Scientific Papers. Series A. Agronomy, Vol. LVII, 2014
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

AGRO BIOLOGICAL PECULIARITIES OF GIANT KNOTWEED AND CUP PLANT AFTER FERTILIZATION WITH SEWAGE SLUDGE

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Abstract

In the context of climate changes and sharp rise in fossil energy prices, the development of the sustainable and efficient agriculture requires finding innovative solutions for adapting the technologies of plant cultivation and animal breeding which can ensure the food security and safety, favourable for improving the quality of life in the rural areas. An important role in solving the above mentioned problems is played by the implementation in the culture of herbaceous perennial plant species, which, on the one hand, can provide animals with fodder, and, on the other hand, can become a reliable source for obtaining biomass for the production of energy. The purpose of the research was to investigate the effect of fertilization with sewage sludge produced as a result of municipal wastewater treatment on the productivity and the quality of natural forage of the Gigant variety of giant knotweed (Fallopia sachalinense) and the Vital variety of the cup plant (Silphium perfoliatum). It was established that the application of urban sewage sludge in a dose of 50 t / ha contributes significantly to the productivity growth of the cup plant and giant knotweed. Also, the fodder obtained has a higher protein and fat content, and decreased cellulose content in comparison with the unfertilized plants. The implementation of these cultures can help to ensure the animals with qualitative feed, to produce renewable energy and to increase the share of agriculture in gross domestic product.

Key words: *cup plant, forage quality, giant knotweed, productivity, urban sewage sludge.*

INTRODUCTION

Agriculture plays a strategic role in all the world countries, since it is the main sector responsible for the food security of the population, having, at the same time, a special contribution to the overall process of sustainable economic development and environmental protection. The development of agriculture depends decisively on natural, social and economic factors, which affect not only the volume of production but also the structure and the pace of development, both globally and regionally.

In the context of climate change and sharp rise in fossil energy prices, the development of a sustainable and efficient agriculture requires finding innovative solutions to adapt the techniques and technologies of plant cultivation and animal husbandry to ensure food security and safety, favourable for improving the quality of life in rural areas. It is well known that in the modern and sustainable agriculture, animal husbandry plays an important role, ensuring a balance between phytotechny and zootechnics. Currently, the revitalization of the animal husbandry sector continues to be a serious problem for the Republic of Moldova because of the livestock reduction, deplorable state of pastures and hayfields, decreasing areas of traditional fodder crops, failure to ensure a continuity of fodder, unbalanced ration of vegetable protein, which acts negatively on physiological condition and productivity of animals. Mobilization, improvement and implementation of new suitable fodder species is an important first step in increasing the fodder production. Factors such as the longevity of the species, the type of soil and its fertility, the desired period of use, the type of use, the productive potential and the nutritional value of fodder should be taken into consideration in order to make the best possible choice. As a result of the scientific researches on mobilization and improvement carried out in the Botanical Garden (Institute) of ASM over many decades, new non-traditional plant species with a high potential of efficient use of solar energy and obtaining fodder with high content of vegetable protein have been identified (Teleuţă, 2010; Teleuţă and Ţîţei , 2012). By a high and stable productivity of over 100 t/ha of natural fodder, in the Republic

of Moldova, are distinguished the species giant knotweed, *Fallopia sachalinensis* (124.2 t/ha) and cup plant, *Silphium perfoliatum*(142.2 t/ha) (Teleuţă et. al., 2013; Ţîţei et.al., 2013).

The giant knotweed or the Sakhalin knotweed, *Fallopia sachalinensis* Ronse Decr., syn. *Polygonum sachalinense* F. Schmidt, *Reynoutria sachalinensis* Nakai, *Tiniaria sachalinensis* Janch., fam. *Polygonaceae* Juss. is widespread in the wild flora of northern Japan, Sakhalin Island and Kurile Islands. It appears in Europe the second half of the 19th century, being implemented in culture during the 20th century due to its tolerance to the pedo-climatic factors and stable productivity, serving as fodder from early spring until late autumn (Tmenov, 2001).

The cup plant, *Silphium perfoliatum* L., fam. *Asteraceae L.*, is native to North America and was introduced in Europe in the second half of the 18th century as an ornamental plant in the botanical gardens of France and Great Britain, and in the 20th century - as a non-traditional fodder crop in Ukraine, Russia, France, U.S.A., for the maintenance of the branches of animal husbandry concerned with the meat and milk production (Vavilov and Kondratiev, 1975; Niqueux, 1981; Stanford, 1990; Abramov, 1992).

