Vetiver–grass a new potential energy plant in Saxony-Anhalt

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Vetiver grass, Chrysopogon zizanioides *also known as* Vetiveria zizanioides*, is widely distributed in more than 100 countries. This grass is used for different purposes with strong environmental impact like soil and water conservation, reduction of erosion, slopes stabilisation, pollution control, and water quality improvement. These and many other applications may contribute to mitigate the impact of global warming and climate change. The usability of that grass as renewable energy source in Saxony-Anhalt is the main focus of a project operated in the South of this country. The project studies both energy formation and ways of cultivation. This presentation will give a general survey on results obtained from large field trials in cultivating the grass. Three clones are tested originating from USA (Texas), Australia, and Japan, respectively. All are designated as winter resistant. Cultivation was done in different area: surface mine dumps (recultivation area) and a normal alluvial soil of the river Elster. All soils differ strongly in respect to structure, content of nutrients and homogeneity, respectively. In the two-years trial more than 25,000 plants were cultivated in two steps and on five sites. Biomass production, alterations in leaf composition, the root system, the survival during winter time, respectively, are examples of parameters studied which will be presented and discussed. It is shown that the non-invasive Vetiver can also be used in sites with less valuable soil quality and under the mutating climate conditions of northern Europe.*

Introduction

Global warming and climate changes demand new concepts that contribute the ensure energy supply on the one hand and to minimise and to mitigate both. New sustainable energy concepts including agricultural sources must be based on non-competitive solutions in respect to both food and feed production. Additionally, virgin forests are to be saved as one main deposit of carbon dioxide and source of oxygen. In consequence, new plant sources for energy production are needed that will tolerate alterations in climate conditions, maintain biodiversity contributing the increasing energy demand under conditions of declining sources of fossil energy carriers.

In this context a grass – Vetiver grass - native to India became of interest. Its roots have been used for producing rough material for perfumes for long times. This plant can grow on different soils – in sand or clay, in dryness or submerged in water. In the late 80th of the last century the World Bank initiated a programme to apply Vetiver grass against erosion [GREENFIELD 1987]. Now, it is used in some 100 countries, developing countries but also in the USA, in Australia, Japan, and UK as well. Detailed description of the plant is given by

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MAFFEI [2002]. Some relevant features are summarised in Table 1. Non fertile Vetiver grass cultivars, *Chrysopogon zizanioides*, a.k.a. *Vetiveria zizanioides* is rated minus eight (-8) by a recent risk assessment [anon. 2007].

Tab. 1: Selected characteristics of Vetiver grass (according to TRUONG 2008)

Morphological characteristics	- Not invasive - No rhizomes or stolons; fast-growing root system - Stiff and erect stems - Highly resistant to pests, diseases, and fire - Forming dense hedges – acting as very effective sediment filter and water spreader - New shoots develop from the underground crown (resistance to fire, frost, traffic and heavy grazing pressure)
Physiological characteristics	- Tolerant to extreme climatic variations such as prolonged drought, flood, submergence and extreme temperatures from –14 to 55 °C - Fast regrowing - Tolerance to wide range of pH (pH 3.3 to pH 12.5) - High levels of tolerance to herbicides and pesticides - Highly efficient in absorbing nutrients dissolved (N, O) and pollutants (heavy metals) - Highly tolerant also versus salinity - Highly tolerant versus large number of metals and heavy metals in soil
Recent applications of the Vetiver system	- Erosion control (dune, river banks, coasts, road batter etc.) - Slope stabilisations - Preventing desertification - Treatment of contaminated water and land - Water cleaning - Crop protection (stem borers) - Oil production

Faced with the process of global warming and climate change the aim of the project is to study conditions of cultivation Vetiver grass in local farm land. Based on the experiences reported the application of Vetiver grass in a recultivation field test was established to study its applicability under recent climate conditions. So information should be gained to use this plant in recultivation, rehabilitation of open mining areas with the focus on its erosion defending properties. Finally, the usability of Vetiver grass as sustainable source for biogas production should be studied.

