Journal of Elementology ISSN 1644-2296

Radkowski A., Sosin-Bzducha E., Radkowska I. 2017. *Effects of silicon foliar fertilization of meadow plants on nutritional value of silage fed to dairy cows.* J. Elem., 22(4): 1311-1322. DOI: 10.5601/jelem.2017.22.1.1331

ORIGINAL PAPER

EFFECTS OF SILICON FOLIAR FERTILIZATION OF MEADOW PLANTS ON NUTRITIONAL VALUE OF SILAGE FED TO DAIRY COWS*

Adam Radkowski[1], Ewa Sosin-Bzducha[2] Iwona Radkowska[3]

[1]Department of Grassland Management
University of Agriculture in Krakow, Poland
[2]Department of Animal Genetic Resources Conservation
[3]Department of Technology, Ecology and Economics of Animal Production
National Research Institute of Animal Production, Poland

Abstract

The study presents results of chemical analyses and the nutritional value of silages made from meadow plants exposed to foliar fertilization with silicon (Si doses 46.8 g Si ha^{-1} – variant I and 74.9 g Si ha^{-1} – variant II, preparation Optisil®), and data on the milk yield as well as the basic composition and quality of milk produced by cows fed with these silages. Standard methods (AOAC 2005) were used to determine the basic components of silages. pH and organic acids of silages were measured. The feeding trial was conducted on 30 Polish Holstein-Friesian dairy cows. The control group (C) was fed silage from non Si-fertilized meadow plants. The other two groups were fed with the fodder containing silages from Si-fertilized meadow, i.e. group I silage obtained from variant I (46.8 g Si) and group II silage obtained from variant II (74.9 g Si). The cows were fed with total mixed rations (TMR). The silages made from meadow plants accounted for about 26.3 kg of a daily total ration. The cows were also given hay, barley straw and concentrate feed (triticale, barley, and wheat). The share of papilionaceous plants increased and dicotyledonous plants decreased proportionally to silicon fertilization. The study showed no effects of the biostimulator on the crop yield. The silages made from silicon fertilized plants had a higher nutritional value. Feeding dairy cows with silages made from Si-fertilized plants improved their milk productivity. The total solids, protein and fat of milk were higher in the Si groups. The highest milk yield as well as the milk protein and fat content were achieved in the group of cows fed with the silage made from plants fertilized with the highest silicon preparation dose (group II). Milk contained lower total counts of microorganisms (BPC) and somatic cells (SCC). The best results in this area were noticed for milk produced by group I cows fed with variant I silage.

Keywords: meadow plants, silicon fertilization, silage, nutritional value, milk production.

dr inż. Adam Radkowski, Department of Grassland Management, Institute of Plant Production, University of Agriculture in Krakow, Al. Mickiewicza 21, 31-120 Krakow, Poland, phone: +48 12 662 43 59

* The work has been financed with subsidies for maintaining the research potential granted by the Ministry of Science and Higher Education.

INTRODUCTION

The significantly increased productivity of dairy cows and TMR feeding method require most of the bulky feeds to be provided in the preserved form of silage. In many parts of Europe, New Zealand, Australia or North America grass silage is used in cattle feeding in the winter season and in feeding methods based on total mixed ration – TMR (Keady et al. 2008). The chemical composition and nutritional value of grass silage may be highly variable, depending on botanical and chemical composition of the source plants, their maturity, climatic conditions, fertilization level and method and conditions of the ensiling process (Szabó, Pepó, 2007, Knežević et al. 2007). As Poland lies in the transitional climate zone, crop yield stability to a high extent is determined by the water supply conditions. However, an increasing shortage of precipitation has been observed in Poland for the few past years. Insufficient rainfall and its unfavourable distribution over the plant growing season cause changes in crop yields and plant chemical composition. Fluctuations in the soil water content result in oxidative stress, which involve the accumulation of reactive oxygen species that damage plant cells at the level of their chemical components (Kalandyk et al. 2014). Plant growth regulators or biostimulators are gaining popularity (Nelson 2003). This is a relatively new group of products used to achieve the greatest possible productivity and crop quality, particularly in adverse environmental conditions (Przybysz et al. 2010). They stimulate plant growth, accelerate their physiological processes, may improve their resistance to stress factors and facilitate regeneration after plant exposure to unfavourable factors. Silicon is one of the components that stimulate plant growth and development, and reduce the risk of pest and pathogen attacks (Fauteux et al. 2005, Ma, Yamaji 2006, Fauteux et al. 2006). It is present in considerable amounts in the majority of plants and its content is comparable to that of calcium, magnesium or even phosphorus (Ma, Takahasi 2002, Ma,Yamaji 2006).

