Arch. Biol. Sci., Belgrade, 60 (2), 255-263, 2008 DOI:10.2298/ABS0802255S

USE OF BERMUDA GRASS [*CYNODON DACTYLON* (L.) PERS.] ON ASH AND SLAG DUMPS OF THERMOELECTRIC POWER PLANTS

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Abstract — Biological recultivation is conducted regularly on ash and slag dumps of thermoelectric power plants. New methods and new plant species for use in the process of recultivation are being investigated by experts the world over. Bermuda grass *(Cynodon dactylon)* represents a potentially valuable species that should become an ingredient of sowing mixtures used in the process of revitalisation of ash and slag dumps of thermoelectric power plants.

Key words: Bermuda grass, *Cynodon dactylon* (L.) Pers., ash and slag dumps, eolian erosion

UDC 630*23:582.542.1:581.5

INTRODUCTION

A serious problem of all thermoelectric power plants, both in Serbia and throughout the world at large, is the dispersal of ashes from their dumps. Because ash and slag dumps are usually located in the direct vicinity of settlements, this ecological problem takes on even greater significance. A good way of successfully coping with the given problem is through biological recultivation based on formation of a cover composed of leguminous plants or their mixture with other species.

As a substrate that is sterile, deficient in nitrogen, and high in content of phytotoxic elements, ash imposes the necessity of selecting herbaceous plant species that can develop a good biological "cover" capable of preventing eolian erosion on ash and slag dumps or beside heavily used roadways. However, the possibility of its formation is limited by the extreme temperature conditions and conditions of humidity that prevail on ash and slag dumps (Knežević, 2005).

Even in its compressed form, ash arising from the combustion of lignite has a specific weight that is considerably lower than that of natural soil. It comprises a value of 1910-2130 kg/m^3, which puts it in the category of so-called "volatile substances." Thanks to such a physical structure, ash is subject to various erosive influences (Ivetić and Jaćimović, 2005). Ash particles mainly have a spherical shape and do not form aggregates. There are also particles with very pronounced angles, which can damage the root system of plants. The size of particles differs, depending on their location in the casette.

The water permeability of ash is very high and fluctuates in the range of 10.5-10.6 m/sec, which puts it in the category of substances with good water permeability. Present-day lignite was formed in the ground over a long period of time from remnants of plants. The chemical elements that enter the composition of lignite originate precisely from these remnants, while certain microelements entered coal from underground water.

In regard to chemical composition, the ash relegated to dumps is alumo-silicate ash, with a slightly alkaline reaction and as much as 80% participation of aluminum and silicon oxides. The remaining mass is made up of oxides of iron, calcium, magnesium, potassium, and titanium.

Also relatively high are the concentrations of Ba, B, Kd, and As. In addition, a certain concentration of radioactive elements has been recorded in coal, ash, underground water, and plant cultures. Table 1 gives a survey of the chemical composition of ash in terms of the percentage of participation of individual elements and chemical compounds. Of organic substances, only those found in unburned pieces of coal are present. As one of the most important chemical elements of an organic nature, nitrogen can be found in insignificant traces (<0.05%).

Procedure of collection of Bermuda grass rhizomes

The first step in collection of Bermuda grass rhizomes involved monitoring their development to determine a suitable time for collection, rhizomes being collected when the Bermuda grass achieved a sufficient degree of branching. The localities selected for collection of Bermuda grass were along the "Kej Oslobodenja" riverside promenade from Novi Beograd to Zemun, since the soil substrate at these localities contains a fairly great amount of sand, making it relatively easy to collect rhizomes with minimal damage to them (Mijatović, 1968; Bogdan, 1977). Rhizomes were collected at the indicated localities on June 23, 2005. The withdrawn rhizomes were packed in paper bags with indication of the place and date of collection, and transported in this way to the storage site. In extracting rhizomes from the ground, care was taken to ensure their greatest possible length and avoid doing injury to them. The time from withdrawal to storage on the average was three hours.

Since it is known that the origin of planting material exerts significant influence on the success of planting and that material taken from terrains with identical habitat conditions has the best chances for good development, the majority of experimental parcels were established with material collected on the ash and slag dump of the "Nikola Tesla A" thermoelectric power plant in Obrenovac on the day of planting. Apart from the advantage of coming from the same habitat, this material was not subjected to prolonged storage, a period of from 30 to 60 minutes elapsing from its collection to planting, during which it was kept in a plastic bucket in the shade.

Storage of collected material to planting time

Since the material brought in from the terrain was already in paper bags, they were slightly moist-

Table 1. Chemical composition of ash of the TENT-A ash dump according to content of individual compounds and elements (Popovic, 2002).

