Waldemar ZIELEWICZ[1], Barbara WRÓBEL[2]
[1] Poznań University of Life Sciences, Department of Grassland and Natural Landscape Sciences
ul. Dojazd 11, 60-632 Poznań, Poland
[2] Institute of Technology and Life Sciences, Falenty, Al. Hrabska 3, 05-090 Raszyn, Poland
e-mail: walziel@up.poznan.pl; b.wrobel@itp.edu.pl
Received: 2018-08-24 ; Accepted: 2018-09-11

EFFECT OF DIFFERENTIAL NITROGEN FERTILIZATION ON THE NUTRITIVE VALUE OF FODDER MALLOW (*Malva verticillata* L.) AND MAIZE (*Zea mays* L.) EUROSTAR VARIETY

Summary

The aim of the research was to determine and analyze chemical and biological properties of fodder mallow and maize (Eurostar variety) as well as opportunities of their cultivation in pure sowing and when dedicated to fodder. The research was carried out in the years 2011-2012. Plant research material came from field cultivations of fodder mallow (Malva verticillata L.) and maize (Zea mays L.) located on Experimental Station of the Department of Grassland and Natural Landscape Sciences at Poznań University of Life Sciences located in Brody Experimental Farm (52°43' N, 16°30' E). The research material consisted of fodder mallow plants and maize cultivars Eurostar variety FAO 240. Experimental blocks in three applications formed three variants of nitrogen fertilization: 120 (control), 160 and 200 kg of N·ha^{-1}. Larger doses of nitrogen enhanced a content of crude proteins both in the case of fodder mallow and maize. In the case of soluble sugars, larger amounts of applied nitrogen resulted in an increase of this component in maize and a decrease – in fodder mallow. An advantage of fodder mallow over maize consists in a higher richness in mineral components (especially calcium, phosphorus and potassium). Fodder mallow and maize accumulated similar amounts of silicon, which is favorable for the nutritional value of the obtained fodder. Fodder mallow surpasses maize when the content of crude proteins is concerned. However, a smaller amount of sodium and a higher amount of nitrate nitrogen in fodder mallow may not be positive.
***Key words**: fodder mallow, maize, chlorophyll dyes, crude protein, fiber fractions, mineral composition, Chinese mallow,*

WPŁYW ZRÓŻNICOWANEGO NAWOŻENIA AZOTEM NA WARTOŚĆ POKARMOWĄ MALWY PASTEWNEJ (*Malva verticillata* L.) I KUKURYDZY ZWYCZAJNEJ (*Zea mays* L.) ODMIANY EUROSTAR

Streszczenie

Celem badań było określenie i poznanie właściwości chemicznych i biologicznych malwy pastewnej i kukurydzy odmiany Eurostar oraz możliwości jej uprawy w siewie czystym z przeznaczeniem na cele pastewne. Prace badawcze nad tym gatunkiem prowadzono w latach 2011-2012. Materiałem badawczym były rośliny malwy pastewnej i kukurydzy odmiany Eurostar FAO 240 pochodzące z polowych upraw malwy i kukurydzy zlokalizowanych na terenie Rolniczego Gospodarstwa Doświadczalnego Brody, Uniwersytetu Przyrodniczego w Poznaniu (52°43' N, 16°30' E). Doświadczenie w układzie bloków losowanych w trzech powtórzeniach tworzyły trzy warianty nawożenia azotem: 120 (kontrola), 160 i 200 kg N·ha^{-1}. Zwiększenie dawek nawożenia azotem wpływało korzystnie na wyższą zawartość białka zarówno w roślinach malwy pastewnej, jak i kukurydzy. W przypadku cukrów rozpuszczalnych zwiększenie ilości aplikowanego azotu skutkowało wzrostem zawartości tego składnika w kukurydzy oraz jego zmniejszaniem w roślinach malwy. Zaletą malwy w porównaniu do kukurydzy jest wyższa zasobność w składniki mineralne, zwłaszcza w wapń, fosfor i potas. Malwa pastewna i kukurydza gromadziły podobne ilości krzemu. W ocenie zawartości białka ogólnego malwa zdecydowanie przewyższa pod tym względem kukurydzę. Mankamentem składu pokarmowego malwy pastewnej jest niższa zawartość sodu oraz większe niż u kukurydzy ilości kumulowanego azotu azotanowego pod wpływem wzrastających dawek azotu. Analiza laboratoryjna materiału roślinnego malwy pochodzącej z różnych wariantów nawożenia azotem pozwoliła na aktualną analizę składu pokarmowego i pozytywną ocenę możliwości ponownego wykorzystania tego gatunku do uprawy z przeznaczeniem na paszę dla bydła.
***Słowa kluczowe**: malwa pastewna, kukurydza, barwniki chlorofilowe, białko ogólne, frakcje włókna, składniki mineralne, ślaz okółkowy,*

