BIOLOGICAL PECULIARITIES OF CUP PLANT (*Silphium perfoliatum* L.) AND UTILIZATION POSSIBILITIES IN THE REPUBLIC OF MOLDOVA

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Abstract

The research concerning the improvement and implementation of new species and cultivars of multiple values is dictated by the requirements of the national economy. The cup plant, *Silphium perfoliatum* L., a perennial herbaceous plant in the *Asteraceae* family, native to North America, is of particular interest. The biological particularities, productivity, chemical composition and nutritional value of natural and pickled (silage) fodder, as well as the energy capacity of aerial dry biomass of cup plant, the local variety "Vital", created in the Botanical Garden (Institute) of ASM, registered in the Catalogue of Plant Varieties of the Republic of Moldova in 2012, have been studied. It has been established that the harvest of fresh mass at the first mowing, in late April, reaches 1.60 kg/m^2, during May – 3.66 - 5.62 kg/m^2, the leaves constituting more than 50% and in the bud formation - flowering stage – about 10.21-10.51 kg/m^2, with a content of leaves in the fodder of 33-37%. The fodder of cup plant, harvested in late May, contains an optimal amount of protein (16.33%) and fat (2.26%), but is characterized by a low content of cellulose (24.70%), a rather high content of minerals (14.16%) and nitrogen free extractive substances (42.55%) compared with alfalfa. The fresh mass of cup plant, harvested during June, is ensilaged without applying chemicals, 1 kg of silage contains: 0.13-0.16 nutritive units, digestible protein 87-114 g/nutritive unit. The dry stems of cup plant can be harvested in winter with technical means for harvesting fodder and can be used in the production of solid biofuel, making briquettes and pellets. The harvested biomass has an energy capacity of about 18.3 MJ/kg of dry mass and the ash content of 2.5%.

Key words: cup plant, *Silphium perfoliatum*, biological peculiarities, fodder plant, energy plant, productivity, nutritional value, energy capacity of biomass.

A serious problem for the sustainable development of agriculture, the basic branch of the national economy of the Republic of Moldova, is the revitalization of the zootechnical sector. Because of the lack of a stable conveyor of vegetal fodder and the unbalanced ration in vegetal protein for animals and poultry, an overconsumption of feed per unit of production, especially in the winter-spring season, of up to 50% has been observed. The feed quality influences the physiological condition and the productivity of animals and poultry.

The Republic of Moldova imports 95% of fossil fuels and the use of renewable energy sources is vital to the energy security and national economy.

An important role in solving the above-mentioned problems is played by the fast-growing herbaceous perennial species which would allow providing the zootechnical sector with vegetal fodder, but could also become a source for obtaining biomass for renewable energy production, pharmaceutical, phytosanitary and veterinary preparations.

The scientific researches carried out in the Botanical Garden (Institute) of ASM over many decades were aimed at the identification, mobilization, improvement and implementation of new non-traditional plant species in order to use efficiently the land resources, solar energy and water resources (Teleuţă A., 2010; Teleutsa A., Tsytsey V., 2013).

A promising species is the cup plant, *Silphium perfoliatum* L., family *Asteraceae* L., C3 group of plants, native to North America, introduced as an ornamental plant in the botanical gardens in France and in the UK in the second half of the 18th century and in the 20th century – as a fodder plant (Abramov A., 1992; Niqueux M., 1981; Puia I., Szabo A. T., 1985; Vavilov P., Kondratiev A., 1975). Currently, the species *Silphium perfoliatum* L. is studied in different scientific centres and universities and implemented as an agricultural culture with multiple use in different regions of the Earth (Boe A. et. al., 2012; Davidiants E., 2006; Kowalski R., Kedzia B., 2007; Majkowski W. et. al., 2009; Pichard G., 2012; Šiaudinis G. et al., 2012; Ust'ak S., 2012)).

