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EFFECT OF CROP VARIETY AND COVERING PLANTS ON FORMATION OF BIOCHEMICAL PARAMETERS OF CHINESE CABBAGE (*BRASSICA CHINENSIS* JUSLEN.)

WPŁYW SPOSOBU UPRAWY, ODMIANY ORAZ OKRYWANIA ROŚLIN NA KSZTAŁTOWANIE SIĘ PARAMETRÓW BIOCHEMICZNYCH KAPUSTY CHIŃSKIEJ (*BRASSICA CHINENSIS* JUSLEN.)

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Streszczenie. Zbadano wpływ osłon (folii perforowanej o 100 i 400 otworach na 1 m^2 oraz włókniny polipropylenowej Agryl P17), sposobu uprawy (z siewu nasion oraz z rozsady) na wybrane parametry fizjologiczne (stężenie dwutlenku węgla oraz transpirację) i biochemiczne (stężenie proliny i dialdehydu malanowego) w liściach dwóch odmian kapusty chińskiej (Yoj--Choy F_1 i Green Fortune F_1), rosnących w warunkach polowych. Zastosowane w doświadczeniu osłony wpłynęły na zmianę parametrów biochemicznych w badanych roślinach. Największą asymilację wykazano w przypadku folii perforowanej o 400 otworach na 1 m^2, najmniejszą natomiast w przypadku włókniny. Folia wpłynęła także na wzrost intensywności transpiracji. Włóknina w największym stopniu podwyższała stężenie proliny i dialdehydu malonowego w liściach kapusty. Największe stężenie tych parametrów stwierdzono u odmiany Yoi-Choy F_1.

Key words: chinese cabbage, cover, growth, malondialdehyde, proline.
Słowa kluczowe: dialdehyd malonowy, kapusta chińska, osłony, prolina, wzrost.

INTRODUCTION

Chinese cabbage (*Brassica chinensis* L.) otherwise known as Pak-choi is one of the most-popular vegetable in China and Japan (Tanina et al. 2004). In Poland, chinese cabbage is grown only amateur. Under cover the cultivation has experimental character. Pak-choi does not create typical heads, and a dining area are leaves and fleshy petioles with a mild flavor. It belongs to the long-day plants and suited to the cultivation of the field and under cover in the autumn cycle from fall to spring (Cao et al. 1988; Piróg 1994).

From the studies conducted so far show, that many factors (position, covering of plant varieties, seed sowing time, light intensity) increases photosynthesis and biomass production (Benoit and Ceustermans 1985; Karczmarczyk et al. 1993; Rumpel 1994; Kołota and

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Biesiada 1998; Rumpel et. al. 1998; Słodkowski 1998; Wierzbicka 1999). Photosynthetic activity due to scarcity of water in the soil is most often the difficult penetration of CO_2 into the leaf through the stomata closing (Devlin and Barker 1971; Müller et al. 1986), resulting in a sharp increase in leaf diffusion resistance and a reduction in the intensity of photosynthesis (Kanemasu and Tanner 1969; Boyer 1970; Wilson 1975; Podsiadło 2001).

The response of plants to adverse environmental factors, such as to salinity, as well as negative water balance in the plant, or low temperature, is the accumulation in the cytoplasm, eg. proline. Accumulation of this amino acid in the cells may be involved in the action of many environmental stress factors (Hawrylak 2007; Malik et al. 2010). Chen et al. (2003) and Zhu et al. (2008) argue, that it is a good indicator of the intensity of stress. Proline is involved in the stabilization of membranes and of carbon and nitrogen source in a cell (Özturk and Demir 2002; Kavi Kishor et al. 2005; Ashraf and Foolad 2007; Verbruggen and Hermans 2008). Proline-free and protein-bound proline is one of the solid components of plant cells. Protein rich in proline and hydroxyproline, caused by a post-translational hydroxylation of proline protein, an important structural compound of cell walls in higher plants (Bandurska 1999).

Indicator of stress response in plants is also malondialdehyde (MDA), whose presence in the cell testifies to the cell membrane damage as a result of the consequences of oxidative stress (Woźny and Przybył 2004). Such disruption can cause change the physicochemical properties of the cell structures and disrupt the course of metabolism in the cell – up to abnormal growth and development of plants (Ashraf and Harris 2005).

This may result in reduced productivity of crop plants (Woźny and Przybył 2004). Malondialdehyde (MDA) is created by peroxidation of unsaturated fatty acids (Głód et al. 2006).