Compounds	Average value (%)	Elements	g/t
SiO_2	55.5	As	0
		B	106
Al_2O_3	25.5	Ba	950
		Be	10
Fe_2O_3	7.4	Cd	14
		Co	23
CaO	4.8	Cr	155
		Cu	120
MgO	2.3	Ga	36
		La	100
SO_3	1.30	Mn	950
		Mo	25
P_2O_5	0.07	Ni	420
		Pb	70
Na_2O	0.2	Sc	23
		Se	0
K_2O	1.13	Sn	10
		Sr	350
TiO_2	1.06	V	200
		Zn	280

Table 2. Time and conditions of storage of collected rhizomes.

Sample	Where taken	Collection date	Coll. date	Planting date	Conditions of storage
1	Novi Beograd	23.06.2005	40	02.08.2005	
2	TENT (unwatered site)	02.08.2005	0	02.08.2005	Tv= 26°C Vv= 40% Darkness Moistening
3	TENT (watered site)	02.08.2005	0	02.08.2005	

Ta - air temperature, Ha - atmospheric humidity.

ened, arranged in layers in cardboard boxes, and deposited in this state in the storage room until the day of planting (August 2, 2005). Temperature of the room was approximately constant and comprised 26°C, while the atmospheric humidity was 40%. Every other day, the bags were slightly moistened with an atomizer to avoid excessive drying of the rhizomes and prevent their development, which could occur as a result of excessive watering. The bags were opened every day for the sake of aeration.

In addition to rhizomes, lawn parts taken with a corkscrew at the place where the experiment was conducted were also used in it. In this case too, a plug (a round clod with Bermuda grass) was taken from both watered and unwatered surfaces.

Testing of the state of rhizomes after 20 days of storage

An experiment was set up in laboratory conditions to establish whether the method used to store Bermuda grass rhizomes was appropriate and determine the extent to which the rhizomes retained the ability to develop. The experiment was designed to indicate whether it was necessary to collect an additional quantity of rhizomes or change the conditions of their storage. This experiment was set up 20 days after the collection of rhizomes (on July 13, 2005) and completed on July 27, 2005. Samples contained 10 rhizome cuttings with three buds each. Rhizomes were selected on the principle of random sampling from three different storage bags. Following selection, they were planted in pots filled with fertile soil. They were covered with a thin layer of soil in such a way that parts of the rhizome remained visible, then well watered with the aid of an atomizer. The pots were watered with an atomizer two times every day (in the morning and in the evening).

Buds began to develop after seven days, a total of nine buds being visible in Figs. 1 and 2. The buds are marked by red ball-head pins in Fig. 2. It was established by gently lifting them that four of the rhizome cuttings took root.

The rhizomes were cared for in the same way for seven more days, after which new photographs revealed the development of five additional buds

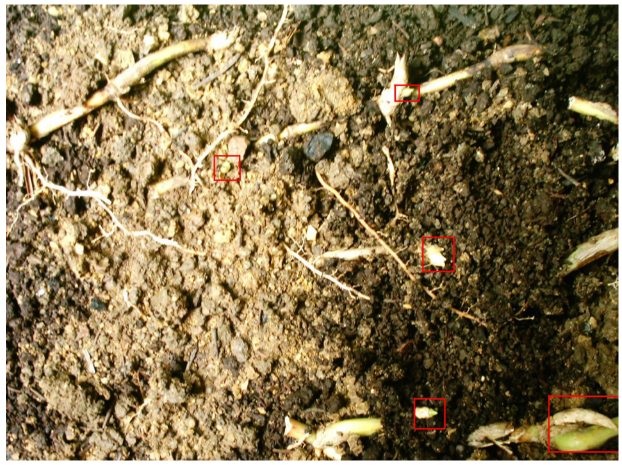

Fig. 1. Details of Bermuda grass rhizomes seven days after planting.

Fig. 2. Condition of Bermuda grass rhizomes seven days after planting.

Fig. 3. Planted Bermuda rhizomes after two weeks.

Table 3. Presentation of experimental results.