1. Introduction and aim of the study

Apart from green growth fodder, maize silage is one of the main nutrition sources of fodder in ruminant livestock farming is maize silage. Tillage in light soils and seasonal droughts in July and August are a barrier to obtain satisfying maize silage yield. A preventive measure in order to gain a satisfying amount of biomass for ensilage in the periods of seasonal drought, was the introduction of an "mixed cropping" of maize with sorghum (*Sorgo bicolor* (L.) Moench) [17, 20, 26, 27]. This species allowed for obtaining a satisfying crop of biomass during seasonal droughts due to a strong root system and a much lower index of transpiration [7, 12, 13, 18]. An interesting proposal consists also supplementation of maize tillage with a dicotyledon species such as fodder mallow (*Malva verticillata* L.) A characteristic feature of a root system of fodder mallow is a taproot which is strongly branched in each soil layer and reaches down to one meter. Shoots of fodder mallow may reach up to two meters and develop numerous branches. Shoots are plentifully covered with round leaves. Flowers are small and placed in the corners of leaves [5, 22]. *Malva verticillata* originated from warm regions in eastern Asia (China, Japan). In Europe it used to be a species which had rarely become wild [23, 29]. In the south-east of Asia, it was used as a productive plant and sometimes – as a medicine one [8, 21]. The plant develops best in sunny or half-shadowed places. In Europe it has been connected to the communities of annual and biennial plants which i.e. the first phase of occupation of ruderal areas [16, 23]. An advantage of this species is related to the ability to a repetitive regrowth after defoliation, alike sorghum, as well as basic requirements in terms of soil's fertility [19]. When mixed with maize, an introduction of this species into a daily ration of a ruminant may enhance fodder's structure, content of proteins and content of mineral elements [11, 31]. Fodder mallow (colloquially referred to as Chinese mallow) is not a new fodder plant in our country – it was cultivated before World War II in Poznan Voivodeship and in Silesia [10]. Fodder mallow is an annual spring species whose vegetation is disrupted only by autumn ground frost. A reaction to the temperature drop is that the plant releases a gluey substance which covers the whole plant [30]. According to Ostrowski and Daczewska [19], fodder mallow is valuable fodder for pigs, but may also serve for dairy cattle and beef cattle. . It may be sown in the main crop, the secondary one (after a winter intercrop harvest or in stubble intercrop). When cultivated in the main crop, it may give out as many as 80.0 tons in three crops and circa 50.0 tons of green feed per hectare as a intercrop. It provides a green mass from the beginning of June to October. It may be used as fodder not only in the form of a green mass yet also ensilaged. Fodder mallow produces numerous small flowers, i.e. an index of reproduction is very high and it is possible to obtain up to 0.5 ton of seeds from a hectare [1, 14]. Relatively high crops and little soil requirements make the cultivation attractive. In 1980s Edmund Fryder, a retired employee of the ZD IHAR Borowo, was in charge of the reproduction of this species [14, 19]. On the basis of the information from 2008, Jan Pilarczyk from Sieczka – a person well known in the region as a popularizer of forgotten and endangered plant species - was still in charge of the cultivation and observation of this species [1]. The aim of the research was to determine and analyze chemical and biological properties of fodder mallow and maize (Eurostar variety) as well as opportunities of their cultivation in pure sowing and when dedicated to fodder.

2. Material and methods

The research was carried out in the years 2011-2012. Plant research material came from field cultivations of fodder mallow (*Malva verticillata* L.*)* and maize (*Zea mays* L.) located on Experimental Station of the Department of Grassland and Natural Landscape Sciences at Poznań University of Life Sciences located in Brody Experimental Farm (52°43' N, 16°30' E). Based on analyzes carried out in Department of Soil Science Poznań University of Life Sciences the content of humus in a soil was 1,21%, share of floatable parts – 16%. Its reaction was slightly acidic (pH_{KCl} = 5,5). The soil contained 84,0 mg of P_2O_5, 144,0 mg K_2O and 67,0 mg MgO in kg^{-1} of a soil dry mass. Sewing was always done after May 10th with 12,0 kg ha^{-1} of fodder mallow with Meteor seed drill and 90.000 seeds ha^{-1} of maize Eurostar variety FAO 240 produced by Euralis with a pneumatic seed drill. After sprouting, the plants were mechanically reduced – the plantation left in 1.0 m^2 was the same as in case of maize. Seeds of fodder mallow were obtained from the University of life Sciences in Lublin. The distans between the rows of maize and fodder mallow was 70 cm. An inter-row mechanical care was applied in order to prevent the species from weeds. During harvest, when maize was cropping for silage, shoots of fodder mallow eached 2.0 m. Experimental blocks in three applications formed three variants of nitrogen fertilization: 120 (control), 160 and 200 kg $N \cdot ha^{-1}$. Experimental plots of each variant were 14.0 m^2 (2 rows x 0.7 m x 10.0 m). Nitrogen fertilization (with ammonium nitrate) was divided into two parts. The first dose for all the variants was applied after crop emergence in the amount of 80 kg and the second one – at the beginning of June by adding 40 kg to the first variant, 80 kg in the second variant and 120 $kg \cdot ha^{-1}$ in the third one. Phosphorus-potassium fertilizers in the dose of 60 $kg \cdot ha^{-1}$ P_2O_5 and 120 $kg \cdot ha^{-1}$ K_2O were applied in soils before sewing. The harvest of green mass was completed in one day: on September 28th in the first year of the research and on September 26th – in the second one. Criteria for the assessment of fodder mallow and maize were selected biological and chemical properties i.e. content of chlorophyll (*a+b*), content of β-carotene and mineral and organic components which were important in terms of nutrition. Concentration of *a+b* chlorophyll was marked in leaf blades; their central part was analyzed with Smith's and Benitez's method [24]. In the assessment of a chemical composition, widely used analytical methods were used: total protein was calculated on the basis of total nitrogen determined with Kjeldahl's method, soluble sugars – with a colorimetric method [4], cellulose and lignin – with Van Soest's method [28], hemicelluloses – with a method described by Heyland [6]. Content of carotene dyes was determined with a chromatographic method [2] and of nitrate nitrogen – with a method by Jonson and Ulrich [9], modified by Daniłowa [3]. From a group of mineral components, a share of phosphorus and magnesium (with a colorimetric method), calcium (with a titration-precipitation method), sodium and potassium (with Flapho flame spectrophotometry method) and silicon (with a weight method) were determined. The analysis of plant material was carried out in laboratory Department of Grassland and Natural Landscape Sciences. Statistical analysis of the results was completed with Statistica, Analwar 5.2 FR and MS Excel. The significance of differences between the means were verified with Tukey's test at the level of significance of p=0.05.