The aim of this study was to examine the influence of covers (foil perforated by 100 and 400 holes per 1 m^2 and polypropylene fabric Argyle P17) of cultivation practices (from sowing seeds and from seedling) on selected physiological parameters (concentration of carbon dioxide and transpiration) and biochemical parameters (concentration of proline and malondialdehyde) in the leaves of two varieties of chinese cabbage (‘Yoj-choy’ and ‘Green Fortune F_1’) in the crop field.

MATERIAL AND METHODS

The experiment was conducted from 20th July 2013 to 20th October 2013 at the Horticultural Experimental Station in Dołuje (near Szczecin) and in the laboratory of the Department of Plant Physiology and Biochemistry at the Faculty of Environmental Management and Agriculture in West Pomeranian University of Technology in Szczecin.

The experiment was conducted on a black soil, classified to the level of the relevant post-bog soils, black soil type, subtype appropriate black soil. It is characterized by the whole profile slightest mechanical composition and good water permeability (Mikiciuk 2000).

Material consisted was plants of two cultivars chinese cabbage (‘Yoj-Choy F_1’ and ‘Green Fortune F_1’) plants were grown from seed is planted directly into the ground, and with no pots seedling produced in seedbeds. The field experiment was founded in a randomized block layout in three replications. Plants were grown in 30 x 25 cm spacing. The third factor experience was the cover (perforated foil with 100 and 400 holes per 1 m^2 and polypropylene fabric Argyle P17). Control plants were the object without the cover. Beauty treatments (weed plants, watering and plant protection) was carried out as for the standard brassica vegetables.

In the final stage of plant growth physiological tests were performed, including the photosynthetic activity of leaves (transpiration intensity) and the concentration of CO_2 in the stomata. Measurements of photosynthetic activity of leaves made gas analyzer type of LCA-4 (ADC Bioscentic Ltd. Hoddedon, UK), working in an open system. During the measurement of the leaf chamber was placed under a halogen lamp (Xenophot HLX, OSRAM) the intensity of PAR 400 $\mu mol \cdot m^{-2} \cdot s^{-1}$. The air was introduced by the rubber hose from the ambient atmospheric air. The measurement results were read on the screen of the analyzer in the tenth minute after the insertion of the leaf into the measuring chamber.

The concentration of free proline in the plant material ninhydrin reaction indicated by Bates et al. (1973) method, while the concentration level of malondialdehyde was performed by Sudhakar et al. (2001) method in the reaction with thiobarbituric acid.

The results of research on the effect of the concentration of bio-stimulators on malondialdehyde and proline in leaves of chinese cabbage were subjected to statistical analysis using analysis of variance in the system fully randomized. The least significant differences (LSD) was calculated using Tukey's test at the significance level $\alpha_{0,05}$.

RESULTS AND DISCUSSION

During the cultivation of chinese cabbage (July to October), average air temperatures were higher than the long-term average temperatures only in October and was 10.9ºC (Table 1). Rainfall in the year under review were lower than the multi-year. Plants in this period require watering.

Table 1. Mileage weather conditions during the growing Chinese cabbage in 2013, recorded in the Meteorological Station in Szczecin Dabie
Tabela 1. Warunki pogodowe w okresie wegetacji kapusty chińskiej w 2013 roku, odnotowane w Stacji Meteorologicznej w Szczecinie-Dąbiu

Months Miesiące	The average air temperature Średnia temperatura powietrza [ºC]	The average temperature of multi-year Średnia temperatura powietrza z wielolecia (2001–2013) [ºC]	Rainfall Suma opadów [mm]	Mean total rainfall of several years Średnia suma opadów z wielolecia (2001–2013) [mm]	Number of days with precipitation Liczba dni z opadami	Insolation Usłonecznienie [h]	Sunshine of the multi-year Usłonecznienie w latach 2001–2013 [h]
July Lipiec	19.3	19.3	50.4	71.0	9	220	249.9
August Sierpień	18.7	18.4	35.9	67.7	10	207	215.6
September Wrzesień	13.0	13.9	43.9	44.6	13	127	157.0
October Październik	10.9	9.8	45.8	47.2	13	94	110.6

Source: Bulletin of Agrometeorological Institute of Meteorology and Water Management (2001–2012 and 2013).
Źródło: Biuletyn Agrometeorologiczny Instytutu Meteorologii i Gospodarki Wodnej (2001–2012 i 2013).

Factors used in the experiment (cover, cultivation, varieties) had a significant impact on photosynthesis Chinese cabbage (Table 2). Perforated foil shielding plants of 400 holes per 1 m^2 had an impact on the growth of leaf photosynthesis of 9.77%, while the use of perforated foil 100 holes per 1 m^2 of photosynthesis decreased by 4.19%, and in the case of non-woven decline by as much as 18.52% compared with the control object.