The aim of the study was to determine the effect of growth biostimulator (silicon) used for foliar fertilization of meadow plants on the chemical composition and nutritional value of silages, and to evaluate the effect of feeding with these silages on the productivity and quality of milk produced by Polish Holstein-Friesian dairy cows.

MATERIAL AND METHODS

The study was conducted on a private farm located in the Province of Silesia, Zawiercie District. The research plots lay on brown acidic soil (pH_{KCl} 5.3), belonging to the fifth class in the Polish soil valuation system. The soil contained moderate amounts of absorbable forms of potassium, manganese and zinc, but low amounts of absorbable phosphorus and copper. The area of each research plot was 2.0 ha. Prior to the experiment, dominant grass species included English ryegrass (*Lolium perenne*), meadow fescue (*Festuca pratensis*), orchard grass (*Dactylis glomerata*), Kentucky bluegrass (*Poa pratensis*), red fescue (*Festuca rubra*), and timothy grass (*Phleum pratense*). Less popular species included crested dog's-tail (*Cynosurus cristatus*) and common bent (*Agrostis capillaris*). The share of papilionaceous plants was 10%, and they were represented mainly by red clover (*Trifolium pratense*). The experimental meadows also contained 12 species of dicotyledonous plants, which accounted for 17% of the entire flora (Table 1).

The annual rainfall in the study period (2013-2014) was 720.5 mm and 820.6 mm, respectively (Table 2). The mean rainfall during the plant growing period (April–September) was 464.4 mm in 2013 and 595.0 mm in 2014. The average annual temperature in 2013-2014 was 8.4°C and 9.0°C, respectively, and 14.8°C and 14.7°C, respectively, between April and September.

Material and experimental design

The study included three variants: control (no treatments) and experimental plots sprayed with two doses of Optysil® preparation (variant I – 0.5 dm^3 ha^{-1} and variant II – 0.8 dm^3 ha^{-1}). Optysil® contains 93.6 g Si L^{-1} of the solution, hence the actual Si doses were 46.8 and 74.9 g Si ha^{-1}. According to the decision of the Ministry of Agriculture and Rural Development No. S-514/15, this fertilizer is classified as a mineral growth stimulator. It is manufactured by INTERMAG Sp. z o.o. The solutions used for spraying were prepared by dissolving appropriate amounts of the silicon preparation in such an amount of water as to obtain 300 dm^3 ha^{-1} of the working solution. The plots were sprayed after the spring plant emergence commenced. The following basic mineral fertilization was provided in all the variants: nitrogen for the first crop at 80 kg N ha^{-1} in the form of ammonium nitrate, a single application of phosphorus in the spring at 52.3 kg P ha^{-1} as enriched superphosphate (17.4% P), and potassium for the first crop at 49.8 kg K ha^{-1} as potassium salt (47.3% K).

The first crop was harvested in two stages. The plants were mowed at the heading stage of dominant grass species with a rotary mower and then dried by single tedding. Raking was performed half an hour before the harvest. Raw material was collected using a single chamber round baler and the bales were transported to a storage area, where they were wrapped into three layers of plastic. The mean time of the bale formation until its wrapping in plastic was up to four hours.