3. Results and discussion

During the experiment, weather conditions were different (Table 1). In the first year of the research, average temperatures in April, May and June were higher whereas precipitation was lower apart from July (total precipitation in July was 175,4 mm/m^2), when compared to the multiannual period. In the second year (2012), precipitation sum was high as for Wielkopolska, June was very wet and relatively cool, and autumn was very dry (with precipitation of 0,8 mm/m^2 in September and 0,9 mm/m^2 in October).

On the basis of the analysis conducted by Malarski [15], 1.0 kg silage from mallow fodder harvested in the phase of blooming, contained 170.0 g of dry mass, 12.9 g of crude protein and had a value of 0.10 oat unit.

Table 1. Weather conditions during the vegetation period in RGD Brody in the years 2011-2012
Tab. 1. Warunki pogodowe w okresie wegetacji w RGD Brody w latach 2011-2012

Month	Temperature [°C]			Precipitations [mm]		
	Year 2011	Year 2012	Average from years	Year 2011	Year 2012	Average from years
IV	11.7	8.8	8.0	13.9	22.9	37.6
V	14.1	14.8	13.2	34.0	77.2	56.9
VI	18.6	16.0	16.6	52.6	163.0	61.6
VII	17.9	19.2	18.2	175.4	197.6	79.4
VIII	18.8	18.7	17.5	34.5	60.1	66.9
IX	15.3	15.0	13.3	46.0	0.8	49.7
X	9.5	8.8	8.5	18.2	0.9	40.8
Annual average	9.4	9.3	-	-	-	-
Annual amount	-	-		537.4	710.6	-