It was found that the shielding plants perforated foil of 400 holes resulted in higher plant transpiration (average 0.84 mol · m^{-2} · s^{-1}), in the case of Green Fortune F_1 varieties grown from seedlings acquired the highest value – 0.94 mol · m^{-2} · s^{-1}.

Podsiadło (2001) found that irrigation resulted in an increase of peak leaf photosynthesis by 33% faba bean, pea – about 42% of white lupine – by 25%, and yellow lupine – by 15%, and high fertilization resulted in an increase in the intensities of: 10, 26, 14 and 4%. Also increased transpiration – the greatest extent in the case of peas (about 89%), and least in the case of yellow lupine (about 37%). The impact of mineral fertilization was clearly smaller, since the transpiration increased from 6% (in the case of lupine yellow) to 19% (in the case of pea) relative to control treatments. The concentration of carbon dioxide in the stomata (C_i) was smaller objects, which had higher photosynthesis, which can be explained by a greater downloading and using CO_2 in the process of assimilation (Podsiadło 2001).

Malinowska and Smolik (2006) found a decrease in the intensity of photosynthesis and transpiration with the increase of the concentration of lead in the soil. Reducing the rate of photosynthesis and transpiration could be associated with disturbances in the functioning of the photosynthetic apparatus of plants, decrease in turgor, inhibition of electron transport in photosynthesis and a decrease in the activity of RuBP carboxylase (Woźny and Krzesłowska 1994; Woźny 1995; Mical et al. 1997; Słowik 1999). In addition, the intensity of the observed changes in the physiological processes of respondents (transpiration, respiration) can be the result of unfavorable conditions in both stress and repair mechanisms (Starck 2002).

Impact on plants of various environmental factors most often leads to changes in the metabolism of plants (Grzyś 2012). Effect of the covers and the various cultivation methods may have different effects both on growth, yield, plant condition, and on cellular metabolism. Presented in the literature data indicate that proline is essential in the plant response to various stresses such as water stress, salinity, increased content of heavy metals in the soil, or variations in temperature, which may be associated with antioxidant properties, ability to protect proline many enzymes as well as the function of chelating metals (Özturk and Demir 2002; Hawrylak 2007). In this study (Table 3) showed that the covers used in the experiment had a significant influence on the increase in the concentration of proline. There was a significant difference in the concentration of proline in the leaves of cabbage varieties Yoj-Choy F_1 (1.466 µmol · g f.m.) compared to the variation 'Greenn Fortune F_1' (0.992 µmol · g f.m.). Larger concentrations of proline were determined in leaves Shielded perforated foil 400 holes per 1 m^2 (2,258 µmol · g^{-1} f.m.) compared with leaves of the control plants in which the concentration of proline was 0.717 µmol · g^{-1} f.m. In the case of the covers increase in the concentration of proline compared to the control plants was 214.9%. It was found that the cultivation of plants from seedlings increased proline content in Chinese cabbage (average 1,524 µmol · g^{-1} f.m).

Given the many factors examined were found when the proline variant Yoj-Choj F_1 seedling were grown in foil with perforated holes 400 per 1 m^2 (3,409 µmol · g^{-1} f.m.). In studies Borowski and Blamowskiego (2009) showed that the concentration of free proline in leaves of *Ocimum basilicum* L. and after the application of bio-stimulators like cover, increased in comparison with the control plants.

Table 2. The effect of covering plants, how to crop and variety in the intensity of CO_2 and transpiration download chinese cabbage

Tabela 2. Wpływ okrywania roślin, sposobu uprawy oraz odmiany na intensywność pobierania CO_2 oraz transpirację kapusty chińskiej

