ACTA SCIENTIARUM POLONORUM *Acta Sci. Pol., Hortorum Cultus 9(4) 2010, 41-51*

EFFECT OF NITROGEN FERTILIZATION ON SUGARS, ASCORBIC ACID AND PHENOLIC COMPOUNDS IN WHITE CABBAGE (*Brassica oleracea* var. *capitata alba* L.)

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Abstract. The aim of this research was to determine the influence of various forms, diverse doses, and methods of application of nitrogen fertilizers and foliar nutrition on the concentration of soluble sugars, ascorbic acid and phenolic compounds in cabbage. The three year (2005–2007) field experiment was carried out with 'Galaxy' F1 white cabbage. Two factors were examined: the type of N fertilizer ammonium sulphate and RSM (solution ammonium nitrate and urea 1 : 1), and method of N application (placement and top dressing – broadcasted with or without foliar nutrition). Climatic conditions considerably affect the concentration of compounds in cabbage. The highest concentration of soluble sugars was fund in cabbage receiving N as RSM in comparison to ammonium sulphate and with foliar nutrition treatment. In each year of the experiment plants fed RSM were characterized highest concentration of ascorbic acid. For means of year 2005–2007 foliar nutrition led to a marked decline in the concentration of ascorbic acid in cabbage. In 2005 and 2007 highest concentration of phenolic compounds was assessed in cabbage plants fed RSM. Cabbage plants fertilized 75% N broadcasted at planting of seedlings with foliar nutrition characterized the lowest concentration of phenolic compounds – means for 2005–2007.

Key words: foliar nutrition, broadcast, placement fertilization, phytochemicals, cabbage quality

INTRODUCTION

Cultivar, soil and climatic conditions affect the concentration of compounds in vegetables, which are important for both human nutrition and taste. Temperature and soil

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moisture during the growing season, fertilization practices (dose, N form and method of N application) have a significant influence on the concentration of phytochemicals in plants such as vitamins, phenolic compounds, and sugars [Lisiewska and Kmiecik 1996, Sady et al. 1996c, Domagała 1997, Rożek and Wojciechowska 2000, Sady et al. 2001, Wojciechowska et al. 2005].

Cabbage is one of the most important vegetables grown worldwide and the most important dietary vegetables consumed in Poland and other Central European countries. It is estimated that in Poland the annual cultivation of cabbage constitutes about 30% of the total production of ground vegetables [Polish Central Statistical Office 2009]. *Brassicaceae* vegetables are good sources of natural antioxidants such as carotenoids, vitamins, flavonoids, and phenolic compounds [Leja et al. 2000, Rożek and Wojciechowska 2000, Rożek et al. 2000a, Rydz 2001, Wojciechowska et al. 2005, Singh et al. 2006, Podsędek 2007]. Frequent intake of *Brassicaceae* vegetables, such as broccoli, cauliflower, cabbage, and Chinese cabbage, which possess antioxidant activity, could be helpful to human health. Epidemiological data as well as in vitro studies strongly suggest that fruits and vegetables having antioxidant phytochemicals have strong protective effects against major degenerative diseases including cancer and cardiovascular diseases [Block et al. 1992, Prior and Cao 2000, Van Duyn and Pivonka 2000].

White cabbage is consumed both raw and processed in different ways, e.g. stewed or fermented. Fermented cabbage known as sauerkraut is very popular in Poland and frequently consumed, especially throughout the winter period. The fermentation of cabbage by lactic bacteria increases antioxidative activity. The fermentative bacteria require carbohydrates – either simple sugars such as glucose and fructose or complex carbohydrates such as starch or cellulose. The energy requirements of micro-organisms are very high. Limiting the amount of substrate available can check their growth [Kusznierewicz et al. 2008].

The possibility of increasing phytochemicals content and nutri-constituents by control of certain environmental factors and by breeding has received attention in the case of vegetables crops. Leskovar and al. [2007] indicated that agronomic strategies may significantly modify and/or improve phytochemicals concentration and profiles in vegetables crops.