Rhizomes	No. of dried-up buds	No. of green buds	Number of offshoots	Height of offshoots (cm)	Extent of root development
1	3				
2	3				
3	3				
4	3				
5	1	2			+
6	2		1	1,7	+ +
7	1	1	1	0,8	+ + +
8	0	1	2	1,5 3,0	+ + +
9	0	2	1	5,5	+ + +
10	0	3			+ + +
Σ	16	9	5		

+ roots weakly developed, up to 1.0 cm long
++ roots well developed, from 1.1 to 5 cm long
+++ roots very well developed, 5.1 cm long and longer

(Fig. 3). When they were carefully withdrawn from the ground, it could be seen that three rhizome cuttings were completely dried-up (the buds were dry and new rooting had not begun to develop). One rhizome cutting showed weakly expressed changes, i.e., formation of new root hairs was discernible, although there was a tendency for one bud at the most to develop. On the remaining rhizome cuttings, the roots were considerably better developed, while one of the buds developed into an offshoot with a height of 0.8 cm and more.

Fourteen days of observing the development of rhizome cuttings were enough to establish how many were capable of development and how many were not. Since more than half (60%, to be more precise) underwent scarification, we decided not to collect new rhizomes, but rather to plant the stored rhizomes at a shorter distance apart than in those collected on site at the dump, since it is certain that after further storage and due to the considerably more unfavorable conditions on the dump in Obrenovac, a large number of them will wilt.

Plan of experiment

The experiment was set up on August 8, 2005 at two localities on the TENT A ash dump in Obrenovac. The first locality (locality I) was characterized by an inclination of approximately 18% and a southwest orientation. Three experimental surfaces with an area of 1 m^2 (1 m x 1 m) were formed at it and marked off with strips of plastic.

The first experimental surface (I-1) at locality I was formed by transplanting parts of lawn (plugging) at intervals of 30 x 30 cm apart from each other. The second experimental surface (I-2) was formed by planting rhizome cuttings at intervals of 10 x 10 cm apart from each other. Rhizomes were taken from sample 1. The third experimental surface (I-3) was likewise formed by planting Bermuda grass rhizome cuttings, but at intervals of 10 x 25 cm apart from each other. Rhizomes were taken from sample 2.

The experimental procedure included the following steps:

- Cleaning of the experimental surface to get rid of grass, branches, and other waste material of organic and inorganic origin;

- Leveling of the substrate;

- Measuring and demarcation of three surfaces of 1 m^2 each. Sticks were first set up at the corners of a square with sides measuring 1 m, then connected by a plastic strip for marking purposes;

- Withdrawal of lawn parts with the aid of a probe (corkscrew). Altogether, nine plugs measuring 12.5 cm in diameter were withdrawn. The plugs

Fig. 4. Schematic presentation of parcels formed at locality I.

Fig. 5. Plugs (clods) of Bermuda grass on experimental surface I-1.

Fig. 6. Planting of rhizome cuttings on experimental surface I-2.

Fig. 7. Plugs (clods) of Bermuda grass on experimental surface I-1.

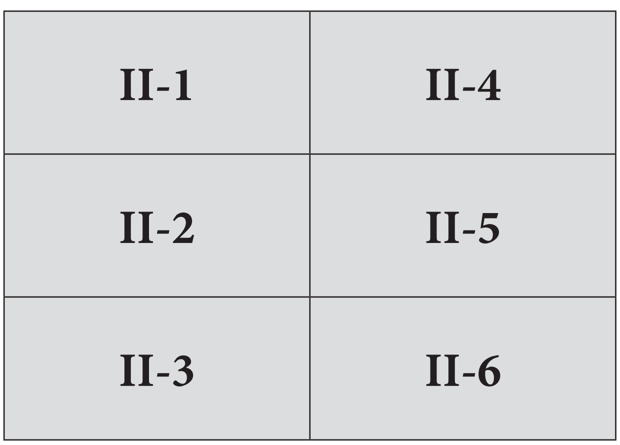

Fig. 8. Schematic presentation of parcels formed at locality II.

Fig. 9. Set-up of experiment at locality II.

were taken near the experimental surface at a place that was not watered and in which Bermuda grass develops spontaneously; and

• Planting of withdrawn parts of the lawn cover at intervals of 30 x 30 cm.

The procedure of planting of clods (plugs) involved making an excavation in the substrate corresponding to dimensions (diameter and depth) of the clod, placing the clod in the cavity thus formed, and gently filling the cavity to the level existing before it was dug. The interval between plugs comprised 30 cm, so that a total of nine plugs were planted on experimental surface I-1 (Fig. 5).

Rhizomes were divided in preparation for planting. So as to prevent as far as possible drying of the rhizomes during storage, they were not divided until the moment of planting. Delivered rhizomes were taken out of their boxes and paper bags, then divided into parts with three buds each. In determining how many buds should be allotted to each rhizome, it was assumed that buds at the edges (next to the cut) are more subject to drying than ones in the middle, so it was decided that rhizome cuttings should contain three buds each. If the buds at the edges dry up, the one in the middle is left and should retain its vitality and develop into a new plant. Dividing of rhizhomes was carried out in the shade with pruning shears.