A method of cultivation Sposób uprawy	Cover Osłona	Cultivar Odmiana	Assimilation CO_2 Asymilacja CO_2 [$\mu mol \cdot m^{-2} \cdot s^{-1}$] range zakres	mean średnia	Transpiration Transpiracja [$mol \cdot m^{-2} \cdot s^{-1}$] range zakres	mean średnia
Sowing Siew	control kontrola	'Yoj-Choy F_1'	6.7–8.3	7.50	0.54–0.70	0.62
		'Green Fortune F_1'	9.4–10.2	9.80	0.57–0.70	0.64
		Średnia – Mean	8.5–8.9	8.65	0.56–0.70	0.63
	perforated foil (100) folia perforowana	'Yoj-Choy F_1'	5.5–6.4	5.95	0.55–0.63	0.59
		'Green Fortune F_1'	11.2–12.6	11.90	0.81–0.86	0.84
		mean – średnia	8.4–9.5	8.93	0.68–0.75	0.71
	perforated foil (400) folia perforowana	'Yoj-Choy F_1'	7.1–9.4	8.25	0.53–0.54	0.54
		'Green Fortune F_1'	10.2–11.9	11.05	0.74–0.78	0.76
		mean – średnia	8.7–10.7	9.65	0.64–0.66	0.65
	non-woven polyproplene włóknina polipropylenowa	'Yoj-Choy F_1'	10.6–12.2	11.40	0.34–0.53	0.44
		'Green Fortune F_1'	11.6–12.3	11.95	0.76–0.90	0.83
		mean – średnia	11.1–12.3	11.68	0.55–0.72	0.63
	mean – średnia		91–10,3	9.73	0.61–0.71	0.66
Seedling Rozsada	control kontrola	'Yoj-Choy F_1'	8.1–9.2	11.30	0.70–0.77	0.85
		'Green Fortune F_1'	11.6–11.7	11.35	1.07–1.10	0.85
		Średnia – Mean	9.9–10.5	11.32	0.89–0.98	0.85
	perforated foil (100) folia perforowana	'Yoj-Choy F_1'	8.9–9.5	9.20	0.76–0.78	0.77
		'Green Fortune F_1'	11.9–12.2	12.05	0.86–1.02	0.94
		mean – średnia	10.4–10.9	10.63	0.81–0.90	0.86
	perforated foil (400) folia perforowana	'Yoj-Choy F_1'	8.0–9.8	8.90	0.71–0.76	0.74
		'Green Fortune F_1'	12.5–12.6	12.55	0.80–1.02	0.91
		mean – średnia	10.3–11.2	10.73	0.76–0.89	0.82
	non-woven polyproplene włóknina polipropylenowa	'Yoj-Choy F_1'	10.1–12.6	11.64	0.77–0.91	0.87
		'Green Fortune F_1'	11.5–12.9	11.18	1.01–1.04	0.84
		mean – średnia	10.8–12.8	11.41	0.89–0.98	0.86
	mean – średnia		10.3–11.3	11.02	0.84–0.93	0.85
Mean for cultivar Średnia dla odmiany		'Yoj-Choy F_1'	8.1–9.7	9.27	0.61–0.70	0.68
		'Green Fortune F_1'	11.3–12.0	11.48	0.83–0.93	0.83
Mean for cover Średnia dla osłon		control kontrola	9.5–10.9	10.19	0.70–0.78	0.74
		perforated foil (100) folia perforowana	9.4–10.2	9.78	0.75–0.82	0.78
		perforated foil (400) folia perforowana	10.5–11.3	10.88	0.79–0.88	0.84
		non-woven polyproplene włóknina polipropylenowa	8.5–9.9	9.18	0.68–0.74	0.71
$LSD_{0.05}$ for – $NIR_{0.05}$ dla						
a method of cultivation – sposobu uprawy (A)				1.192*		0.064*
covers – osłon (B)				0.814*		0.065*
cultivars – odmiany (C)				0.508*		0.038*
interaction – interakcji (A x B x C)				1.436*		0.106*

* Statistically significant differences – Statystycznie istotne różnice.

Table 3. The effect of covering plants. how to crop and variety in the amount of MDA [nmol · g^{-1} f.m.] and the content of proline [μmol · g^{-1} f.m.]
Tabela 3. Wpływ okrywania roślin, sposobu uprawy oraz odmiany na ilość MDA [nmol · g^{-1} śm.] oraz zawartość proliny [μmol · g^{-1} śm.]