The main objective of this study was to determine the effect of N forms (ammonium sulphate, RSM), method of N application (broadcast, placement) and foliar nutrition on phytochemicals and sugars concentration in cabbage.

MATERIAL AND METHODS

The three year (2005–2007) field experiment was carried out with white 'Galaxy' F_1 cabbage on a loamy soil containing 0.91–1.02% organic carbon and soil acidity pH_{KCl} 6.17–7.10. The plots were located at a private farm, specialized in cabbage production (Zagorzyce, Poland 50°23' and 20°04'). The experiment was arranged in a split-plot design, each year on a different site within a single soil complex owned by a single horticultural farm. Each experiment treatment was randomized in four repetitions on 3.6 m × 3.0 m (11 m^2). The total area used for the experiment was 520 m^2. Two factors

were examined: the type of N fertilizer – ammonium sulphate and RSM (solution ammonium nitrate and urea 1 : 1), and method of N application. The treatments were as follows:

1. Control – 100% N rate (120 kg ha^{-1}) broadcasted at planting of seedlings,
2. 75% N rate broadcasted at planting of seedlings + 25% N during plant grow,
3. 75% N rate broadcasted at planting of seedlings + foliar fertilization,
4. 75% N placement at seedlings planting,
5. 75% N placement at seedlings planting + 25% N during plant growth,
6. 75% N placement at seedlings planting + foliar fertilization.

Nitrogen fertilizer was applied at the rate of 120 kg N ha^{-1} (100% N). With the placement fertilization method fertilizer was applied on the rows in 10 cm depth and 10 cm distance on each plant (plant were spaced 67.5 × 67.5 cm) at transplanting seedlings times. Plants were sprayed three-times with: 2% (w/v) urea, a 1% (v/v) solution of multicomponent 'Supervit R' fertilizer, and again with 2% (w/v) urea. Foliar sprayings started at the beginning of intensive leaves growth and conducted at growing season in two weeks interval.

Each year cabbage was harvested on thirst decade of November. The analyses of cabbage plants were performed on fresh plant material. The total soluble sugars were determined by anthronic method [Yemm and Willis 1954], ascorbic acid level was determined by the iodate method of Duliński et al. [1988] and total phenolic compounds were assessed with Folin and Ciocalteu reagents [Swain and Hillis 1959].

The obtain results were verified statistically with the ANOVA module of 'Statistica 7.1 PL'. The significance of the differences for nitrogen fertilization, and combinations of fertilizer and N application method was calculated by variation analysis ($P < 0.05$).

RESULTS AND DISCUSSION

Climatic conditions during the experimental period. Environmental factors significantly influenced the cabbage yield and its quality. The highest yield was obtained in 2007 (88.4 t ha^{-1}), slightly less in 2005 r (83.8 t ha^{-1}), and lowest in 2006 (64.3 t ha^{-1}) (data no published). The efficiency and utilization of N by crops was limited by the water availability. In 2005 and 2007 rainfalls were 327 and 420 mm of precipitation (during the growing season) respectively, but distributed regularly only in 2005 (fig. 1). In 2007 low temperature and high rainfalls were observed in September (134 mm). The year 2006 was characterized by a higher than average monthly temperature compared with 2005 and 2007 (fig. 1). Growing season of 2006 was also dry (253 mm) with extremely dry months July (7.9 mm) and October (4.5 mm of precipitation).

Concentration of soluble sugars in cabbage. Cabbage cultivars contained from about 3.0–6.0% total sugars, and glucose was the most abundant sugar in entire cabbage heads [Polak and Elkner 1996, Gawęcki and Hryniewiecki 2006]. Total and relative amounts of sugars in plants are likely to vary with the growing season, since they may accumulate as a response either to water deficit [Marchner 1995].