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MATERIAL AND METHOD

The local variety "Vital" of cup plant, *Silphium perfoliatum* L., created in the Botanical Garden (Institute) of the ASM, registered in 2012, in the Catalogue of Plant Varieties of the Republic of Moldova, now – in process of patenting at the Agency on Intellectual Property of the Republic of Moldova, served as object of study. The experiments were performed on non-irrigated experimental land in the Botanical Garden on deeply processed soil in autumn, leguminous fodder species served as precursor. Plot area – 10 m^2, in 4 repetitions. The traditional fodder crop – alfalfa, *Medicago sativa* L., served as control. Scientific researches on agro biological peculiarities were performed according to the methodical indications (Ivanov A.I. 1985; Novoselov Iu. et al.1983), biochemical composition and nutritional value of natural and pickled (silage) fodder (Ermakov A. et al., 1987, Petukhov Y. et al., 1989), the evaluation of dry biomass – according to CEN/TC 335, the calorific value of dry biomass was determined by calorimetric method using the device LAGET MS 10A.

RESULTS AND DISCUSSIONS

As a result of scientific researches on growth and development of cup plants in 2013, it has been found that, the first month after the start of vegetation, the growth and development of the aerial part of the plants is slow, forming a rosette of 6-8 oblong leaves of intense green colour. At the end of April, the development of stem starts. The fresh mass productivity during this period reaches 1.60 kg/m^2 or 0.22 kg/m^2 dry matter. In May, the growth and development accelerate, so in the middle of the month, the shoots reach a height of 115 cm with 6 to 8 developed leaves, the yield of fresh mass reaches 3.66 kg/m^2, with a decreased dry matter content in the fodder because of the high hydration of shoots (*table 1*). In the next ten days of May, the cup plants develop another 4 to 6 leaves and reach a height of 153 cm, being characterized by a high rate of accumulation of both fresh mass and dry matter or 0.20 kg/m^2/day fresh mass and 0.04 kg/m^2/day dry matter, respectively. In the first ten days of June, the growth rate of cup plants is maintained the same as in the previous period, but, we have found that the daily aerial biomass accumulation is slower and the leaf content in the harvested fodder decreases. In the second half of June, the plants exceed the height of 250 cm, the formation of the flower buds and the development of inflorescence started, the yield of fresh mass reaches 8-9 kg/m^2, the leaf content in the harvested fodder being of 40%. We might mention that, in July, the plants reach the flowering stage. In the first ten days of July, the yield of fresh mass is 10.22 kg/m^2 and 1.75 kg/m^2 dry matter, reaching the highest yield at the first mowing in the middle of July – 10.56 kg/m^2 fresh mass and 1.96 kg/m^2 dry matter, respectively. We have found that, during the flowering stage, the first 6 leaves on the shoot are already dry and that influences both: the reduction in yield (9.16 kg/m^2) and the leaf content in the fodder (20.1%).

Table 1

Biological peculiarities and productivity of cup plants, first mowing 2013 y.

Harvest period	Plant height, *cm*	Number of leaves on a shoot	Natural fodder, *kg/m^2*	Dry matter, *kg/m^2*	Content of leaves in the fodder,*%*
25 April	35	-	1.60	0.22	93.1
17 May	115	8	3.66	0.38	58.5
27 May	153	14	5.62	0.78	58.6
6 June	205	16	6.57	1.10	44.4
19 June	265	18	8.67	1.49	40.3
3 July	295	20	10.22	1.75	37.0
18 July	309	14	10.51	1.96	33.0
25 July	319	14	9.16	1.92	20.1

At implementation of new plant species, it is necessary to assess the agro biological peculiarities in comparison with traditional fodder crops (Vavilov P., Kondratiev A. 1975). At the end of May, the traditional fodder crop alfalfa, *Medicago sativa* L. reaches the stage of flower buds formation and the optimal period for harvesting of natural fodder. Due to the rapidly growth and development the yield of natural fodder, in this period, at cup plants reaches 5.62 kg/m^2 (alfalfa - 1.67 kg/m^2), but the accumulation of dry matter is reduced and reaches 0.78 kg/m^2 (*table 2*).

The natural fodder of cup plant is distinguished by a high content of leaves. Analyzing the achieved results in determining the biochemical composition, we could mention that, in the dry matter of natural fodder of cup plant, the protein content is 16.33% being lower in comparison with alfalfa and the fat content is at the same level. The fodder of cup plant is characterized by a low content of cellulose (24.70%), a rather high content of minerals (14.16%) and nitrogen free extractive substances (42.55%) in comparison with alfalfa.