For the formation of 10 tonnes of natural fodder, the giant knotweed extracts from the soil 40-50 kg of nitrogen, 9-10 kg of phosphorus, 50-60 kg of potassium and 19-23 kg of calcium (Tmenov, 2001) and the cup plant - 46-54 kg of nitrogen, 6-9 kg of phosphorus, 48-50 kg of potassium and 53-57 kg of calcium (Vavilov and Kondratiev, 1975; Abramov, 1992). For the fulfilment of the genetic potential of the *Fallopia sachalinensis* and *Silphium perfoliatum* plants it is necessary to find fertilization methods and to form a positive balance of humus and bio file elements in the soil. Nowadays, because of the surging prices of mineral fertilizers and shortage of financial resources from the agricultural sector it is possible to use, at best, the mineral fertilization only with nitrogen of the wheat and sugar beet crops (Andrieş, 2007). The Republic of Moldova is currently facing a serious problem – the storage and use of the urban sewage sludge. According to the data presented by the JSK Apă-Canal Chisinău, yearly, at the wastewater treatment plant accumulate about 110-115 thousands m^3 of urban sewage sludge, that is dewatered since 2009 according to a new method - in geotubes. Compared with the method of dewatering on drying beds, the technique of dewatering the urban sewage sludge in geotubes reduces three to five times the dehydration time, the need of land surfaces and the spread of the disagreeable odour. Unconventional organic fertilizers (sludge and compost from wastewater treatment) can contribute to improving the situation regarding the preservation of soil humus, because they have variable nutrient content. The urban sewage sludge is a feasible source of phosphorus – one of the most important nutrients for crop production (Lixandru, 2005; Andrieş, 2007). The influence of urban sewage sludge on the chemical properties of the soil, forage productivity and quality were highlighted in numerous studies (Borkowska and Wardzinska, 2003; Lixandru, 2005; Denisov et. al., 2010; Vidican et. al., 2013).

The given species are currently investigated and implemented in different regions of the Earth not only as a source of obtaining fodder, but also as raw material for the pharmaceutical industry and bioenergetics (Ostapko and Poglyad, 2003; Majkowski et.al., 2009; Pichard, 2012; Ustʹak, 2012; Conrad and Biertümpfel, 2013; Seppälä , 2013).

The purpose of the researches was to investigate the effect of the fertilization with sludge obtained as a result of urban wastewater treatment on the agro-biological peculiarities of the plants giant knotweed *Fallopia sachalinensis* and cup plant *Silphium perfoliatum* in the conditions of the Republic of Moldova.

MATERIALS AND METHODS

The plants: giant knotweed *Fallopia sachalinensis*, the "Gigant" variety and cup plant *Silphium perfoliatum*, the "Vital" variety served as object of study. The varieties of the studied species were created in the Botanical Garden (Institute) of the ASM and registered in the catalogue of varieties approved in the Republic of Moldova. The sludge dewatered in the geotube, with the duration of storage of four months, from the wastewater treatment the JSK Apă-Canal Chisinău, with a moisture content of 75.5% was used as fertilizer. In the

dry matter, the content of organic matter exceeds 80%; the nutrients valuable for plants reach values of 2.6% of nitrogen, 1.7% of phosphorus and 0.22% of potassium. The nitric nitrogen constitutes 95.5 mg/100g. The heavy metals in the analyzed sludge don't exceed the Admissible Concentration Limit (Rusu A. et al., 2012) with the values for lead of 310.75 mg/kg, cadmium - 30.8 mg/kg, chromium - 315.3 mg/kg, nickel - 86.3 mg/kg, copper 117.3 mg/kg, zinc 371.3 mg/kg.

The experiments were mounted on the ground with carbonate black earth on clay, with humus content of: 2.1%, nutrients: NO_3 -1.35 mg/100 g soil, NH_4-0.35 mg/100 g soil, P_2O_5 – 1.65 mg/100 g soil, K_2O – 30 mg/100 g soil (Macighin method), pH=7.5. The scheme of the experience includes the following versions: fertilization with sludge 50 t/ha (12.8 t/ha dry matter) and as control served the plants on plots without fertilization. The evidence area of the plot constitutes 10 m^2. The number of repetitions - 4. The experiments started at the end of March 2011 by planting rhizomes of giant knotweed at a depth of 8-10 cm and sowing seeds of cup plant (previously stratified) at a depth of 2 cm resulting from the density of 22 000 bushes/ha. The scientific researches on the growth, development and productivity of the plants were performed according to the methodical indications (Novosiolov et al., 1983; Ivanov, 1985), biochemical composition and nutritional value of the fodder (Ermakov et al., 1987; Petukhov et al., 1989).