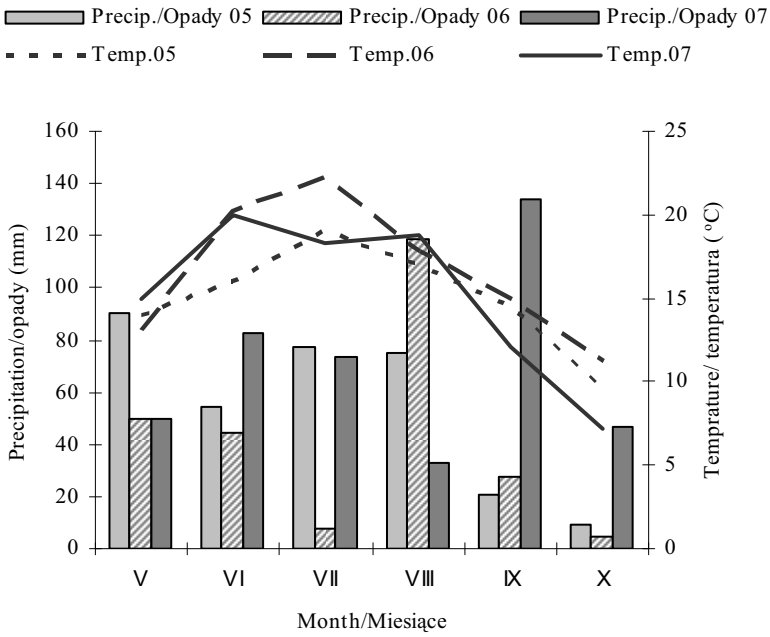

Fig. 1. Mean temperature and precipitation for 2005–2007
Ryc. 1. Średnia temperatura i suma opadów w latach 2005–2007

The highest concentration of soluble sugar in cabbage was assessed in the driest 2005 (4913 mg 100 g^{-1} f.m.). In 2006 and 2007 determined similarly amount of these compounds, 4540 mg 100 g^{-1} f.m. and 4402 mg respectively (tab. 1). The higher temperatures during growing season might affect carbon metabolism in the plant organs resulting in changes in the sugar partitioning as demonstrated in other crops [Wolf et al. 1991, Domagała 1997, Smoleń and Sady 2009]. Studies of Rosa et al. [2001] revealed that the growing season influenced the free sugars content, with generally higher levels in the spring/summer than in the summer/winter season in broccoli, while an opposite tendency was noted in the other *Brassica* species.

A significant effect of nitrogen fertilization and foliar nutrition on soluble sugar concentrations in cabbage was revealed. The highest concentration of soluble sugars (means for 2005–2007) was found in cabbage receiving N as RSM in comparison to ammonium sulphate. This tendency was observed in 2005 and 2007. In 2005 and 2006 N placement fertilization applied on the rows of plants significantly increased concentration of soluble sugars in cabbage in relation to control plants (100% N at seedlings planting). The inverse effect was noticed in 2007 when generally the lowest concentration of soluble sugars in cabbage was assessed. A similiarly profitable effect of placement N fertilization on soluble sugars level on cabbage was also reported by Sady et al. [1999].

Table 1. Effect of nitrogen fertilization on soluble sugars content (mg 100 g^{-1} f.m) in 'Galaxy' F_1 cabbage in 2005–2007

Tabela 1. Wpływ nawożenia azotem na zawartość cukrów rozpuszczalnych (mg 100 g^{-1} ś.m.) w kapuście głowiastej białej odm. 'Galaxy' F_1 w latach 2005–2007

Factor Czynnik	Application method Sposób nawożenia		Soluble sugars Cukry rozpuszczalne			Mean Średnia
			2005	2006	2007	
$(NH_4)_2SO_4$	broadcast rzutowy	1	4104	4285	4573	4321
		2	4493	4631	4474	4533
		3	4059	4889	4388	4445
	placement zlokalizowany	4	4417	4774	4140	4444
		5	5333	4451	4289	4691
		6	5097	4351	4057	4502
RSM	broadcast rzutowy	1	5281	4361	4467	4703
		2	4927	4479	4372	4593
		3	5146	4611	4818	4858
	placement zlokalizowany	4	5267	4465	4398	4710
		5	5653	4576	4550	4926
		6	5180	4604	4296	4693
Mean for years – Średnia z lat			4913	4540	4402	
Fertilizer Nawóz	Ammonium sulphate Siarczan amonu		4584	4563	4320	4489
	RSM		5242	4516	4483	4747
Application method Sposób stosowania	1. 100% N broadcast/rzutowo		4693	4323	4520	4512
	2. 75% N broadcast/rzutowo + 25% N		4710	4555	4423	4563
	3. 75% N broadcast/rzutowo + foliar spray/dolistnie		4602	4750	4603	4652
	4. 75% N placement/zlokalizowanie		4842	4620	4269	4577
	5. 75% N placement/zlokalizowanie + 25% N		5493	4514	4420	4809
	6. 75% N placement/zlokalizowanie + foliar spray/dolistnie		5139	4477	4176	4598
$LSD_{(0.05)}$	Year					76
	Fertilizer		129	32	28	
	Application method		223	56	49	
	Fertilizer × Application method		316	79	69	