A method of cultivation Sposób uprawy	Cover Osłona	Cultivar Odmiana	MDA [nmol · g^{-1} f.m. – śm.]	Proline Prolina [μmol · g^{-1} f.m. – śm.]
Sowing Siew	control kontrola	'Yoj-Choy F_1'	18.656	0.653
		'Green Fortune F_1'	17.634	0.429
		mean – średnia	18.145	0.541
	perforated foil (100) folia perforowana	'Yoj-Choy F_1'	19.838	0.826
		'Green Fortune F_1'	20.215	0.626
		mean – średnia	20.027	0.726
	perforated foil (400) folia perforowana	'Yoj-Choy F_1'	21.236	2.284
		'Green Fortune F_1'	21.290	1.509
		mean – średnia	21.263	1.897
	non-woven polyproplene włóknina poli-propylenowa	'Yoj-Choy F_1'	17.634	0.718
		'Green Fortune F_1'	18.710	0.433
		mean – średnia	18.172	0.576
	mean – średnia		19.402	0.935
Seedling Rozsada	control kontrola	'Yoj-Choy F_1'	20.654	0.933
		'Green Fortune F_1'	17.849	0.854
		mean – średnia	19.252	0.894
	perforated foil (100) folia perforowana	'Yoj-Choy F_1'	24.516	1.815
		'Green Fortune F_1'	23.495	1.399
		mean – średnia	24.006	1.607
	perforated foil (400) folia perforowana	'Yoj-Choy F_1'	25.860	3.409
		'Green Fortune F_1'	25.161	1.828
		mean – średnia	25.511	2.619
	non-woven polyproplene włóknina poli-propylenowa	'Yoj-Choy F_1'	21.398	1.092
		'Green Fortune F_1'	20.860	0.859
		mean – średnia	21.129	0.976
	mean – średnia		22.474	1.524
Mean for cultivar Średnia dla odmiany		'Yoj-Choy F_1'	21.224	1.466
		'Green Fortune F_1'	20.652	0.992
Mean for cover Średnia dla osłon		control kontrola	18.698	0.717
		perforated foil (100) folia perforowana	22.016	1.167
		perforated foil (400) folia perforowana	23.387	2.258
		non-woven polyproplene włóknina polipropylenowa	19.651	0.776
$LSD_{0.05}$ for – $NIR_{0.05}$ dla			1.873*	0.018*
a method of cultivation – sposobu uprawy (A)			0.856*	0.019*
covers – osłon (B)			0.827	0.013*
cultivars – odmiany (C)			2.340*	0.035*

* Statistically significant differences – Statystycznie istotne różnice.

Used in the experiment covers also affected a significant increase in the concentration of MDA in the cabbage from 5.04% in the case of using the nonwoven fabric to 25.08% when the plant was covered foil at 400 holes per 1 m^2. compared to control plants. Higher concentration of MDA was found in the cultivation of 'Yoi-Choy F_1' (21.224 nmol · g^{-1} f.m.).

The biggest concentration of MDA in cabbage crops were found in both varieties grown from a seedling into perforated foil 400 holes per 1 m^2 (mean 25.511 nmol · g^{-1} f.m.). Elevated concentrations of proline and malondialdehyde may indicate the occurrence of stress in plants.

Grzyś (2012) states that the effect of different methods of cultivation and protection of plants may be the result of the interaction of many factors. some of which are beyond the control of the manufacturer. Dey et al. (2007) in their study found that an increase in the concentration of MDA in the roots and shoots of *Triticum aestivum* occurs under the influence of Cd and Pb.

In studies of lipid peroxidation is the most commonly used method based on reaction resulting in catabolic metabolism of these compounds MDA with thiobarbituric acid (Bartosz 2003). Shall be adopted in that the increased concentration of MDA in the cell is indicative of oxidative damage to cell membranes (Krzesłowska 2004).

The biggest concentration of MDA in cabbage crops were found in both varieties of seedling under the perforated foil 400 holes per 1 m^2 (mean 25.511 nmol · g^{-1} f.m). Elevated concentration proline and malondialdehyde may indicate the occurrence of stress in plants.

CONCLUSIONS

1. Chinese cabbage grown in foil perforated 400 holes per 1 m^2 significantly positively characterized by a collection of CO_2 intensity (average 10.88 μmol · m^{-2} · s^{-1}). The greatest value of this trait was found for this covers when grown variety 'Greeen Fortune F_1' seedling (12.55 μmol · m^{-2} · s^{-1}). Similarly. the impact of this film has been shown to increase plant transpiration.
2. Test experiment cover (perforated foil and a nonwoven fabric) significantly increased oxidative stress parameters such as the concentration of proline and malondialdehyde in leaves of cabbage.
3. Polypropylene fabric caused an increase in the concentration of MDA and proline content in Chinese cabbage.

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Abstract. The aim of the study was to investigate the effect of covers (foil perforated by 100 and 400 holes per 1 m^2 and woven polypropylene Argyle P17) and method of cultivation (sowing seed and a base solution) on selected physiological parameters (concentration of carbon dioxide and transpiration) and bio-chemical (concentration of proline and malondialdehyde) in the leaves of two varieties of Chinese cabbage (Yoj-Choy and Green Fortune F_1) growing in the field. Cover used in the experiment affected the biochemical parameters studied plants. The highest uptake assimilation was demonstrated in the case of perforated foil 400 holes per 1 m^2, whereas the smallest in the case of non-woven polypropylene. The foil also consed the highest level of transpiration. Woven to the greatest extent caused the increase the concentration of proline and malondialdehyde in leaves of cabbage. The highest concentrations of these parameters were found in a Yoi-Choy F_1 variety.