Source: own study / Źródło: opracowanie własne

In their research with a fertilization dose of 200 kg N·ha^{-1} Ostrowski and Daczewska [19] found 180.0-220.0 g·kg^{-1} of crude protein dry mass in fodder mallow green matter. In the case of raw fiber, the scope was relatively large from 200.0 to 280.0 g·kg^{-1} in dry mass. Young green matter from fodder mallow contained relatively large amount of ash. Postponement of mowing resulted in the drop in the content of protein to 140.0 g·kg^{-1} in dry mass and a simultaneously increase in fiber even up to 340.0 g·kg^{-1} in dry mass. According to the author's individual research, in a single crop of fodder mallow for ensilage, in a controlled nitrogen fertilization variant of 120 kg·ha^{-1}, plant resource with 178.0 g·kg^{-1} of protein in dry mass was obtained in the first year and of 167.0 g·kg^{-1} of protein in dry mass – in the second year. An increase of nitrogen fertilizer to 180 kg N·ha^{-1} resulted in the growth of the latter component when compared to the control variant by 5.6 g per kg in dry mass in the first year and by 4.7 g – in the second one. Fodder mallow from a variant fertilized with 200 kg·ha^{-1}of nitrogen gave an increase in the content of this component when compared to a control variant by 10.9 g and 9.9 g·kg^{-1} of dry mass in both years, respectively. Various doses of nitrogen has an significant impact on the content of this component in fodder mallow green mass (Table 2). On the other hand, an increase in nitrogen fertilization resulted in the drop in the content of soluble sugars in fodder mallow, which was quite opposite in maize. In the first year of the research, fodder mallow from a control variant contained ca. 52.1 g·kg^{-1} of soluble sugars in dry mass. In the fertilization variant of 200 kg N·ha^{-1}, a drop in this content in the plants was observed when compared to the control by 14.7 g to the level of 37.4 g·kg^{-1} in dry mass. In the second year, an influence of a higher dose of nitrogen on the level of sugars was more visible. The difference was almost 24.0 g per kg in dry mass in a control variant from the level of 58.1 g to the content of 34.2 g·kg^{-1} in dry mass in the variant of application of 200 kg N·ha^{-1}. Also in the case of ADF and NDF complexes, a drop in the content of structural sugars was visible due to the growing doses of nitrogen fertilization in both species. In the first year, fodder mallow was fertilized with a control dose and contained 384.6 g ADF and 503.4 g·kg^{-1} NDF in dry mass. An increase in the dose to 200 kg N·ha^{-1} resulted in the drop of ADF by 18.5 g to the level of 366.1 g·kg^{-1} in dry mass and of NDF – by 26,7 g to the level of 476.7 g·kg^{-1} in dry mass. Next year, slightly larger differences were observed: 36.2 in the content of ADF and 48.7 g·kg^{-1} in dry mass in the content of NDF. In the complex of mineral components, an increase in phosphorus and sodium was observed as a result of growing doses of nitrogen. The content of magnesium, phosphorus and sodium in fodder mallow grew slightly under the influence of higher doses of nitrogen, yet the influence of N dose was not significant in both years. Higher doses of nitrogen also enhanced the drop in silicon in plants. In the first year, in a control variant, fodder mallow contained 1.3 g·kg^{-1} Si in dry mass, yet when fertilized with 200 kg N·ha^{-1}- only 0,8 g·kg^{-1} of this component in dry mass.

Table 2. The effect of different doses of nitrogen fertilization on nutrient content in fodder mallow (g·kg^{-1} DM)
Tab. 2. Wpływ zróżnicowanych dawek nawożenia azotem na skład pokarmowy malwy pastewnej (g·kg^{-1} s.m.)

Component	Year 2011				Year 2012			
	Fertilisation treatments [kg N ha^{-1}]			$LSD_{0,05}$	Fertilisation treatments [kg N ha^{-1}]			$LSD_{0,05}$
	120	160	200		120	160	200	
Crude protein	178.6	184.2	189.5	2.990	167.5	172.2	177.4	2.662
Sugars	52.1	41.1	37.4	3.537	58.1	45.4	34.2	3.118
Cellulose	346.2	333.7	329.5	3.482	367.1	346.2	335.6	3.395
Hemicelluloses	118.8	112.1	110.6	6.977	128.6	119.4	116.1	1.571
Lignins	38.4	38.0	36.6	0.329	39.8	38.5	35.1	0.820
ADF	384.6	371.7	366.1	9.761	406.9	383.7	370.7	0.350
NDF	503.4	483.8	476.7	19.252	535.5	503.1	486.8	16.477
Magnesium	1.1	1.2	1.4	n.s.	1.0	1.0	1.2	n.s.
Calcium	21.7	21.9	22.6	0.788	19.3	22.4	21.8	0.238
Phosphorus	3.7	3.8	3.8	n.s.	3.2	3.4	3.5	n.s.
Potassium	28.6	30.2	31.6	0.194	24.8	27.2	27.8	0.776
Sodium	0.7	0.8	0.8	n.s.	0.6	0.7	0.7	n.s.
Silicon	1.3	1.1	0.8	0.336	0.9	0.8	0.8	0.034
Nitrate nitrogen	0.20	0.27	0.31	0.044	0.19	0.22	0.28	0.036

n.s. - not significant

Source: own study / Źródło: opracowanie własne

In the following year of the research, in a control variant, plants contained 0.9 g·kg^{-1} of Si in dry mass and the ones from 160 and 200 kg N·ha^{-1} variants - 0.8 g·kg^{-1} each in dry mass. Growing doses of nitrogen in each variant of fertilization had minor yet significant influence on the determination of nitrate nitrogen in plants. In a control variant with a dose of 120 kg N·ha^{-1}, fodder mallow cumulated 0.20 g·kg^{-1} N-NO_3in the first year and up to 0.19 g·kg^{-1} in dry mass in the second one. Fodder mallow fertilized with the highest dose of the substance, contained 0.31 g of it in the first year and 0.28 g·kg^{-1} in dry mass in the second year of the research (Table 2). Alike fodder mallow, an increase in the doses of nitrogen fertilizer enhanced the content of total proteins in plants also in the case of maize. In a control variant, maize contained 92.1 g in the first year and 88.5 g·kg^{-1} in dry mass in the second year of the research. Increasing fertilization to 200 kg N·ha^{-1} resulted in the growth of this component to 101,6 in the first year and to 96,2 g·kg^{-1} in dry mass in the second year of the research. The obtained growth in protein in the research years was 9.5 g and 7.7 g·kg^{-1} in dry mass of maize, respectively. Higher doses of nitrogen also resulted in the growth of content of soluble sugars, which was the opposite in the case of fodder mallow. The difference in the content of this component between a control variant and the one fertilized with the highest dose of nitrogen were 8.8 g in the first year and 12.3 g·kg^{-1} in dry mass in the second one. Statistical differences were not high, yet significant: 0.513 in the first year and 0.606 in the second year of the research. Application of higher doses of nitrogen resulted in the drop in ADF and NDF fractions in maize. In the year 2011 plants from a variant fertilized with a dose of 200 kg N·ha^{-1} contained 185.2 g ADF and 433.4 g·kg^{-1} NDF in dry mass. When compared to a control variant, the content was lower by 23,4 g ADF and 47.0 g·kg^{-1} NDF in dry mass. In the second year, there were also differences yet not as significant as in the previous year: 11.1 g ADF and 11.8 g·kg^{-1} NDF in dry mass. In the complex of mineral components marked in maize, an increase in the content of calcium, phosphorus, potassium and nitrate nitrogen was observed under the influence of growing doses of nitrogen. In the case of magnesium, sodium and silicon, higher doses of nitrogen caused their lower cumulation in plants (Table 3).