Material and methods

The plant material, Vetiver, *Chrysopogon zizanioides*, a.k.a. *Vetiveria zizanioides, in-vitro* multiplied was obtained from AMykor GmbH[1]. Three clones were applied which came from Australia (AU), Texas, USA (TX), and Japan (JP). All clones are designated as winter resistant. All plants had been treated with specific mycorrhiza (AMykor GmbH) before planting.

[1] Authors thank AMykor GmbH for kind co-operation.

Four different sites were selected for planting: Farm land (alluvial soil of the river Elster), three sites were surface mine dumps (recultivation areas). Table 2 summarises some soil parameters of the respective sites.

In 2006 initial plantations (four plants per m²) were done by hand in May (farm land A, one recultivation area P1, for abbreviations see Table 2) followed by another in August (only recultivation areas P2, P3, P4). In the following year plants were bedded out in early May (A, P5). In a sum more than 25,000 cions of Vetiver planted in these two years. The plants in reclamation areas were not cared; in farm land water and initial fertilisation were provided in the first month.

Tab. 2: Characterisation of sites selected for plantations of Vetiver grass

Site	Soil texture	pH-value	Phosphorus [mg/100g]	Potassium [mg/100g]	Magnesium [mg/100g]	Organic substances[%]	Fineness [<0.0063 mm]
Farm land							
A	Clayey loam	6.8	2.6	5.4	13.5	n.d. [1]	n.d.
Reclamation sites							
P1, P2, **P5**	Loamy sand	7.7	1.5	4.2	8.4	0.2	6.7
P3	Sand	2.9	1.3	2.5	6.4	2.6	-
P4	Clayey loam	3.6	3.1	2.3	22.2	0.8	-

[1] not determined

Growth was controlled by counting the shoots of a representative number of plants and measuring the length of leaves at regular intervals. Biomass was harvested from a part of the farm land and applied to silage separately for each clone in 2007.

Studies in respect to biogas productions were done in accordance with the German technical guideline VDI 4630. Batch processes were performed in flasks (2 l) and in a 5-l-fermenter, respectively, at 36°C. Biogas composition was estimated by gas chromatography.

Results

Growth

Vetiver grass has been cultivated since 2006 in sites described above. The report will focus on the farm land and in part on two fields (P1 and P 5) in dump areas of brown coal surface mining.

Plantations of a minor initial quantity were done in May during a dry period. Plants were watered only in the site A. After a lag phase lasting six to eight weeks the plants had been adopted expressed by continuous increase in number of shoots and prolongation of leaves on both sites (A, P1). Growth ceased with the end of vegetation period (October). In the farm land, clones AU and JP, respectively, showed the largest number of shoots per plant (partially more than 160). Yields of fresh matter per ha were 13 t/ha, 22 t/ha, and 19 t/ha, respectively, for AU, JP, and TX.

The development of plants (only clone JP) in the recultivation area correlates with the conditions met. Growth was slower, and biomass producing only 10% to 20% of that calculated in field A. Remarkably, the relation of leaf mass to root mass indicated with 1 to 1 a significant more expressed root formation. The ratio in farm land was between 2 to 1 to 3 to 1.

Tab. 3: Survival rate of Vetiver grass after winter 2006/2007

Site	Clone	Survival rate [%]	Plantation	Remarks
Farm land A	TX	56%	May	Not cutted
	JP	13%	May	Not cutted
	AU	25%	May	Not cutted
		3%		Cutted, <20 cm
P1	JP	78%	May	Not cutted
P2		0%	August	Not cutted
P3		0%	August	Not cutted
P4		0%	August	Not cutted

During this first phase 3,800 plants were used. Under recent climate conditions survival rates after winter 2006/2007 became of interest. Table 3 summarises data calculated. Survival rates were in part disappointing. Behind this observation seems to be no systematic behaviour with the exception that planting late in the year will not result in sufficient time to adapt. Remarkably, survival rates of the clone TX were better than those of the other two clones on the farm land under identical conditions. Otherwise, nearly 80% of clone JP survived on the recultivation site. Cutting the plants late in the year will not promote survival.