Before feeding the cows with the silage (minimum six weeks after preparation) five samples were collected from each type of silage for chemical analysis. The content of basic components was determined according to AOAC (2005), and pH of the silages was determined with TOLEDO

Table 1

Botanical composition and percentage share of individual species in the meadow flora depending on the dose of the silicon growth stimulator

Species	Before experiment	Control	Variant I	Variant II
	(%) share			
Grasses	**73**	**76**	**76**	**78**
English ryegrass (*Lolium perenne* L.)	18	22	23	25
Meadow fescue (*Festuca pratensis* L.)	14	15	14	17
Orchard grass (*Dactylis glomerata* L.)	14	15	14	14
Kentucky bluegrass (*Poa pratensis* L.)	9	10	8	13
Red fescue (*Festuca rubra* L.)	5	4	4	4
Timothy grass (*Phleum pratense* L.)	4	4	5	4
Crested dog's-tail (*Cynosurus cristatus*)	3	3	4	–
Common bent (*Agrostis capillaris*)	3	1	2	–
Rough bluegrass (*Poa trivialis* L.)	3	2	2	1
Papilionaceous plants	**10**	**11**	**14**	**17**
Red clover (*Trifolium pratense* L.)	8	8	11	14
White clover (*Trifolium repens* L.)	2	3	3	3
Dicotyledonous plants	**17**	**13**	**10**	**5**
English plantain (*Plantago lanceolata L.)*	2	1	2	1
Broadleaf plantain (*Plantago major* L.)	2	1	+	+
Small-flowered crane's-bill (*Geranium pusillum* L.)	+	1	1	+
Common chicory (C*ichorium intybus* L.)	+	–	–	+
Chickweed (*Stellaria media* (L.)	+	+	+	+
Creeping buttercup (*Ranunculus repens* L.)	2	1	1	+
Common yarrow (*Achillea millefolium* L.)	3	2	1	1
Common dandelion (*Taraxacum officinale* coll.)	4	3	2	2
Plume thistle (*Cirsium rivulare* (Jacq.) *All.*)	1	2	+	+
Curlytop knotweed (*Polygonum lapathifolium* L. subsp. *lapathifolium)*	+	+	1	+
Spotted ladysthumb (*Polygonum persicaria*)	+	+	–	+
Wild chamomile (*Matricaria discoidea DC.*)	1	1	+	+

pH-meter (Mettler Toledo, Switzerland). The content of organic acids was determined using a liquid chromatograph LCP 5020 produced by INGOS (Czech Republic), with a steel column 8×250 mm filled with OSTION LG-KS 0800 H^+ from Tessek, mobile phase: 5 mM H_2SO_4. The silage quality was

Table 2

Total precipitation and mean temperature for individual months of 2013 and 2014 and in a long-term period (Variety Testing Station Słupia Jędrzejowska)

Month	Precipitation (mm)			Temperature (°C)		
	2013	2014	2000-2012	2013	2014	2000-2012
January	61.9	42.4	32.0	-3.1	-2.1	-2.7
February	23.3	29.0	22.0	1.4	0.9	-2.0
March	64.0	46.5	29.3	-2.0	5.7	2.3
April	23.9	55.3	38.6	7.7	9.5	8.3
May	103.7	63.5	71.3	14.0	13.0	13.4
June	132.7	102.5	60.0	17.4	14.6	16.5
July	86.1	166.4	114.6	19.2	19.3	18.7
August	44.1	145.7	67.5	18.7	17.4	18.1
September	73.9	61.6	51.7	11.6	14.5	12.8
October	11.0	49.8	37.5	9.5	9.5	7.9
November	60.5	35.0	36.9	4.5	5.1	3.6
December	35.4	22.9	27.0	1.7	0.4	-1.4

evaluated according to Flieg-Zimmer scale accounting for the ratio of individual organic acids. Nutritional value of the silages was assessed using INRA -tion Prevalim 3.3 software and our chemical analyses. Tabular coefficients of protein distribution in the rumen and intestines were adopted.