Prepared rhizome cuttings from sample 1 (which spent 40 days in storage) were planted at intervals of 10 x 10 cm on experimental surface I-2. The arranged cuttings were buried with a layer of substrate about 1 cm thick (Fig. 6).

• Since it was assumed that planting material which was not stored has better chances of taking root and developing, rhizomes from sample 2 were planted at intervals of 10 x 25 cm apart from each other at the same depth of 1 cm.

• Experimental surfaces I-1. I-2, and I-3 were watered with 6.5 l/m^2 of water.

Established in this way, the first experimental surface was not watered in the further course of the experiment. Even though it was almost certain in setting up the experiment that this procedure cannot be used for recultivation, it was important to test in practice the threshold of tolerance of the species *Cynodon dactylon* to deficiency of moisture and nutrients in the substrate for development.

The locality referred as the second one (locality II, Fig. 7) was characterized by an inclination of 45% and a western orientation. Six experimental surfaces with an area of 1 m^2 were formed on it according to the arrangement schematically presented in Fig. 8. As in forming experimental surfaces at locality I, the site for experimentation was cleaned and the substrate leveled, after which places were measured off for sticks to be set up in order to obtain six surfaces (in two rows of three sticks) having a square shape with sides measuring 1 m, the whole experimental surface being marked by plastic strips.

The first experimental surface (II-1) was formed by planting rhizome cuttings from sample U2, which came from the ash dump where the surface was not watered. Rhizome cuttings were planted at intervals of 10 x 10 cm and then buried with a layer of substrate up to 0.5 cm thick so that parts of them remained uncovered.The second (II-2) and third (II-3) experimental surfaces were formed by planting rhizome cuttings from sample U3 (close to a place that was regularly watered) at intervals of 10 x 25 cm. The rhizomes were arranged and buried with substrate in the usual manner. The fourth (II-4) and fifth (II-5) experimental surfaces were formed by planting plugs (clods with Bermuda grass) from places on the dump that were regularly watered. The plugs were planted at intervals of 30 x 30 cm. The sixth (I-6) experimental surface was left empty as a control.

DISCUSSION

The enormous ecological problems caused by ash dumping call for an urgent response and point to the need to find new methods that could reduce its negative influence on the environment (I v e t i ć and J a ć i m o v i ć , 2005).

Biological recultivation is a method that has already been used for 20 years. However, as was stressed at a meeting of ecologists (the First Conference on Problems of Ash and Slag Dumps of Thermoelectric Power Plants, Obrenovac, 2005), existing methods do not provide the required level of protection against ash dispersal. Use of the method of biological recultivation is exclusively limited to the spring and fall periods, so experiments need to be organized that would enable the method (when perfected) to be used during the summer (Stavretović et al., 2005).

Because ash is not a natural substrate for plant growth and development, it is necessary to select plant species that in a short period of time can adapt to such a substrate and maintain themselves on it. A second requirement arising from the need to reduce eolian erosion as quickly as possible is that the selected species be characterized by a strong root system and rapid growth. Plant species that appear spontaneously on ash and slag dumps are potentially good candidates.

In order to improve the method of biological sanation of the ash and slag dumps of thermoelectric power plants, an experiment was conducted with the species *Cynodon dactylon* (L.) Pers. (Bermuda grass). The attributes that make Bermuda grass a potentially good species for use on ash and slag dumps are as follows:

- Origin. Thanks to its origin, Bermuda grass is a species well adapted to high temperatures. According to Richard L. Duble (Texas Cooperative Extension), the daytime temperature optimal for its growth and development is from 35 to 37.7°C;

- Sunlight requirements. Bermuda grass is a heliophilous species;

- Soil requirements. Slightly moist and drained soil is most suitable for growth and development of Bermuda grass, which was also adjust to droughts. It develops well in nutrient-poor soil and easily tolerates pH values of 5 to 8 (Deputy et al., 1998); and

- Rapid growth. Bermuda grass grows rapidly by means of stolons, and its roots and rhizomes can penetrate to depths of up to 1 m in extreme cases, form dense clods, and firmly bind soil (including sandy soil).

Analysis of the possibility of collecting *Cynodon dactylon* rhizomes well before the time of planting indicated that rhizomes kept in the described manner retain greater than 50% ability to develop for about 20 days after collection. This percentage decreases significantly later on. Rhizomes stored for a long time cannot be employed for recultivation of ash and slag dumps because the conditions for growth are poor and planting material of better quality must be used. The experiments showed that a surface planted with rhizome cuttings from sample I (stored rhizomes) remained empty at the end of the examined seven-day period.