A detailed list of the influence of various doses of nitrogen on changes in each component marked in leaf blades and stalks of fodder mallow was presented in Tables 4 and 5. On the basis of the analysis, it may be concluded that an average content of proteins and soluble sugars in leaf blades in this species was 197.3 g and 47.0 g·kg^{-1} in dry mass. For comparison, the content of these components in fodder mallows'stalks was 58.9 g and 34.3 g·kg^{-1} in dry mass. On the basis of the analysis of a carbohydrate and lignin complex and an average content of lignin, cellulose and hemicellulose, it may be derived that leaf blades contained 270.0 g ADF and 421.0 g·kg^{-1} NDF in dry mass. Stalks were richer in structural sugars as they contained 461.7 g ADF and 621.8 g·kg^{-1} NDF in dry mass. When comparing average contents of mineral components in fodder mallow morphological organs, their higher values in leaf blades were observed. Differences between leaf blades and stalks were: 1.54 g (in the case of magnesium), 7.9 g (calcium), 3.74 g (phosphorus), 4.6 (potassium) and 0.6 g·kg^{-1} (sodium) in dry mass. Stalks were richer than leaf blades in silicon and nitrate nitrogen. The content of chlorophyll dyes in plants is a reflection of their current state and the level of nitrogen nutrition. In fodder mallow leaf blades, in a control variant fertilized with 120 kg N ha^{-1}, the concentration of chlorophyll (*a*+*b*) in the first year of the research was 6.93 mg·g^{-1} in dry mass.

In the second year and the same variant of fertilization, the amount was similar - 6.84 mg·g^{-1} in dry mass. Application of nitrogen in a dose of 200 kg per ha^{-1} resulted in an increase of concentration of chlorophyll (*a*+*b*) by 0.35 mg (up to 7.28 mg·g^{-1} in dry mass) in the first year and by 0.24 mg (up to 7.08 mg·g^{-1} in dry mass) in the next one. In the second year, diversification of nitrogen doses did not significantly influence the content of chlorophyll (*a*+*b*). Maize leaf blades from a control variant contained a bit higher concentration of the dyes than fodder mallow (7.86 mg in the first year and 6.87 mg·g^{-1} in dry mass in the second year). Maize from a variant fertilized with a dose of 200 kg N·ha^{-1} contained 8.14 mg and 7.64 mg·g^{-1} of dyes in dry mass in the first and the second year, respectively. In the first year, doses of nitrogen did not have much influence on the concentration of chlorophyll (*a*+*b*), in the second year, the influence reached the level of 0.017. When comparing concentration of β-carotene and the reaction of both species to the applied doses of nitrogen, it may be concluded, on the basis of the obtained averages, that the contents of this dyes were at a similar level:5.4 mg·g^{-1} in dry mass in the first year and 5.1 in the second year of the research (Table 6).

Table 3. The effect of different doses of nitrogen fertilization on nutrient content in maize (g·kg^{-1} DM)
Tab. 3. Wpływ zróżnicowanych dawek nawożenia azotem na skład pokarmowy kukurydzy (g·kg^{-1} s.m.)