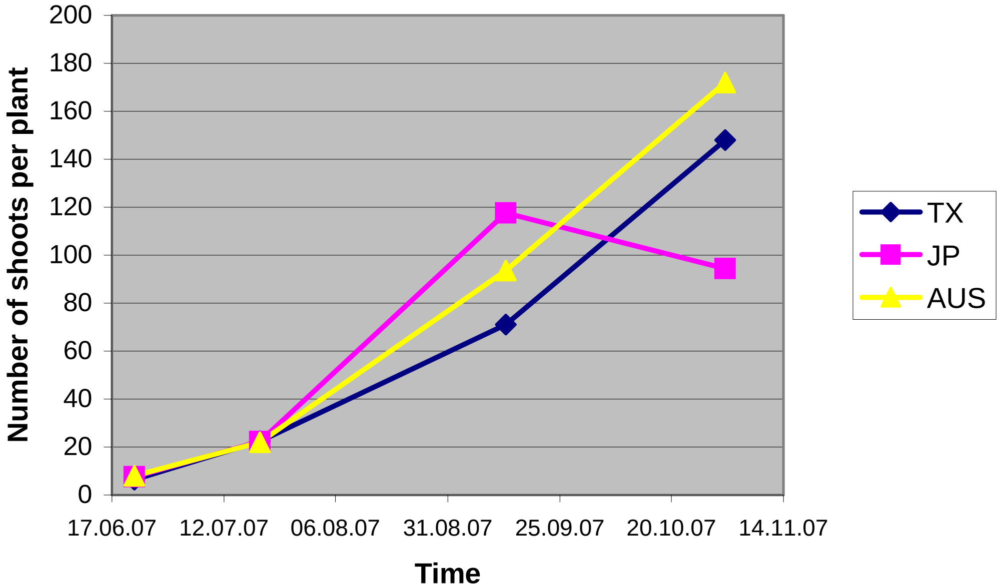

Fig. 1: Total number of shoots per plant (in average) bedded out in 2007 on the site A

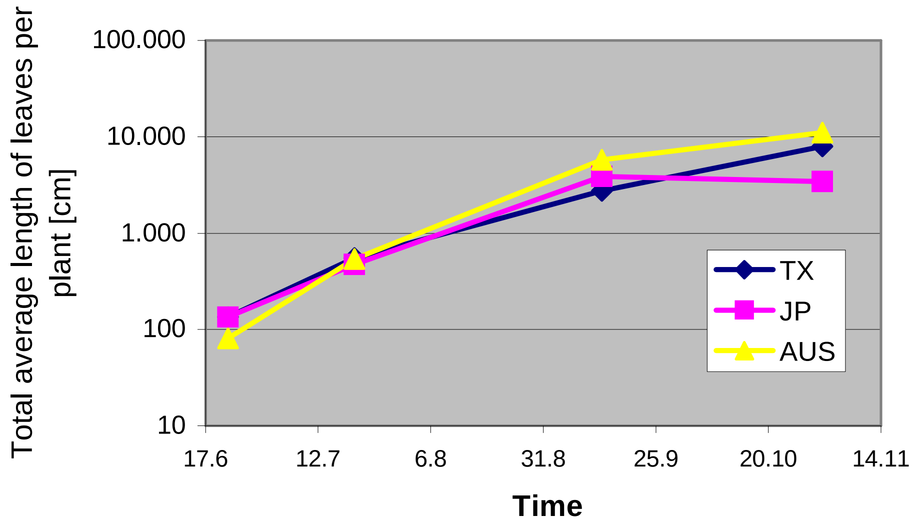

Fig. 2: Time courses of biomass production by Vetiver clones (length of leaves for each plant) bedded out in 2007 on the site A

In 2007 nearly 19,000 plants (all clones) were bedded out on site A and 1,000 on site P5, nearby site P1. Lag phases were comparable to the year before. Figure 1 shows the development of shoots in site A. In the same manner behaved the biomass formation expressed as length of leaves (Figure 2).