1. Control – 100% N rate (120 kg ha^{-1}) broadcasted at planting of seedlings, 2. 75% N rate broadcasted at planting of seedlings + 25% N during plant grow, 3. 75% N rate broadcasted at planting of seedlings + foliar fertilization, 4. 75% N placement at seedlings planting, 5. 75% N placement at seedlings planting + 25% N during plant growth, 75% N placement at seedlings planting + foliar fertilization.

1. Kontrola – 100% poziomu N (120 kg ha^{-1}) rzutowo w okresie sadzenia rozsady, 2. 75% poziomu N rzutowo w okresie sadzenia rozsady + 25% N podczas wzrostu roślin, 3. 75% N rzutowo w okresie sadzenia rozsady + dokarmianie pozakorzeniowe, 4. 75% N zlokalizowane w okresie sadzenia rozsady, 5. 75% N zlokalizowane w okresie sadzenia rozsady + 25% N podczas wzrostu roślin, 75% N zlokalizowane w okresie sadzenia rozsady + dokarmianie pozakorzeniowe.

The experiment demonstrated an apparent influence of foliar nutrition on soluble sugar concentration in cabbage harvested in 2006 – regardless of method of N application and N source. In 2007 for cabbage plants fed RSM broadcasted at planting of seedlings, and in 2005 for plants placement fertilized with ammonium sulphate similar profitable tendency of foliar nutrition was observed (tab. 1). Studies of Rydz [2001] demonstrated any distinct effect of foliar nutrition and N fertilizers rates on soluble sugar in

broccoli. Smoleń and Sady [2009] reported the foliar nutrition (with urea) caused a decline in sugar concentration in harvested carrot roots.

Ascorbic acid concentration in cabbage. Ascorbic acid content is now recognized as a quality of major importance in many plant foods. This water soluble dietary antioxidant significantly decreases the adverse effect of free radials that can cause many chronic diseases including cardiovascular diseases, stroke, cancer and neurodegenerative disease [Halliwell and Gutteridge 1992]. Generally, among *Brassica* vegetables, white cabbage is the poorest source of vitamin C. However in Poland, white cabbage is the most popular species of *Brassica* vegetables [Gawęcki and Hryniewiecki 2006].

The wide range in this vitamin reported for cabbage varieties under various conditions points to the complexity of the factors involved [Polak and Elkner 1996, Kurilich et al. 1999, Singh et al. 2006]. Our experiment demonstrated an apparent influence of

Table 2. Effect of nitrogen fertilization on ascorbic acid (mg 100 g^{-1} f.m.) in 'Galaxy' F_1 cabbage in 2005– 2007

Tabela 2. Wpływ nawożenia azotem na zawartość kwasu askorbinowego (mg 100 g^{-1} ś.m.) w kapuście głowiastej białej odm. 'Galaxy' F_1 w latach 2005–2007