Component	Year 2011				Year 2012			
	Fertilisation treatments [kg N ha^{-1}]			$LSD_{0,05}$	Fertilisation treatments [kg N ha^{-1}]			$LSD_{0,05}$
	120	160	200		120	160	200	
Crude protein	92.1	98.4	101.6	1.272	88.5	91.1	96.2	0.336
Sugars	79.8	84.4	88.6	0.513	85.4	88.1	97.7	0.606
Cellulose	191.5	181.2	169.4	1.866	206.1	189.6	174.7	0.194
Hemicelluloses	271.8	260.6	248.2	0.238	283.4	272.1	252.7	1.363
Lignins	17.1	16.5	15.8	n.s.	18.4	17.5	16.7	0.257
ADF	208.6	197.7	185.2	0.699	202.5	201.1	191.4	0.291
NDF	480.4	458.3	433.4	0.470	455.9	453.2	444.1	1.354
Magnesium	1.2	1.0	0.9	0.097	1.2	1.0	1.0	n.s.
Calcium	6.3	6.6	6.4	0.119	6.2	6.4	6.6	n.s.
Phosphorus	2.2	2.6	2.9	0.122	2.7	2.9	3.3	0.168
Potassium	13.3	14.2	14.6	0.151	13.7	13.9	14.4	0.174
Sodium	5.2	5.1	4.9	n.s.	4.8	4.6	4.2	0.082
Silicon	1.3	1.0	1.2	0.119	1.2	1.1	1.0	0.097
Nitrate nitrogen	0.022	0.028	0.038	0.052	0.018	0.022	0.031	n.s.

n.s. - not significant

Source: own study / Źródło: opracowanie własne

Table 4. The effect of different doses of nitrogen fertilization on the content of nutrients in mallow fodder stems (average values from years of research) ($g \cdot kg^{-1}$ DM)

Tab. 4. Wpływ zróżnicowanych dawek nawożenia azotem na zawartość składników pokarmowych w łodygach malwy pastewnej (wartości średnie z lat badań) ($g \cdot kg^{-1}$ s.m.)

Component	Fertilisation treatments [kg N ha^{-1}]			Average from fertilisation treatments	$LSD_{0,05}$
	120	160	200		
Crude protein	54.2	59.7	62.8	58.9	0.455
Sugars	38.2	33.7	31.1	34.3	0.266
Cellulose	473.2	452.7	443.6	456.5	1.766
Hemicelluloses	168.3	159.4	152.6	160.1	0.097
Lignins	5.31	5.21	5.14	5.22	0.033
ADF	478.5	457.9	448.7	461.7	7.456
NDF	646.8	617.3	601.3	621.8	0.153
Magnesium	0.5	0.5	0.7	0.56	0.017
Calcium	10.8	11.2	11.8	11.2	0.557
Phosphorus	1.8	1.9	2.2	1.96	0.223
Potassium	24.4	25.6	26.8	25.6	0.629
Sodium	0.2	0.3	0.3	0.26	n.s.
Silicon	0.6	0.6	0.5	0.56	n.s.
Nitrate nitrogen	0.6	0.8	0.8	0.73	0.017

n.s. - not significant *Source: own study / Źródło: opracowanie własne*

Table 5. The effect of different doses of nitrogen fertilization on the content of nutrients in leaf blades of fodder mallow (average values of years of research) ($g \cdot kg^{-1}$ DM)

Tab. 5. Wpływ zróżnicowanych dawek nawożenia azotem na zawartość składników pokarmowych w blaszkach liściowych malwy pastewnej (wartości średnie z lat badań) ($g \cdot kg^{-1}$ s.m.)

Component	Fertilisation treatments [kg N ha^{-1}]			Average from fertilisation treatments	$LSD_{0,05}$
	120	160	200		
Crude protein	187.2	193.5	211.4	197.3	0.153
Sugars	52.1	46.7	42.3	47.0	0.504
Cellulose	276.5	268.2	255.4	266.7	0.369
Hemicelluloses	158.5	149.6	144.9	151.0	1.176
Lignins	3.47	3.38	3.21	3.35	0.052
ADF	279.9	271.6	258.6	270.0	0.153
NDF	438.4	421.1	403.5	421.0	0.257
Magnesium	2.1	2.2	2.2	2.1	n.s.
Calcium	18.8	19.2	19.4	19.1	n.s.
Phosphorus	5.6	5.8	5.9	5.7	n.s.
Potassium	29.6	30.2	30.9	30.2	0.097
Sodium	0.8	0.9	0.9	0.86	n.s.
Silicon	0.5	0.4	0.4	0.43	n.s.
Nitrate nitrogen	0.4	0.6	0.6	0.53	0.034

n.s. - not significant *Source: own study / Źródło: opracowanie własne*

Table 6. The effect of different doses of nitrogen fertilization on the content of dyes in leaf blades of fodder mallow and maize ($mg \cdot g^{-1}$ DM)

Tab. 6. Wpływ zróżnicowanych dawek nawożenia azotem na zawartość barwników w blaszkach liściowych malwy pastewnej i kukurydzy ($mg \cdot g^{-1}$ s.m.)