Table 2

Biological peculiarities, productivity, biochemical composition and nutritional value of fodder cup plant and alfalfa, first mowing 2013 y.

Indices	*Medicago sativa* L	*Silphium perfoliatum L.*
Plant height, *cm*	83	153
Yield of natural fodder, *kg/m²*	1.67	5.62
Yield of dry matter content, *kg/m²*	0.44	0.78
Content of leaves in the fodder,%	42.1	58.6
Biochemical composition:		
- raw protein, % dry matter	17.03	16.33
- raw fats, % dry matter	2.30	2.26
- raw cellulose, % dry matter	33.31	24.70
- nitrogen free extractive substances,% dry matter.	39.41	42.55
- mineral substances, % dry matter	8.01	14.16
1kg of natural fodder contains:		
- nutritive units	0.21	0.13
- metabolizable energy for cattle, MJ/kg	2.28	1.41
- dry matter, g	263.70	167.1
Digestible protein, g/nutritive unit	164.3	133.4
Nutritive units, t/ha	3.51	7.31
Digestible protein, kg/ha	577	975

It has been found that the natural fodder of cup plant has a very low content of dry matter due to high hydration of stems (about 90%), a fact that has a negative impact on the nutritional value, so, 1kg of natural fodder contains 0.13 nutritive units and 1.41 MJ metabolizable energy for cattle and alfalfa – 0.21 nutritive units and 2.28 MJ, respectively.

Harvesting the natural fodder of cup plant in late May allows obtaining 7.31 t/ha nutritive units ensured with 975 kg/ha digestible protein, surpassing the traditional fodder crop - alfalfa.

The biological value of the protein depends on its amino acid composition. The role of amino acids in the animal organism is very important; each having specific functions and their number and the way how they enter into the structure of proteins as well as their way of grouping provide the so-called specificity of proteins. For a better use of proteins, it is necessary to ensure a balanced diet in terms of energy, vitamins, minerals and a certain ratio between the essential amino acids. The specific deficiency in certain essential amino acids, involves, in addition to losing weight of animals, various morph functional aspects, depending on the action of the deficient amino acid. Lysine, methionine and tryptophan are amino acids that cause the biggest problems in the supply of animals and are called limiting amino acids, as they limit the use of other amino acids and protein, respectively. Of course, any essential amino acid that is found in small quantities and limits the use of others can become a limiting amino acid (Pârvu G., 1992). Analyzing the contents of amino acids we could mention that in the natural fodder of cup plant, there are the same essential amino acids that are found in alfalfa, but differences concerning their quantity are observed (*table* 3). Thus, the amount of essential amino acids in cup plant is higher. The fodder of cup plant is characterized by a higher content of leucine (34%), valine (33%) and threonine (23%), but – a lower content of isoleucine (20%), lysine (17%), phenylalanine (15%) and methionine (9%) in comparison with alfalfa.

Table 3

The content of amino acids in the natural forage (mg/ kg dry matter), first mowing 2013 y.

amino acids	*Medicago sativa* L.	*Silphium perfoliatum* L.
asparagine	17.11	11.95
threonine	5.64	6.94
serine	6.87	4.32
glutamine	13.60	18.91
proline	9.22	6.43
glycine	5.50	6.48
alanine	6.74	9.05
valine	5.59	7.41
methionine	1.39	1.26
isoleucine	4.59	3.69
leucine	9.13	12.22
tyrosine	4.58	3.71
phenylalanine	8.50	7.22
histidine	3.26	2.14
lysine	6.19	5.16
arginine	6.55	4.03
the sum of essential amino acids	41.03	43.90

The specialized literature states that the fresh mass of cup plant can be used to prepare silage (Abramov A., 1992; Niqueux M., 1981;. Majkowski W. et. al., 2009; Pichard G., 2012). We could mention that the silage made from fresh mass of cup plant, harvested during June (*table 4*) is characterized by a pleasant smell of pickled vegetables, the plant structure is well preserved, the colour of stems is green-yellow and colour of leaves is dark green to brown, the dry matter constitutes 13.58-16.36 %; 1kg of silage contains 0.13- 0.16 nutritive units, the digestible protein content is of 87-114 g/nutritive unit. The PH index was at a level characteristic of qualitative silage and ranged within 4.22-4.89. The content of organic

acids, both free and fixed, the obtained silage correspond to the requirements, lactic acid predominates and constitutes 58-74% of the total organic acids, which is a good indicator, given that the standard requirements for a silage made of traditional plants provide a level of at least 50-55% for the quality I class (Cosman S. et. al., 1996).