Factor Czynnik	Application method Sposób nawożenia		Ascorbic acid Kwas ascorbinowy			Mean Średnia
			2005	2006	2007	
$(NH_4)_2SO_4$	broadcast rzutowy	1*	29.9	26.0	23.8	26.5
		2	29.0	23.8	24.2	25.7
		3	23.2	23.3	21.6	22.7
	placement zlokalizowany	4	29.9	22.9	20.2	24.3
		5	30.8	22.9	22.0	25.2
		6	27.0	22.9	25.6	25.1
RSM	broadcast rzutowy	1	33.1	30.4	26.4	30.0
		2	33.4	28.6	31.2	31.1
		3	29.6	29.5	30.4	29.8
	placement zlokalizowany	4	33.7	27.7	29.5	30.3
		5	32.0	26.8	24.6	27.8
		6	30.5	28.6	25.5	28.2
Mean for years – Średnia z lat			30.2	26.1	25.4	
Fertilizer Nawóz	Ammonium sulphate Siarczan amonu		28.3	23.6	22.9	24.9
	RSM		32.1	28.6	27.9	29.5
Application method Sposób stosownia	1. 100% N broadcast/rzutowo		31.5	28.2	25.1	28.2
	2. 75% N broadcast/rzutowo + 25% N		26.4	26.4	26.0	26.2
	3. 75% N broadcast/rzutowo + foliar spray/dolistnie		26.4	26.4	26.0	26.2
	4. 75% N placement/zlokalizowanie		31.8	25.3	24.9	27.3
	5. 75% N placement/zlokalizowanie + 25% N		31.4	24.9	23.3	26.5
	6. 75% N placement/zlokalizowanie + foliar spray/dolistnie		28.7	25.7	25.5	26.7
$LSD_{(0.05)}$	Year					0.93
	Fertilizer		1.56	0.39	0.56	
	Application method		2.70	0.68	0.97	
	Fertilizer × Application method		ni/ns	0.96	1.38	

ns – no significant for p = 0.05 – ni – nieistotne dla p = 0,05
*see Table 1 – objaśnienia w tabeli 1

variable weather conditions and different N source on ascorbic acid concentration in cabbage plants. The highest amount of AA was found in plants harvested in 2005 (30.2 mg 100 g^{-1} f.m.). The lowest value of ascorbic acid was assessed in cabbage in 2007 (25.4 mg) (tab. 2).

In each year of the experiment plants fed RSM were characterized highest concentration of AA compared to plants received ammonium sulphate. Lisiewska and Kmiecik [1996] reported that nitrogen fertilization did not affect the content of vitamin C in broccoli, but increasing amount of nitrogen fertilizer from 80 to 120 kg ha^{-1} decreased the vitamin C content by 7% in cauliflower.

Studies of Sady et al. [1999] demonstrated no significant effect of N fertilization technique (placement or broadcast) on the ascorbic acid level determined in cabbage heads at harvest. In the investigations of Rożek et al. [2000b], concerning the effect of different N fertilizer applied either by the broadcast or by the placement technique on ascorbic acid content in white cabbage, both the form and the application method affected its level. Generally, placement technique with ammonium sulphate decreased the amount of ascorbic acid in cabbage plants in compared to broadcast treatment. Leja et al. [2007] demonstrated the interaction between nitrogen fertilization and climatic conditions on AA concentration in cabbage. Authors found the lowest content of ascorbic acid in the control (without N application) and in the plants fed with urea in 2003/04, however in the next two year of study, the differentiation between the treatments was less distinct and the highest level of AA was noticed just in the urea treatment.

In our experiment the means for 2006 and 2007 showed a decrease in ascorbic acid concentration in cabbage plants with placement N fertilization treatment in comparison to brodcasted.

For means of year 2005–2007 foliar nutrition led to a marked decline in the concentration of ascorbic acid in cabbage (regardless of method of N application) in comparison with the control. The similar tendency to decrease AA concentration was noticed in 2005 and 2006. Rydz [2001] reported that foliar nutrition with 2% urea caused its non significant decrease ascorbic acid in broccoli, but effect was strongly influenced by climatic conditions.

Total concentration of phenolic compound in cabbage. The consumption of food rich in phenolic content can prevent chronic diseases related to oxidative stress in the human body [Ismail et al. 2004, Podsędek 2007]. The content of phenolic compounds in vegetables, like levels of other phytochemicals, can be influenced by various factors such as varieties climatic conditions and cultural practices, maturity of harvest, and storage conditions [Sady et al. 1999, Leja and al. 2000, Smoleń and Sady 2009].

