on the size of heads formed and their shape can be found in the available literature (de Moel and Everaarts, 1990; Kleinhenz and Wszelaki, 2004). As reported by the above-mentioned authors, delayed planting of seedlings promotes a reduction in head weight and, besides, cabbage heads show a tendency towards elongation. Furthermore, fertilization and irrigation can also modify head size and head shape parameters (Acar and Paksoy, 2006; Kołota and Chohura, 2008; Ijoyah and Sophie, 2009).

The obtained results allow one to determine the proper time for starting red cabbage production using the traditional method of sowing in a nursery bed and under the conditions in unheated greenhouses with the possibility of producing seedlings in pots. It could be stated unequivocally that early production of seedlings in multicell trays in the cultivars under study was conducive to higher yields and desired traits of red cabbage heads.

CONCLUSIONS

1. Red cabbage proved to be a plant reliable in cultivation, taking into account different times of starting seedling production, method of seedling production, and high variations in cultivar traits.
2. Among the factors under investigation, the cultivar was found to have the greatest effect on yield. The cultivar 'Zelox F_1' proved to be the most productive, whereas the cultivar 'Kalibos', whose heads are conically shaped, was the least productive.
3. The time of sowing to produce seedlings significantly affected yield. The earliest time of sowing (2nd decade of April), both in multicell trays and in the nursery bed, resulted in significantly higher yield compared to delayed sowing by 20 days in the 1st decade of May.
4. The study showed in most of the cultivars that, irrespective of the time of seedling production, the production of seedlings in multicell trays under the conditions of an unheated greenhouse had a significant effect on higher head weight and higher red cabbage yield.

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Wpływ metody i terminu produkcji rozsady na plon kapusty czerwonej (*Brassica oleracea* L. ssp. *oleracea* convar. *capitata* (L.) Alef. var. *capicata* L. f. *rubra* DC.)

Streszczenie

Badania przeprowadzone w latach 2006-2008 obejmowały ocenę plonowania i cech użytkowych kapusty czerwonej uprawianej z rozsady produkowanej z siewu nasion w trzech terminach (druga dekada kwietnia, trzecia dekada kwietnia i pierwsza dekada maja). Rozsadę produkowano w wielodoniczkach (multiplatach) w nieogrzewanej szklarni i na rozsadniku z siewu nasion w tym samym terminie. W doświadczeniu uwzględniono 6 odmian kapusty czerwonej ('Huzaro F_1', 'Kalibos', 'Langedijker Polana', 'Rodeo F_1',

'Roxy F_1', 'Zelox F_1'). Po zbiorze główek w drugiej dekadzie października (w każdym roku) określono plon ogólny i handlowy, masę pojedynczych główek z każdego obiektu badań oraz ich wskaźnik kształtu.

Wykazano, że plon kapusty czerwonej zależał istotnie od odmiany, terminu siewu nasion i sposobu produkcji rozsady. Spośród badanych odmian, niezależnie od pozostałych czynników doświadczenia, najplenniejsze okazały się 'Zelox F_1' (plon handlowy wynosił średnio 398,11 kg×100 m^{-2}), 'Roxy F_1' (plon handlowy wynosił średnio 368,82 kg×100 m^{-2}) oraz 'Rodeo F_1' (plon handlowy wynosił średnio 331,59 kg×100 m^{-2}). Najmniejszym plonem handlowym charakteryzowała się odmiana 'Kalibos' (średnio 257,09 kg×100 m^{-2}). Opóźnienie siewu nasion w celu wyprodukowania rozsady o 10 i 20 dni, w porównaniu z najwcześniejszym terminem siewu, wpłynęło istotnie na obniżenie wielkości plonu ogólnego i handlowego.

Niezależnie od terminu siewu, przygotowywanie rozsady w wielodoniczkach w warunkach szklarni nieogrzewanej u większości odmian nie wpłynęło istotnie na uzyskanie większej masy pojedynczych główek. Natomiast istotny był wpływ odmiany – główki o największej masie stwierdzono w plonie odmiany 'Zelox F_1' (średnio wynosiła 1,71 kg). Wskaźnik kształtu główek wynosił ponad 1, a nie przekraczał średnio 1,35. Najbardziej wydłużone główki miała stożkowa odmiana 'Kalibos', a najbardziej zbliżone do kształtu kulistego – odmiana 'Langedijker Polana'.