Feeding experiment included 30 Polish Holstein-Friesian (75% pHF) cows, between day 90 and 120 of lactation, kept in a barn with the mean annual milk yield of 6600 kg. During the study, daily production of milk ranged from 18 to 24 kg. An analogue method was used to divide the cows into three groups of 10 individuals each. The control group (C) was fed with fodder containing mainly silage from non Si-fertilized meadow plants. The other two groups were fed with fodder containing silages from Si-fertilized meadow, i.e. group I was provided with the silage obtained from variant I (46.8 g Si) and group II was given the silage obtained from variant II (74.9 g Si). The cows were fed with total mixed rations (TMR). The silages made from meadow plants accounted for about 26.3 kg of a daily total ration. The cows were also given hay, barley straw and mixed feed (triticale 50%, barley 30%, and wheat 20%) in the respective amounts of 5.9 kg, 2.3 kg and 5.0 kg per animal. The rations contained the silage made from the first crop. The rations were calculated as per IZ PIB-INRA (2014) recommendations in the INRAtion software (ver. 4.05, Copyright INRA, 1988-2004). The silages were used for cow feeding at least six weeks after ensiling. The amount of feed intake was evaluated daily by weighing the leftovers. After the first, preliminary month of this experimental diet, three milk samples were collected at monthly intervals. The protein and fat content in milk was determined in a Foss Electric – Milkoscan FT 120 device. Milk quality was evaluated based on such quality parameters as total microorganism count and somatic cell count in 1 ml, in line with the Polish standard PN-A-86002.

The results were subjected to statistical analysis in Statistica ver. 9.1 (Statsoft 2009). As the year of the study did not affect the yield of the ensiled crops, chemical composition or nutritional value of the silages, this factor was excluded from the analysis. Single factor analysis of variance was used and differences between means were assessed with the Duncan's test. The results were considered significant at $p \leq 0.05$, and highly significant at $p \leq 0.01$; and the values adopted for trends were $0.06 \leq p \leq 0.1$.

RESULTS AND DISCUSSION

The study showed that foliar fertilization with silicon affected the botanical composition of meadow plants (Table 1). The experimental plots comprised more papilionaceous plants than the control one (14% and 17% for variant I and II, respectively vs. 11% in control). The share of papilionaceous plants increased at the expense of dicotyledonous plants. The abundance of dicotyledonous plants in the meadow sprayed with the higher silicon concentration (variant II) was nearly three times lower than in the control meadow. The grass share was relatively constant at 77%. Changes in the botanical composition of the meadows consisting in an increased share of papilionaceous plants and reduced abundance of dicotyledonous plants might be due to the presence of silicon. Silicon improves water management in plants and also shows detoxifying and antifungal properties. Papilionaceous plants, including *Trifolium pratense* L., have high soil and water requirements and are not very tolerant to fungal infections. Sacała (2009) claimed that beneficial effects of silicon fertilization might be a result of better and more effective osmoregulation, improved water balance, reduced water loss by transpiration, ensurance of a proper supply of necessary nutrients, reduced intake of toxic ions and improved performance of antioxidant mechanisms. Ma (2004) and Ma, Yamaji (2006) also reported that silicon improved plant resistance to fungal diseases and adverse environmental conditions, such as low temperature and water shortage.

The study revealed no effects of the silicon biostimulator on dry matter yield of the crops (Table 3). No effects of the biostimulator on the crop yield were observed, which may be due to the low ability of the meadow plants to accumulate silicon. All plants are capable of absorbing silicon from soil, but the content of this element in their dry matter varies considerably between species. Considering their ability to accumulate silicon, plants may be divided into three categories: effective, moderate and ineffective accumulators (Takahashi et al. 1990). Differences in plants' silicon content are due to their different abilities to absorb this component. Beneficial effects of silicon are also attributed to its interactions with such macronutrients as nitrogen, phosphorus or potassium (Singh et al. 2005), which may affect crop productivity. The growth biostimulator Optysil used in fertilization of sugar beet, which is an effective accumulator of silicon, improved root yield by around 15% (Artyszak et al. 2015, 2016). Similar results were reported for soybean (*Glycine max* L. Merr), where the number of pods was by 14% higher and seed weight per plant 21% greater than in control under field conditions (Kalandyk et al. 2014). The results for leaf yield were less clear, as both no effects (Artyszak et al. 2015) and an increase in the leaf yield by 21% were observed (Artyszak et al. 2014).