Level of nitrogen fertilization kg N ha^{-1}	Year 2011			
	Malva verticillata		*Zea mais*	
	Chlorophyll (*a+b*)	β-carotene	Chlorophyll (*a+b*)	β-carotene
120	6.93	5.23	7.86	5.30
160	7.18	5.44	7.96	5.61
200	7.28	5.75	8.14	5.73
Mean	7.13	5.47	7.98	5.54
$LSD_{0,05}$	0.336	0.302	n.s.	0.308
	Year 2012			
120	6.84	4.65	6.87	4.86
160	6.92	5.17	7.21	5.13
200	7.08	5.53	7.64	5.43
Mean	6.94	5.11	7.24	5.14
$LSD_{0,05}$	n.s.	n.s.	0.017	0.042

Source: own study / Źródło: opracowanie własne

Significance of experimental factors:

$LSD_{0,05}$ for years of research - chlorophyll content in the fodder mallow: not significant, $LSD_{0,05}$ for years of research - chlorophyll content in maize: 0.232, $LSD_{0,05}$ for years of research - β-carotene content in the fodder mallow: n.s. - not significant, $LSD_{0,05}$ for years of research - β-carotene content in maize: n.s. - not significant

It may also be concluded that fodder mallow is a valuable nutrient. Certainly, it is so due to chemical composition determined in fodder mallow and its comparison to maize in the same soil conditions and fertilized with the same nitrogen doses. When the content of crude proteins is concerned, fodder mallow surpasses maize (Table 2 and 3). The content of proteins in the mass of whole shoots may reach 180.0 $g \cdot kg^{-1}$ in dry mass. A share of this component in the mass of leaves may even go beyond 220.0 $g \cdot kg^{-1}$ in dry mass, depending on the level of nitrogen fertilization. Therefore, in terms of content of proteins, fodder mallow may be compared to white clover or alfalfa. When harvest is belated, the content of total proteins in fodder mallow may drop to 140.0 $g \cdot kg^{-1}$ in dry mass [31]. When maize was harvested for ensilage, fodder mallow contained larger amounts of cellulose and lignin, which impair digestibility of fodder. When analyzing a carbohydrate-lignin complex of fodder mallow, it was only hemicellulose that had a smaller share when compared to maize. These differences were also visible in the presence of acidic detergent fiber (ADF) and neutral detergent fiber (NDF), fodder mallow contained more of them than maize regardless of a fertilization variant. Therefore, fodder mallow should be cultivated separately and harvested several times in the vegetation period in the phase of early development i.e. when the plants reach height of 70-100 cm [19]. When compared to maize, fodder mallow contained much fewer soluble sugars – depending on the level of fertilization and the year of the research, the values were from 34.0 to 58.0 $g \cdot kg^{-1}$ in dry mass. Application of higher doses of nitrogen resulted in a decrease of this component in fodder mallow and subsequently – in smaller content of energy and lower flavorsomeness of fodder. Therefore, when ensilaging fodder mallow, it is advised to add plants of higher concentration of soluble sugars such as maize or sorghum. For comparison, when doses of nitrogen were higher an higher, the amount of sugars in maize rose. Fodder mallow surpasses maize when it comes to their richness in mineral components (especially calcium, phosphorus and potassium). Alike maize, fodder mallow accumulates a similar amount of silicon, which is favorable for its nutritional value. When compared to maize, this species accumulates a smaller amount of sodium and a higher amount of nitrate nitrogen, which is not beneficial.

4. Conclusions

1. Larger doses of nitrogen enhanced a content of crude proteins both in the case of fodder mallow and maize.
2. Fodder mallow surpasses maize when the content of crude proteins is concerned. However, a smaller amount of sodium and a higher amount of nitrate nitrogen in fodder mallow may not be concerned positive.
3. In the case of soluble sugars, larger amounts of applied nitrogen resulted in an increase in this component in maize and a decrease – in fodder mallow.
4. Fodder mallow compared to maize is higher richness in mineral components (especially calcium, phosphorus and potassium). Fodder mallow and maize accumulated similar small amounts of silicon, which is favorable for the nutritional value of the obtained fodder.

5. References

[1] Artyszak A.: Malwa na nowo. Farmer 2008, 7: 66.

[2] Berger S.: Metoda ilościowego oznaczania karotenu (prowitamina A) i sumy karotenów w niektórych produktach roślinnych. Roczniki Państwowego Zakładu Higieny, 1953, 4: 473-479.

[3] Daniłowa C.: Opredielenie nitratov v rastitielnom materiale. Fizjologia Rastieni, 1963, 4: 46-59.

[4] Dubois M., Gilles K.A., Hamilton J.K., Robers P.A., Smith F.: Colorimetric method for determination of sugars and related substances. Analytic Chemistry, 1956, 28 (3): 350-356.

[5] Hegi G.: Ilustrierte Flora von Mittel-Europa. 5. 1. J.F. Lechmans Verlag München, 1935.

[6] Heyland K.U.: Der Verlauf der Einlagerung von Gerüststubstanzen und andern Kohlenhydraten in den Spross von Weizen und Roggen zwischen Ahrenschieben und Todreife. Z. für Äcker und Pflanzenbau, 1959, 108, 4: 473-496.

[7] Hołubowicz-Kliza G.: Uprawa sorga cukrowego w technologii „mix cropping". IUNG Puławy 2007, 135: 3-10.