RESULTS AND DISCUSSIONS

As a result of the study of the biological peculiarities in the first year of vegetation, we can mention that that during 20-25 days after planting the rhizomes of giant knotweed starts the development of the aerial part and by the end of May the plants reach a height of 47-63 cm, having formed 5-7 internodes with 19-23 cm long and 8-11 cm wide leaves. During the next period, the branching of the central stem is observed, forming first degree shoots which continue to branch out until the end of the vegetation by developing five and four degree shoots, being formed a bush with a height of 164-170 cm. At the cup plant, it was found that the emergence of plantlets was simultaneous 15 days after sowing in both versions and until the end of vegetation, the plants have developed a rosette composed of 16 to 18 leaves with a height of 37-43 cm. At both species, the root system developed and extended and the rhizomes were formed during the vegetation. In the first year of vegetation, no essential differences were observed regarding rate of growth and development of the giant knotweed and cup plant depending on the level of fertilization, but we found out that the plants fertilized with sludge have a darker coloration of the leaves. The fresh mass productivity of the plants of giant knotweed in the version with sludge was of 2.59 kg/m^2, which was by 10.4% more compared to the control version, and at the cup plant - 1.57 kg/m^2 respectively and 1.27 kg/m^2 at the plants grown on unfertilized soil.

In the following years, in spring, when the air temperature exceeded 5° C, at the studied species, started the growth and development of the shoots from the generative from buds formed on the rhizomes, the plants went through all stages of ontogenetic development. The vegetation of cup plant started 3-5 days earlier than the vegetation of giant knotweed. The growth and development of giant knotweed was faster, thus in the middle of April the giant knotweed plants exceeded a height of 65-70 cm, while the cup plants – only 31-37 cm. It was observed that, in the version with fertilization of the soil, at the studied species, the number of shoots increased, the internodes were longer and thicker, and the leaves were larger, fine, with a darker coloration.

In the second year of vegetation (2012) the first harvest of the natural fodder of giant knotweed was performed in the middle of May when the plants were over 2 m tall, having developed 16-18 leaves. The productivity of the harvested fresh mass, Table 1, of the plants which grew on soil fertilized with sludge was of 6.45 kg/m^2 or 1.46 kg/m^2 dry matter, the content of the leaves in the fodder constituted 48% and the productivity of the plants from the control version - 4.98 kg/m^2 or 1.23 kg/m^2 dry matter, respectively, with a content of 43% leaves in the fodder.

Table1. Agro-biological peculiarities of the giant knotweed *Fallopia sachalinensis* Ronse Decr. and cup plant *Silphium perfoliatum* L. fertilized with urban sewage sludge (2012 year)

Indices	Giant knotweed *Fallopia sachalinensis*		Cup plant *Silphium perfoliatum*	
	Control	Sewage sludge fertilization	Control	Sewage sludge fertilization
First harvest				
plant height, *cm*	219	238	185	180
natural fodder harvest, *kg/m²*	4.98	6.45	4.60	6.00
dry matter content,*%*	24.65	22.63	13.69	14.33
content of leaves in the fodder,*%*	43	48	43	56
Second harvest				
plant height, *cm*	149	208	49	108
natural fodder harvest, *kg/m²*	2.36	4.18	0.36	1.18
dry matter content,*%*	33.20	30,10	27.71	28.10
content of leaves in the fodder,*%*	37	45	100	55
Annual productivity				
natural fodder, *kg/m²*	7.34	10.63	4.96	7.18
dry matter, *kg/m²*	2.01	2.72	0.73	1.19

As it was previously mentioned, the growth of cup plant is slower and the first harvest of the fodder was performed in early June, when the shoots exceeded the height of 1.80 m, having developed 12-14 leaves and the leaves from the bottom of the plant reached the senility stage. It was found that in the version with sludge, the productivity of the harvested fresh mass, Table 1, had reached 6.00 kg/m^2 or 0.86 kg/m^2 dry matter, with a content of 56% leaves in the fodder in comparison with the productivity of 4.60 kg/m^2 fresh mass or 0.63 kg/m^2 dry matter, with a satisfactory content of 43% leaves in the fodder of the plants grown on unfertilized soil.

The restart of vegetation and revival of giant knotweed after the harvest was different. It was established that the plants from the version with sludge at 6-8 days restarted their growth and formation of new shoots which by the end of vegetation, in the middle of October, reached a height of 2.08 m. A more delayed and uneven growth and development was observed at the unfertilized plants which, at the end of the vegetation, had not exceeded the height of 1.49 m, this fact had a negative impact on the rate of formation of natural fodder and accumulation of dry matter. It was found that at the second harvest the productivity of the plants from the version with sludge was of 4.18 kg/m^2 fresh mass (1.26 kg/m^2 dry matter) having a content of 45% leaves in the fodder and in the control version - 2.36 kg/m^2 fresh mass (0.73 kg/m^2 dry matter) and 37% leaves in the fodder. So, the annual productivity of the giant knotweed in the version with sludge reached 10.63 kg/m^2 fresh mass and 7.34 kg/m^2 in the control version.