The study demonstrated a positive effect of silicon fertilization (variant I and II) on the nutritional value of the silages (Table 3). The silages made from the crops fertilized with the biostimulator showed a tendency for a higher total protein content. The silages made from the plants fertilized with silicon had a higher protein nutritional value expressed in BTJ units and a higher energy value expressed in JPM units as compared with the silage made from non Si-fertilized plants. Nutritional value of silages is largely determined by the dry matter content of ensiled plants (Yahaya et al. 2001). An excessive moisture content in crops adversely affects fermentation and the silage produced has a low protein content, excessive acidity and a high share of acetic acid and ammonia. An insufficient content of dry matter is associated with the enhanced activity of undesirable bacteria of *Clostridium* spp., and decomposition of sucrose and protein to butyric acid and ammonia. However, an excessively high content of dry matter together with the strong crushing force applied to ensiled material may result in the overheating of silage and significant loss of nutrients. An optimum content of dry matter is 28-30% (Jeroch et al. 1999). The silages prepared in this study had a high dry matter content (Table 3) and high pH (over 6). The silage quality assessment revealed a proper ratio of organic acids, absence of butyric acid and low percentage of ammonia nitrogen ($N\text{-}NH_3$) in the total nitrogen.

The study showed no impact of silicon preparation on the content of dry matter and other components, except for protein, in the silages. A trend towards a higher protein content might be caused by the higher share of papilionaceous plants in the botanical composition of the meadow plants and the increased protein content in these plants. As reported by Kurdali et al. (2013), a reduced ability to bind atmospheric nitrogen due to water shortage negatively affects the nitrogen balance in the plant. The use of silicon in fertilization of chickpeas, a known papilionaceous plant, improved the binding or atmospheric nitrogen (% Ndfa) by 51% in plants exposed to a water deficit and by 47% in plants grown under optimal conditions. Mali and Aery (2008) suggested that the beneficial effect of silicon on nitrogen fixation might be due to the higher content of leghemoglobin, an oxygen fixing hemeprotein present in root nodules of papilionaceous plants. Double soil fertilization with silicon and potassium at different doses ($Si_{50}K^+$, $Si_{100}K^+$, $Si_{200}K^+$) positively affected the plant's nitrogen balance (+146, +144 and +169 mg N/pod, respectively) (Kurdali et al. 2013). The improved nitrogen balance seemed to

Table 3

Yield of the crop after foliar fertilization with the silicon growth stimulator and the chemical composition and nutritional value of the silages

Detailed description	Control	Variant I	Variant II
Crop dry matter yield (t ha^{-1})	5.96	5.26	5.66
Chemical composition (%)			
dry matter	43.34	44.63	45.60
raw ash	7.51	7.72	7.85
total protein	9.66^{x}	10.24^{y}	10.40^{y}
raw fat	2.27	2.37	2.42
raw fiber	36.90	36.57	35.50
NDF	67.57	66.89	64.90
ADF	42.96	42.56	41.30
NFC	8.42	8.67	8.84
pH	6.34	6.55	6.64
Total VFA (%)	2.01	2.07	2.10
lactic acid	1.84	1.91	1.95
acetic acid	0.12	0.11	0.10
propionic acid	0.05	0.05	0.05
butyric acid	0.0	0.0	0.0
N-NH_3, % N	5.30	5.46	5.63
Quality assessment acc. to Fliege - Zimmer	very good	very good	very good
Nutritional value			
PDIN (g)	56^{A}	77^{B}	78^{B}
PDIE (g)	55^{A}	70^{B}	64^{AB}
UFL	0.62^{A}	0.80^{B}	0.79^{B}
UFV	0.51^{A}	0.71^{B}	0.72^{B}
CFU	1.16^{A}	1.17^{A}	1.05^{B}

^{x,y} tendency ^{a,b} $p \leq 0,05$; ^{A,B} $p \leq 0,01$; Units of IZ-INRA (2014) system: PDIN – protein digested in the small intestine limited by N, PDIE – protein digested in the small intestine limited by energy; UFL – energy unit for milk production, UFV – energy unit for meat production, CFU – cattle fill unit.

be the result of silicon application, as no significant results were achieved following the fertilization with potassium preparation (Kurdali et al. 2013).