[8] Jäger E. J., Ebel F., Hanelt P., Müller G. K.: Exkursionsflora von Deutschland. Band 5. Krautige Zier- und Nutzpflanzen. Spektrum Akademischer Verlag, 2008: 880-881.

[9] Johnson C. M., Ulrich A.: Determination of nitrate in plant material. Anal. Chem., 1950, 22 (12): 1526-1529.

[10] Kalicki A.: Rośliny pastewne. PWRiL, 1954.

[11] Kozłowski S., Zielewicz W., Lutyński A.: Określenie wartości energetycznej *Sorghum saccharatum* (L.) Moench, *Zea mais* L. i *Malva verticillata* L. Łąkarstwo w Polsce, 2007, 10: 131-140.

[12] Kozłowski S., Zielewicz W., Oliwa R., Jakubowski M.: Właściwości biologiczne i chemiczne *Sorghum saccharatum* w aspekcie możliwości jego uprawy w Polsce. Łąkarstwo w Polsce, 2006, 9: 101-112.

[13] Kozłowski S., Zielewicz W., Potkański A., Cieślak A., Szumacher-Strabel M.: Plant chemical composition and different cultivation technologies of sugar sorghum from the point of view on its utilisation for silage production. Acta Agronomica Hungarica, 2009, 57 (1): 67-78.

[14] Kumor P., Szczepaniak W.: Uprawa i użytkowanie prawaślazu pastewnego. Trzoda chlewna, 1981, 7/8: 14-16.

[15] Malarski H.: Wskazówki układania dawek paszy dla zwierząt gospodarskich. Wydawnictwo PZT Kraków, 1946.

[16] Matuszkiewicz W.: Przewodnik do oznaczania zbiorowisk roślinnych Polski. PWN, 2011.

[17] Michalski T.: Czy uprawiać sorgo. Farmer, 2008, 5: 66-70.

[18] MichalskiT., Szulc P., Kowalik I.: Plant parts structure and yielding of sorghum intercropped with maize and spaced alternately in every two rows. Journal of Research and Applications in Agricultural Engineering, 2016, 61(4): 58-64.

[19] Ostrowski R., Daczewska M.: Wstępne wyniki badań nad wartością gospodarczą i pastewną ślazu paszowego. Zesz. Problemowe Postępów Nauk Rolniczych, 1984, 257: 249-255.

[20] Petersen J., Schmitt S., Lang O.: Hirse oder Mais. Mais, 2009, 1: 22-25.

[21] Rachmetov D.B.: Kormovye malvy v agrofitocenozach lesostepi Ukrainy: introdukcja, biolgia, sorta, vozdelyvanie. Kiev, Fitosociocentr, 2000: 288-289.

[22] Ralski E., Majlert W., Przegaliński A., Kopański R.: Szczegółowa uprawa roślin. PWRiL, 1957: 340-343.

[23] Rothmaler W., Jäger E.J., Werner K.: Exkursionsflora von Deutschland. Band 4 Gefäßpflanzen: Kritischer Band. Elsevier, Spektrum Akademischer Verlag, München, 2005: 980-982.

[24] Smith J.H.C., Benitez A.: Chlorophylls: analysis in plant materials. In: Peach K., Tracey M.V. (eds) Moderne Methoden der Pflanzenanalyse. Band 4, Verlag Springer, Berlin, 1955: 142-196.

[25] Sowiński J., Król B.: Kiszonki z sorga: przydatność surowca. www.agrofakt.pl, 2016: 1-5.

[26] Sowiński J.: Porównanie plonowania kukurydzy i sorga cukrowego pod wpływem zróżnicowanych dawek nawożenia azotem. Pam. Puław., 2009, 151: 649-661.

[27] Toews T.: *Sorghum* als alternative zu *Mais*. Mais, 2014, 1 (41): 14-17.

[28] Van Soest P.J., Wine R.H.: Determination of lignin and cellulose in acid detergent fibre with permanganate. Journal AOAC, 1968, 51, 4: 780-785.

[29] Walas J.: *Malvaceae,* Ślazowate. In: W. Szafer i B. Pawłowski (eds.). Flora polska. Rośliny naczyniowe Polski i ziem ościennych. Wydawnictwo PWN, Warszawa, 1959, 8: 278-301.

[30] Zielewicz W., Kozłowski S.: Malwa na nowo. Farmer, 2007, 23: 30-32.

[31] Zielewicz W., Kozłowski S., Leszkiewicz B.: Malwa pastewna (*Malva verticillata* L.) – cenną rośliną pastewną. Zeszyty Naukowe, Wydawnictwo Wyższej Szkoły Agrobiznesu w Łomży, 2008, 37: 306-311.

Acknowledgements

Research financed by the own research project 418/R/08/W418/R/08/W "Biological and chemical properties of fodder plants determining their fodder and energy use values".

Badania finansowane w ramach projektu badań własnych 418/R/08/W „Właściwości biologiczne i chemiczne roślin pastewnych determinujących ich wartość użytkową w sferze paszowej i energetycznej".