We mention that cup plant start growing slower after the first harvest in comparison with giant knotweed, probably due to the high temperatures of 25-30 ° C and the increasing deficit of humidity in the air and soil in this period of the year 2012. Thus, by the end of the vegetation (middle of October), the fertilized plants developed shoots with 7-8 leaves and a height of 1.08 m, reaching a fresh mass productivity of 1.18 kg/m^2 (0.42 kg/m^2 dry matter) with a content of 55% leaves in the fodder and the unfertilized plants developed only a rosette composed of 4-6 leaves and reached a fresh mass productivity of 0.36 kg/m^2 (0.10 kg/m^2 dry matter). We mention that the sludge fertilization contributes to the better fulfilment of the productive potential of cup plant reaching a mass fresh productivity of 7.18 kg/m^2 compared to 4.96 kg/m^2 in the control version and the accumulation of dry matter over the year under the influence of fertilization increases by 63%.

Analyzing the data presented in Table 1, we could mention that, in the next year, the fertilization also influences the rate of growth and development of the plants. So, the height of the fertilized giant knotweed plants at the first harvest in 2013 exceeds with 24 cm the control and the natural fodder harvest increases by about 37%, constituting 6.95 kg/m^2, having also a

higher content of leaves. At cup plant the fertilization didn't influence essentially the growth and they were only 7 cm higher, but it influenced more the development, the shoots were thicker with bigger leaves, which influenced positively the formation of natural fodder harvest, reaching 8.01 kg/m^2 with a higher content of leaves, it also contributed to the accumulation of dry matter.

Table 2. Agro-biological peculiarities of the giant knotweed *Fallopia sachalinensis* Ronse Decr. and cup plant *Silphium perfoliatum* L. fertilized with urban sewage sludge (2013 year)

Indices	Giant knotweed *Fallopia sachalinensis*		Cup plant *Silphium perfoliatum*	
	Control	Sewage sludge fertilization	Control	Sewage sludge fertilization
First harvest				
plant height, *cm*	208	232	180	187
natural fodder harvest, *kg/m^2*	5.06	6.95	5.68	8.01
dry matter content,*%*	23.64	22.83	14.19	15.00
content of leaves in the fodder,*%*	45	51	43	56
Second harvest				
plant height, *cm*	163	218	103	168
natural fodder harvest, *kg/m^2*	2,86	4.03	2.16	3.78
dry matter content,*%*	31.81	32.10	27.50	28.03
content of leaves in the fodder,*%*	37	45	40	55
Annual productivity				
natural fodder, *kg/m^2*	7.92	10.98	7.84	11.79
dry matter, *kg/m^2*	2.10	2.88	1.39	2.27

Due to the quite favourable weather conditions from 2013, the restart of vegetation after the first harvest was more homogeneous at both species in comparison with the previous year, especially of cup plant, which, in both versions reached the stage of flower buttons formation. We could mention that the plants of the studied species from the version with fertilization grow and develop intensively until the end of vegetation. Thus, the fertilized plants of giant knotweed at the end of October reached a height of 218 cm, and those of cup plant - 168 cm, exceeding the control version plants with 55 cm and 65 cm respectively. The natural fodder harvest essentially changes due to the fertilization with sludge. It was found that at the second mowing the fodder harvest of fertilized plants of cup plant increases by 75% and giant knotweed – by 41% compared to the control version. The annual harvest of natural fodder is higher at cup plant (11.79 kg/m^2) and the dry matter accumulation at giant knotweed (2.88 kg/m^2). The fertilization with sludge contributed to the increase of the annual productivity of dry matter of giant knotweed by 37% and of cup plant – by 63%.

The annual productivity of natural fodder and dry matter of the studied species in 2013 increased in comparison with the previous year. A significant increase, in 2013, was found at cup plant, the annual harvest of natural fodder of the plants fertilized with sludge increased by 64% compared to 58% of the unfertilized plants.

It is well known that the amount of fodder depends on the dry matter content and its biochemical composition.

Analyzing the data presented in Table 2, we could mention that the accumulation of dry matter in the natural fodder is higher at *Fallopia sachalinensis* (262.20-265.15 g/kg) compared to *Silphium perfoliatum* (177.30 - 191.68 g/kg). It was found that the sludge fertilization essentially influenced the increase of the dry matter content in the fodder of cup plant (14.38 g/kg).