The intake of feed and nutrients was higher in the groups fed with the experimental silages than in the control one (Table 4). The highest milk yield was achieved in the cows fed with the silage made from plants fertilized with the highest silicon preparation dose (group II). It was on average 5 kg more than in the control group (Table 5). The improved productivity and higher content of fat and protein in the milk of the cows fed with silages made from Si-fertilized plants could have resulted from their higher intake of dry mat-

Table 4

TMR doses and daily feed intake in dairy cows

Detailed description	Control	Group I	Group II
TMR composition (per kg of feed)			
Control silage	26.3	-	-
Silage – variant I	-	26.3	-
Silage – variant II	-	-	26.3
Meadow hay	5.9	5.9	5.9
Barley straw	2.3	2.3	2.3
Compound feed	5.0	5.0	5.0
TMR composition (per kg of dry matter)			
Control silage	11.5	-	-
Silage – variant I	-	11.4	-
Silage – variant II	-	-	12.3
Meadow hay	5.0	5.0	5.0
Barley straw	2.0	2.0	2.0
Compound feed	4.36	4.36	4.36
Nutrient concentration in TMR (kg of dry matter)			
DM (%)	0.58	0.58	0.6
PDIN (g)	75	76	76
PDIE (g)	74	73	75
UFL	0.70	0.70	0.72
(PDIN-PDIE)/UFL	1.8	3.9	0.4
Daily dose/animal (kg DW)	22.94	22.79	23.73
Leftovers, daily/animal (%)	14	10	8
Dry matter and nutrient intake, daily/animal			
DM (kg)	19.26	20.50	21.83
PDIN (g)	1445	1558	1659
PDIE (g)	1425	1497	1637
UFL	13.48	14.35	15.71

Units of IZ-INRA (2014) system: PDIN – protein digested in the small intestine limited by N, PDIE – protein digested in the small intestine limited by energy; UFL – energy unit for milk production.

ter from TMR, the higher nutritional value of the feeds, and a better balance of nutrients in the supplied rations, especially in group II.

The increased milk fat content (from 0.5% to 0.2% higher depending on a group) affected the results of milk productivity and fat corrected milk (FCM). Similar results in terms of improved productivity of dairy cows were

Table 5

Milk yielding, basic composition and microbiological quality of milk in the cows fed with silages made from plants fertilized with silicon preparation

Detailed description	Control	Group I	Group II
Productivity (kg d^{-1})			
Milk	18.32^{A}	20.06^{B}	21.81^{C}
FCM	17.86^{A}	20.36^{B}	22.79^{C}
Fat	0.70^{Aa}	0.82^{b}	0.94^{Bb}
Protein	0.57^{Aa}	0.66^{b}	0.76^{Bc}
Total solids	11.93^{Aa}	12.85^{b}	13.62^{Bc}
Fat	3.83^{x}	4.10^{xy}	4.30^{y}
Total protein	3.13	3.30	3.50
SCC (k cm^{-3} milk)	297.8^{A}	205.7^{B}	224.2^{B}
BPC (k cm^{-3} milk)	89.6^{Aa}	60.4^{Bb}	69.6^{Bc}

^{x,y} tendency ^{a,b} $p \leq 0{,}05$; ^{A,B} $p \leq 0{,}01$; FCM – fat corrected milk; SCC – somatic cell count, thous.cm^{-3} of milk; BPC – bacteria plate count, k cm^{-3} of milk; According to the Polish Norm PN-A-86002" Raw milk for purchase" requirements for extra class are as follows: somatic cell count per 1 cm^{3} should be less than 400.000; bacteria plate count per 1 cm^{3} should be less than 100.000.

reported by Zielińska et al. (2008), who produced silages from meadow plants treated with a bacterial-mineral-vitamin preparation. This preparation also improved the quality of silages by reducing their pH and enhancing the content of lactic acid and some micro- and macronutrients. In our study, no significant differences in the content of organic acids were observed, except for a tendency to a slightly lower percentage content of acetic acid in the silages made from Si-fertilized plants. However, the content of micro- and macronutrients in the silages, which might have changed following an application of the biostimulator, due to the effects produced by silicon on the uptake of minerals, was not investigated.