On unwatered experimental surface I-3, it was established after two months of monitoring rhizome development that 7.5% of fresh rhizome cuttings underwent scarification and continued to grow, which on the one hand confirms the exceptional ability of Bermuda grass to develop under such conditions of extreme drought, but on the other hand clearly excludes the possibility of using this procedure for recultivation if watering is not conducted.

Transplantation of clods on unwatered experimental surface I proved to be somewhat more successful than planting of rhizome cuttings. However, this procedure too was inadequate, since it did not produce the slightest movement in the direction of growth and occupation of the space between clods to the end of the examined period.

Establishment of an experimental surface at a regularly watered dump locality proved to be slightly more successful. In the initial two-week period, about 65% of rhizome cuttings took root and started to develop. After a month, the rhizomes started to grow, creating aboveground offshoots at the same time. However, favorable weather conditions did not last long, so that at the end of the examined period (November 17, 2005) about 50% of the rhizomes were firmly attached to the substrate and with their growth enlarged the coverage of the examined experimental surface by only about 10% in relation to the starting state on August 2, 2005. On the basis of the obtained results, this procedure was also rejected as a method of biological sanation of ash and slag dumps.

In comparison with planting of rhizome cuttings, transplantation of clods at regularly watered location II gave better results. New buds appeared eight days after planting, and Bermuda grass on experimental surfaces II-4 and II-5 showed expansion of about 20% at the end of the examined period. Better results were obtained by transplanting clods than by planting rhizome cuttings due to the existence of a significantly greater number of buds and greater amount of retained moisture in the clods. Based on the extent of covering of the experimental surface seven weeks after its establishment, it can be concluded that the method of clod transplantation used in the described manner does not give satisfactory results. Comprehensive analysis of the state of the employed planting material, climatic conditions during the period from August 2 to November 12 of 2005, and the obtained experimental results indicate that the amount of precipitation (or water introduced into the soil substrate by watering) and air temperature exerted decisive influence on the rate of development of Bermuda grass. Rhizome growth is most energetic in late spring and early summer, while the rate of Bermuda grass growth in August turned out to be unsatisfactory. Stagnation of development of Bermuda grass on the experimental surfaces began in the first half of September. We therefore conclude that there was not enough time from August 2, 2005 (when the experiment was set up) to the end of the growing season for the plant to overcome the stress that arose due to damage incurred during transplantation, take root, and develop in the way expected to prevent drifting of ash from the experimental surface.

CONCLUSION

Planting of rhizomes and transplantation of clods of Bermuda grass cannot be used in the spring because it is impossible to collect planting material before June, whereas in the fall these methods are rejected in favor of the considerably more effective method of seed sowing, which has already been used for many years. Moreover, in keeping with the basic principle of successful recultivation, it is impossible to recommend the use of any method that does not give fast results. It is therefore necessary to investigate further the possibilities of the employed methods.

By employing more intensive nurturing methods (Deputy et al., 1998), primarily more generous watering and fertilizing, much better results (i.e., better formation of a covering of Bermuda grass) could be obtained, thereby ensuring better protection from eolian erosion.

In view of the proven resistance of Bermuda grass to drought and strong solar radiation, it is possible to recommend its use on ash and slag dumps as a component of grass mixtures, where the defects of one employed species are made up for by the positive attributes of others. It is fair to expect development of Bermuda grass under conditions of the months of summer, when other plant species stagnate in development. The short stature of Bermuda grass and its dense network of rhizomes make it effective material in checking the rise of ash particles.

Further experiments need to be conducted with the species *Cynodon dactylon*, since its positive attributes are evident. Future research should involve combining Bermuda grass with other species in sowing mixtures and more intensive maintenance.

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КОРИШЋЕЊЕ ВРСТЕ *CYNODON DACTYLON* (L.) PERS. У РЕКУЛТИВАЦИЈИ ЈАЛОВИШТА ОКО ТЕРМОЕЛЕКТРАНА

Н. СТАВРЕТОВИЋ и СУЗАНА МАЊАСЕК

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Биолошка рекултивација се регуларно спроводи на јаловиштима око термоелектрана. Широм света стручњаци уводе нове методе и нове врсте биљака у процес рекултивације.

Cynodon dactylon представља потенцијално вредну врсту у смислу њеног укључивања за коришћење у процесу ревитализације јаловишта у непосредној близини система термоелектрана.