The urban sewage sludge fertilization influences the biochemical composition of dry matter in the fodder.

Proteins are very important nutritive substances, as the only source of essential amino acids, they are part of all cells, participate in the formation of ferments and participate in all the vital processes in the body forming different complexes (protein-lipid, protein-glucidic, protein-mineral, protein-vitamin, protein-hydric), participate in the

maintenance of osmotic balance, in the distribution of water and substances dissolved in it in different parts of the body. The giant knotweed plants are characterized by a rather high content of raw protein – 42.16 -51.93 g/kg natural fodder. The increase of protein content due to the application of fertilization constitutes about 23% at giant knotweed compared with 15% at cup plant.

Table 3. The forage value and productivity of the giant knotweed *Fallopia sachalinensis* and cup plant *Silphium perfoliatum* fertilized with urban sewage sludge (y. 2013)

Indices	Giant knotweed *Fallopia sachalinensis*		Cup plant *Silphium perfoliatum*	
	Control	Sewage sludge fertilization	Control	Sewage sludge fertilization
1 kg of natural fodder has:				
dry matter, g	265.15	262.20	177.30	191.68
raw protein, g	42.16	51.93	25.78	29.65
digestible protein, g	27.71	31.68	21.39	24.61
raw fat, g	7.49	9.87	7.18	8.11
raw cellulose, g	102.13	67.19	65.82	40.80
nitrogen free extractive substances, g	94.61	113.69	62.62	98.92
minerals, g	16.96	17.52	15.90	14.20
Digestible protein, g/ nutritive unit	113.4	134.4	121.5	119.4
Annual productivity:				
digestible protein, t/ha	2.19	3.48	1.68	2.90
nutritive unit, t/ha	17.9	25.9	13.8	24.3
metabolizable energy, Gj/ha	184.2	271.1	140.2	252.2

The dry matter of the fertilized plants has a higher fat content, at giant knotweed by 31% and at cup plant by 13% compared to the control.

The sludge fertilization contributes to the reduction of the cellulose content by 34-38% and to the increase of nitrogen free extractive substance content by 20-58%. The highest indices are at the fertilized *Silphium perfoliatum* plants.

The content of minerals depending on fertilization at the species studied varies, so, at giant knotweed plants it increases insignificantly while at cup plant was observed a decrease of about 9.0%.

If we analyze the productivity of the plants based on the forage value, we mention that the fertilization increases more essentially the productivity of *Silphium perfoliatum* plants: digestible protein by 73%, nutritive units by 76% and accumulation of metabolizable energy for cattle by 80%, but at *Fallopia sachalinensis* – 59%, 45% and 48% respectively.

The provision with protein of a nutritive unit is in accordance with the zootechnical requirements. An influence of the fertilization on the increase of the digestible protein content was found at the fodder of giant knotweed - 134.4 grams per nutritive unit surpassing by 21.0 grams the control version.

The studied species can serve as a valuable source of pollen for bees and of obtaining raw material to produce thermal energy.

Dried stems of giant knotweed *Fallopia sachalinensis* and cup plant *Silphium perfoliatum* can be harvested in winter with the technical means of harvesting fodder and used to produce solid bio fuel, to make briquettes and pellets (Ţîţei and Teleuţă, 2012). In autumn, with the establishment of negative temperatures, we have found that all the leaves of the Sakhalin knotweed fall, but the leaves of cup plant remain attached to the stem until spring. The drying rate of the stems of the studied species is slower at the fertilized plants. The energy capacity of the harvested biomass does not change much depending on fertilization and is about 19.3-19.4 MJ/kg dry matter at *Fallopia sachalinensis* and about 18.1-18.3 MJ/kg at *Silphium perfoliatum* but with a higher content of ash (3%).

CONCLUSIONS

The studied species, giant knotweed *Fallopia sachalinensis* and cup plant *Silphium*

perfoliatum starting with the second year, have an accelerated growth and development which allows obtaining high yields of fodder early.

The fertilization with urban sewage sludge (50 t/ha) contributes to a better fulfilment of the productive potential of plants. Under the influence of fertilization, the natural fodder production of giant knotweed and *Silphium perfoliatum* plants increases by about 45% compared to the control and the productivity of dry matter increases by 36% and 62% respectively.

The fertilization also increases at the giant knotweed and cup plant the yield of digestible protein (59% and 73%), nutritive units (45% and 76%) and metabolizable energetic capacity of the harvested fodder.

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