Moreover, the milk produced by the cows fed with silages made from the fertilized plants contained lower total counts of microorganisms (BPC) and somatic cells (SCC). The best results in this area were achieved for the milk produced by group I cows fed with variant I silage. Both the count of somatic cells and the total count of bacteria correlate positively with mastitis. Therefore, the above study's outcome justifies the conclusion that the high quality of milk could be due to the low morbidity of the cows. Lower counts of somatic cells and bacteria in the milk of the cows fed with the silages made from Si-fertilized plants might indicate a better health status of these animals. Parantainen et al. (1987) reported a significant negative correlation between the silicon concentration and the count of somatic cells (r = -0.47) and electric conductivity of milk (r = -0.54). These authors stated that the cows with clinical mastitis had significantly lower levels of silicon both in milk and in the blood serum compared to healthy cows (respectively 0.36 ppm and

1.02 ppm vs. 0.84 ppm and 1.63 ppm). Silicon shows antioxidant activity, similarly to selenium, which is widely used in nutrition of dairy cows. However, the available literature on silicon properties is scarce, particularly in comparison with reports on selenium, probably due to toxic effects of large silicon doses. Silicon may cause kidney concretions in cattle (Bailey 1967), and its toxicity may be manifested by nephritis and renal fibrosis (Parantainen et al. 1987). The content of silicon in silage or in milk or blood serum of cows was not determined in our study, but the significant difference in the total count of milk bacteria depending on the type of silage may confirm the need for optimum and precise supplementation with silicon.

CONCLUSIONS

The study showed that foliar fertilization with a silicon biostimulator affected the botanical composition of pasture flora and thus improved the nutritional value of ensiled feed. The cows fed with the silage made from the soiling crops fertilized with the biostimulator produced milk of higher quality and higher content of total solids, protein and fat as well as of better microbiological quality. The research clearly indicated that our knowledge on the quality of silage made from meadow plants fertilized with a silicon biostimulator needs to be expanded. This could be done by determining the content of micro- and macronutrients in silages and making an analysis of their microbiological quality indicators and oxidative stability. Considering potential benefits of silicon supplementation in dairy cattle, more extensive and updated research on the absorption and effects of this micronutrient on the productivity and health of dairy cows, especially high-yielding cows, would be advisable.

ACKNOWLEDGMENTS

The authors thank Intermag LLC from Olkusz for their assistance in conducting this experiment, particularly Mr. Piotr Lubaszka, Sales Manager.

REFERENCES

Artyszak A., Gozdowski D., Kucińska K. 2014. *The effect of foliar fertilization with marine calcite in sugar beet.* Plant Soil Environ., 60: 413-417.

Artyszak A., Gozdowski D., Kucińska K. 2015. *The effect of silicon foliar fertilization in sugar beet-Beta vulgaris (*L.*)* ssp. *culgaris conv. crassa (*Alef.*) prov. altissima (*Döll*)*. Turk J. Field Crops., 20(1): 115-119. http://dergipark.ulakbim.gov.tr/tjfc/article/view/5000119271

Artyszak A., Gozdowski D., Kucińska K. 2016. *Effect of foliar fertilization with silicon on the chosen physiological features and yield of sugar beet.* Fragm. Agron., 33(2): 7-14.

Bailey C.A. 1967. *Siliceous urinary calculi in calves: Prevention by addition of sodium chloride in the diet.* Science, 155: 696-697.

Fauteux F., Chain F., Belzile F., Menzies J.G., Belanger R.R. 2006. *The protective role of silicon in the Arabidopsis-powdery mildew pathosystem.* Proc. Natl Acad. Sci. USA, 103: 17554-17559. DOI: 10.1073/pnas.0606330103

Fauteux F., Remus-Borel W., Menzies J.G., Belanger R.R. 2005. *Silicon and plant disease resistance against pathogenic fungi.* FEMS Microbiol. Lett., 249: 1-6. DOI: 10.1016/j.femsle.2005.06.034

IZ PIB – INRA. 2014. *Feeding Recommendation for Ruminants and Feed Tables.* Ed. Strzetelski J., IZ PIB Kraków. pp. 392.

Jeroch D., Drochner W., Simon O. 1999. *Ernährung landwirtschaflichen Nutztiere.* Berlin, Springer Verlag, 544.