The highest concentration of phenolic compounds in cabbage was noticed in 2005 (30.6 mg 100 g^{-1} f.m.). In 2006 and 2007 were found 28.6 mg i 27.6 mg 100 g^{-1} f.m. respectively (tab. 3). The total content of phenolic compounds in vegetables is a cultivar characteristic, however, it is greatly modified by the rate of N and the method of N fertilization [Domagała 1997, Domagała and Sady 1998, Rożek and Wojciechowska 2000], foliar nutrition [Rożek et al. 2000a, Smoleń and Sady 2009], nitrogen form [Sady et al. 1996 a, b, Smoleń and Sady 2009] and also by the soil and climate conditions during cultivation [Sady et al. 1996c, Domagała 1997, Rożek 2000b]. Singh et al. [2006] studied the total phenolic content in 14 cultivar of white cabbage and found the

values ranged from 12.58 to 34.41 mg 100 g^{-1} fresh weigh. Chu et al. [2002] estimated total phenolic compounds in cabbage in the range 36.66 ± 6.93 mg 100 g^{-1} fresh weigh.

The experiment registered the effect of applied nitrogen fertilization on phenolic compound in cabbage. In 2005 and 2007 higher concentration of these compounds was assessed in cabbage plants fed RSM (solution ammonium nitrate and urea 1 : 1). Opposite in 2006 plants fertilized with ammonium sulphate had the higher level of phenolic compounds in comparison with plants fed RSM (tab. 3).

Studies of Sady et al. [1999] demonstrated the highest level of total phenolic compounds in cabbage fed ammonium sulphate and the lowest with urea treatments. The studies of Smoleń and Sady [2007] of pot cultivation of carrot plants fertilized with $Ca(NO_3)_2$, showed a decrease in the phenolic compound content in storage roots when compared to fertilization with $(NH_4)_2SO_4$, NH_4NO_3, $CO(NH_2)_2$ and the control without nitrogen fertilization.

Table 3. Effect of nitrogen fertilization on phenolic compound (mg 100 g^{-1} f.m) in 'Galaxy' F_1 cabbage in 2005–2007

Tabela 3. Wpływ nawożenia azotem na zawartość związków fenolowych (mg 100 g^{-1} św.m.) w kapuście głowiastej białej odm. 'Galaxy' F_1 w latach 2005–2007

Factor Czynnik	Application method Sposób nawożenia		Phenolic compounds Zawartość fenoli			Mean Średnia
			2005	2006	2007	
$(NH_4)_2SO_4$	broadcast rzutowy	1*	25.2	31.3	26.4	27.6
		2	26.2	30.6	27.6	28.1
		3	24.2	30.5	28.3	27.7
	placement zlokalizowany	4	31.3	30.3	27.7	29.8
		5	34.0	28.4	28.5	30.3
		6	32.2	28.6	28.7	29.8
RSM	broadcast rzutowy	1	33.7	24.7	29.6	29.3
		2	33.1	26.9	29.8	29.9
		3	32.0	24.3	27.5	27.9
	placement zlokalizowany	4	33.2	25.7	29.5	29.5
		5	31.6	26.2	30.3	29.3
		6	30.4	24.0	29.3	27.9
Mean for years – Średnia z lat			30.6	27.6	28.6	
Fertilizer Nawóz	Ammonium sulphate Siarczan amonu		28.9	29.9	27.9	28.9
	RSM		32.3	25.3	29.3	29.0
Application method Sposób stosownia	1. 100% N broadcast/rzutowo		29.5	28.0	28.0	28.5
	2. 75% N broadcast/rzutowo + 25% N		29.7	28.7	28.7	29.0
	3. 75% N broadcast/rzutowo + foliar spray/dolistnie		28.2	27.4	27.9	27.8
	4. 75% N placement/zlokalizowanie		32.3	28.0	28.6	29.6
	5. 75% N placement/zlokalizowanie + 25% N		32.8	27.3	29.3	29.8
	6. 75% N placement/zlokalizowanie + foliar spray/dolistnie		31.3	26.3	29.0	28.9
$LSD_{(0.05)}$	Year					0.72
	Fertilizer		1.24	0.28	0.24	
	Application method		2.15	0.49	0.42	
	Fertilizer × Application method		3.03	0.69	0.59	