Table 4

Biochemical composition and nutritional value of silage of cup plant, first mowing, 2013 y.

Indices	Period of ensilage	
	6 June	19 June
Dry matter,%	13.58	16.36
Biochemical composition:		
- raw protein,% dry matter	12.19	10.30
- raw fat, % dry matter	3.70	2.09
- raw cellulose,% dry matter	31.51	29.52
- nitrogen free extractive substances,% dry matter	36.94	46.30
- minerals,% dry matter	15.66	11.46
1 kg of silage contains:		
- nutritive units	0.13	0.16
- metabolizable energy, MJ/kg	1.32	1.66
Digestible protein g/ nutritive unit	114	87
pH of the silage		
Total organic acids, % dry matter	4.89	4.22
Acetic acid, % dry matter	1.86	3.19
- free acetic acid, % dry matter	0.79	0.84
- fixed acetic acid, % dry matter	0.13	0.30
Lactic acid, % dry matter	0.66	0.54
- free lactic acid, % dry matter	1.07	2.35
- fixed lactic acid, % dry matter	0.38	0.66
	0.69	1.56

The cup plant, due to its well-developed foliage and root system, is distinguished by a high capacity to protect the soil against erosion, to improve the soil with surplus moisture, is characterized by good resistance to bending of stems during vegetation. These qualities allow exploiting the degraded lands by establishing plantations of cup plant which can be used to obtain biomass for producing heat and electricity and also can serve as source of pollen and nectar for bees, for medium and late harvest.

Table 5

Characteristics of the biomass of cup plant, 2013 y.

Indices	
Humidity of the stems December ,%	19
Humidity of the stems January,%	13
Humidity of the stems March,%	11
Bulk density of the dry matter, kg/ m^3	241
Heat capacity of abs. dry mass, MJ / kg	18.3
Density of briquettes, kg/ m^3	951
Ash of briquettes,%	2.5
Potential of energy production, GJ/ha	380
- *equivalent coal, t*	13
- *equivalent conventional oil*	9

We might mention that, with the establishment of negative temperatures in autumn, the dehydration of stems of cup plants accelerates reaching 19% in December (*table* 5) we have also found that some of the leaves remain on stems until spring. Dry stems can be harvested in winter with technical means for harvesting fodder, the bulk density of dry matter (chopped stems) is of 241 kg/m^3. Chopped stems can be used directly in furnaces or to make briquettes and pellets. The density of briquettes is of 961 kg/m^3. The heat capacity abs. dry mass – 18.3 MJ/kg, ash content - 2.5%. The potential of energy production from biomass of cup plant harvested in 2013 constitutes 380 GJ/ha, equivalent to 13 t of coal or 9 t of conventional oil.

CONCLUSIONS

The fresh mass yield, in 2013, at the first mowing, at the end of April reached, 1.60 kg/m^2, during May 3.66 - 5.62 kg/m^2, the leaves constituted more than 50% of the fodder, at bud formation - flowering phase, the yield was of about 10.21-10.51 kg/m^2, with a content of 33-37% leaves in the fodder, and at the end of July (full flowering stage), it decreased to 9.16 kg/m^2, with a content of 20.1% leaves in the fodder.

The dry matter from the fodder of cup plant, harvested in late May, contained an optimal amount of protein (16.33%) and fat (2.26%), but was characterized by a low content of cellulose (24.70%), a rather high content of minerals (14.16%) and nitrogen free extractive substances (42.55%) compared with alfalfa.

The fresh mass of cup plant, harvested during June, is ensilaged without the application of chemical preservatives, 1 kg of silage

contained: 0.13- 0.16 nutritive units, 87-114 g/nutritive unit digestible protein. The dry stems of cup plant can be harvested in winter with technical means for harvesting fodder and can be used in the production of solid biofuel, making briquettes and pellets. The harvested biomass has an energy capacity of about 18.3 MJ/kg of dry matter; ash content of 2.5%.

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