Kalandyk A., Waligórski P., Dubert F. 2014. *Application of biostimulators in alleviation of effects of drought and other environmental stresses in common soybean (Glycine max.* L. Merr.*).* Episteme, 22: 267-274. (in Polish)

Keady T.W.J., Kilpatrick D.J., Mayne C.S., Gordon F.J. 2008. *Effects of replacing grass silage with maize silages, differing in maturity, on performance and potential concentrate sapring effect of dairy cows offered two feed value grass silages.* Livestock Sci., 119(1): 1-11.

Knežević M., Leto J., Perčulija G., Bošnjak K., Vranić M. 2007. *Effects of liquid manure application on yield, quality and botanical composition of grassland.* Cereal Res. Commun, 35(2): 637-640.

Kurdali F., Al-Chammaa M., Mouasess A. 2013. *Growth and nitrogen fixation in silicon and/or potassium fed chickpeas grown under drought and well-watered conditions.* J. Stress Physiol. Biochem., 9(3): 386-406. http://www.jspb.ru/issues/2013/N3/JSPB_2013_3_385-406.pdf

Ma J.F. 2004. *Role of silicon in enhancing the resistance of plants to biotic and abiotic stresses.* Soil Sci. Plant Nutr., 50: 11-18. DOI: org/10.1080/00380768.2004.10408447

Ma J.F., Takahashi E. 2002. *Soil, Fertilizer, and Plant Silicon Research in Japan.* Amsterdam, The Netherlands, Elsevier Sci., pp. 281.

Ma J.F., Yamaji N. 2006. *Silicon uptake and accumulation in higher plants.* Trends Plant Sci., 11: 392-397. DOI: 10.1016/j.tplants.2006.06.007

Mali M., Aery N.C. 2008. *Influence of silicon on nodule growth, dry matter production and mineral nutrition of cowpea (Vigna uniguicata).* J. Plant. Nutr. Soil Sci., 171(6): 835-840.

Nelson P.V. 2003. *Greenhouse operation & managment.* 6th Ed. *Slow-release fertilizers, growth--regulating compounds.* Library of congress cataloging. New Jersey: Prentice Hall, 335, 434.

Parantainen, J., Tenhunen E., Kangasniemi R., Sankari S., Atroshi F. 1987. *Milk and blood levels of silicon and selenium status in bovine mastitis.* Vet. Res. Comm., 11(5): 467-477. DOI: 10.1007/BF00380629

Przybysz A., Wrochna M., Słowiński A., Gawrońska H. 2010. *Stimulatory effect of Asahi SL on selected plant species.* Acta Sci. Pol., Hort. Cult., 9(2): 53-64. http://wydawnictwo.up.lublin.pl/acta/hortorum_cultus/2010/acta_hort_9(2)_art_06.pdf

Sacała E. 2009. *Role of silicon in plant resistance to water stress.* J. Elementol., 14(3): 619-630. http://www.uwm.edu.pl/jold/poj1432009/jurnal-20a.pdf

Singh K., Singh Y., Singh C.S., Singh R., Singh K.K., Singh A.K. 2005. *Silicon nutrition in rice.* Fertilizer News, 50(2): 41-48.

Szabó E., Pepó P. 2007. *Selection of winter wheat (Triticum aestivum* L.*) cultivars meeting complex EU quality requirements.* Cereal Res. Commun., 35(2): 1125-1128.

Takahashi E., Ma J.F., Miyake Y. 1990. *The possibility of silicon as an essential element for higher plants.* Comments Agric. Food Chem. 2: 99-122.

Yahaya M.S., Kawai M., Takahashi J., Matsuoka S. 2000. *The breakdown of structural carbohydrates of lucerne and orchardgrass during different length of ensiling and its effects on nutritive value of silage.* Aust. J. Anim. Sci., 13: 147-153. http://ajas.info/upload/pdf/15_32.pdf

Zielińska K.J., Grzybowski R.A., Stecka K.M., Suterska A.M., Miecznikowski A.H. 2014. *Effect of application of the bacterial-mineral-vitamin preparation in the proces of silaging of meadow cover on milk quality in ecological farms.* J. Res. App. Agri. Eng., 52(4): 153-158.