*see Table 1 – objaśnienia w tabeli 1

In presented studies cabbage plants fertilized 75% N broadcasted at planting of seedlings with foliar nutrition characterized lower concentration of phenolic compounds – mean for years in compared to other combinations. A similar result was noticed in 2005 for both fertilizers and in 2007 for RSM. The plants fed RSM with foliar nutrition characterized a lower level of these compounds in spite of method of soil N application – the means for 2005–2007. A marked effect of foliar nutrition and its interaction with N fertilization on phenolic compound concentration in carrot roots was reported by Rożek and Wojciechowska [2000] and Smoleń and Sady [2009].

CONCLUSIONS

The presented research results demonstrated a different effect of forms (ammonium sulphate, RSM), method of application (broadcast, placement) and foliar nutrition (with solution of multicomponent 'Supervit R' fertilizer, and with 2% (w/v) urea) on the phytochemicals such as ascorbic acid, phenolic compounds, and sugars in 'Galaxy" F1 white cabbage. This study also demonstrated that climatic conditions specifically modified the influence examined factors on cabbage quality. The results of experiment showed that cabbage plants fed RSM (solution ammonium nitrate and urea 1 : 1) generally had highest concentration of soluble sugars, ascorbic acid level and phenolic compounds content in comparison to ammonium sulphate treatment. Foliar nutrition combined with broadcast or placement fertilization significantly caused a rise of soluble sugars in cabbage. However profitable effect of foliar nutrition on sugars level depended on climatic conditions during in cultivation period. Generally, foliar nutrition decreased ascorbic acid concentration in cabbage regardless of method of N application and the source of nitrogen, and phenolic compounds in plants. The experiment revealed the interaction between method and form of nitrogen fertilization and climatic conditions on determined phytochemicals in cabbage. It appears that shaping the quality of cabbage yield with the combined treatment foliar nutrition and soil nitrogen fertilization is a result of variable weather conditions (temperatures as well as amount and distribution of rainfall in the growing season).

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WPŁYW NAWOŻENIA AZOTEM NA ZAWARTOŚĆ CUKRÓW, WITAMINY C I FENOLI W KAPUŚCIE GŁOWIASTEJ BIAŁEJ (*Brassica oleracea* var. *capitata alba* L.)

Streszczenie. Celem badań było określenie wpływu różnych form azotu, metod aplikacji nawozów azotowych i dokarmiania pozakorzeniowego na zawartość cukrów rozpuszczalnych, witaminy C i fenoli w kapuście głowiastej białej. Badania polowe prowadzono w latach 2005–2007 z wykorzystaniem odmiany 'Galaxy' F_1. Badano wpływ rodzaju nawozu azotowego (siarczan amonu, RSM) oraz sposobów aplikacji nawozów azotowych (rzutowe, zlokalizowane) z/lub bez dokarmiania pozakorzeniowego. Warunki klimatyczne istotnie modyfikowały zawartość oznaczanych składników w kapuście. Wyższą zawartością cukrów rozpuszczalnych charakteryzowały się rośliny nawożone RSM w porównaniu z siarczanem amonu oraz rośliny dokarmiane dolistnie. W każdym roku badań RSM zwiększał zawartość witaminy C w roślinach. Średnio w latach 2005–2007 dolistne dokarmianie roślin obniżało koncentrację witaminy C w kapuście. W roku 2005 i 2007 wyższą zawartością fenoli charakteryzowały się rośliny nawożone RSM. Kapusta nawożona 75% N rzutowo i dokarmiana pozakorzeniowo posiadała najniższą zawartość fenoli średnio w okresie 2005–2007.

Słowa kluczowe: dokarmianie pozakorzeniowe, nawożenie rzutowe i zlokalizowane, jakość kapusty

Accepted for print – Zaakceptowano do druku: 7.07.2010