In September half of the plants of each clone were harvested for silage to get leaf material for biogas production. Plants cut continued to grow even during short day and low temperatures.

The yields obtained from the farm land trail with the three Vetiver clones are given in Table 4. Whereas biomass (leaf) productivity of clones Texas and Japan were in the same range as in 2006, clone Australia displayed a significant higher yield. Even its leaf to root mass ratio was shifted to nearly 1 to 1, those of the two other clones were in the range observed before.

Tab. 4: Biomass production of Vetiver clones planted in 2007 in farm land (site A)

	Clone	AU	JP	TX
Root mass	kg/m²	3.7	0.86	1.44
Leaf mass	t d.m./ha	9.74	6.43	6.75

Both sites in the open mining area studied strongly differed to plants growing on field A. As expected, Vetiver clones planted in 2007 revealed harvests ranging between 0.4 and 0.8 t d.m. per ha. In contrast, the root systems were stronger developed than at site A. The mass ratios were between leaf and root ranged between 1 to 2 and 1 to 1.5, respectively. In its second vegetation period clone Japan tends to differ from these data. Biomass formation was with more than 2 t d.m. per ha nearly doubled compared to the first period. The mass ratio of leaf and root remained with 1 to 1 unchanged. These results clearly indicate the development of a strong root system on all sites Vetiver was bedded out. The formation of roots is much more expressed in poor substrates.

In respect to the desired use of Vetiver biomass as substrate for biogas production the composition of leaves was controlled. Table 5 shows data obtained at the beginning of

September 2007 in a strong growth phase and at time of harvesting leaves from farm land (Site A). During growth the content of carbon increased continuously. The content of nitrogen in dry matter decreased to values around and below 1%. The poorer the substrate the higher the C:N ratio the lesser the content of nitrogen and in consequence of crude protein in leaves. This connection seems to be evident with the recultivation sites. The content of inorganic material in leaves was not strongly affected by growth conditions. It varied around 10% of dry matter.

Tab. 5: Composition of leaves harvested at the beginning of September 2007

Clone	Year of plantation	Dry matter – d.m.	Organic dry matter	Carbon	C:N ratio
		[% f.m.]	[% d.m.]	[% f.m.]	
Farm land - site A					
Texas	2007	32.6	89.6	14.4	25.0
Australia	2007	25.1	91.0	13.8	30.5
Japan	2007	23.0	89.4	13.4	15.4
Texas	2006	26.3	91.5	13.9	30.5
Australia	2006	22.8	91.4	14.3	23.5
Japan	2006	23.0	91.1	11.5	26.6
Recultivation area - site P1					
Japan	2006	34.4	89.6	17.6	130.0
Recultivation area - site P5					
Texas	2007	32.6	91.7	15.7	77.1
Australia	2007	32.7	91.3	14.4	61.5
Japan	2007	33.4	88.9	17.8	87.3

Production of biogas

Initial screenings were done to get an impression of Vetiver's potential for biogas production. Based on data given by Truong [2008] in respect to composition of organic matter one can approximate the maximal theoretical gas production and gas quality. More than 780 ml_N /g organic dry matter (o.d.m.) with a content of 53% methane should be theoretically expected. The initial screenings were carried out with plant material from the different clones bedded out in 2007 to come into touch with these theoretical values. Results presented here are data from clone Texas in a 5-l-fermentation system without any post fermentation under mesophilic conditions.

Vetiver grass untreated was used as sole source of carbon. This made is more difficult due to the strength of leaves and their content of fibrous material. In Figure 3 typical time courses of two separate fermentation experiments are given, which were carried out under the same conditions. It is evident that the results can be reproduced in a high degree. With clone TX biogas yields were obtained that range between 460 $ml_N(g\ o.d.m.)^{-1}$ and 500 $ml_N(g\ o.d.m.)^{-1}$. Using more sophisticated systems that allow a specified agitation in a definite manner much more than 650 ml_N $(g\ o.d.m.)^{-1}$ biogas can be obtained.

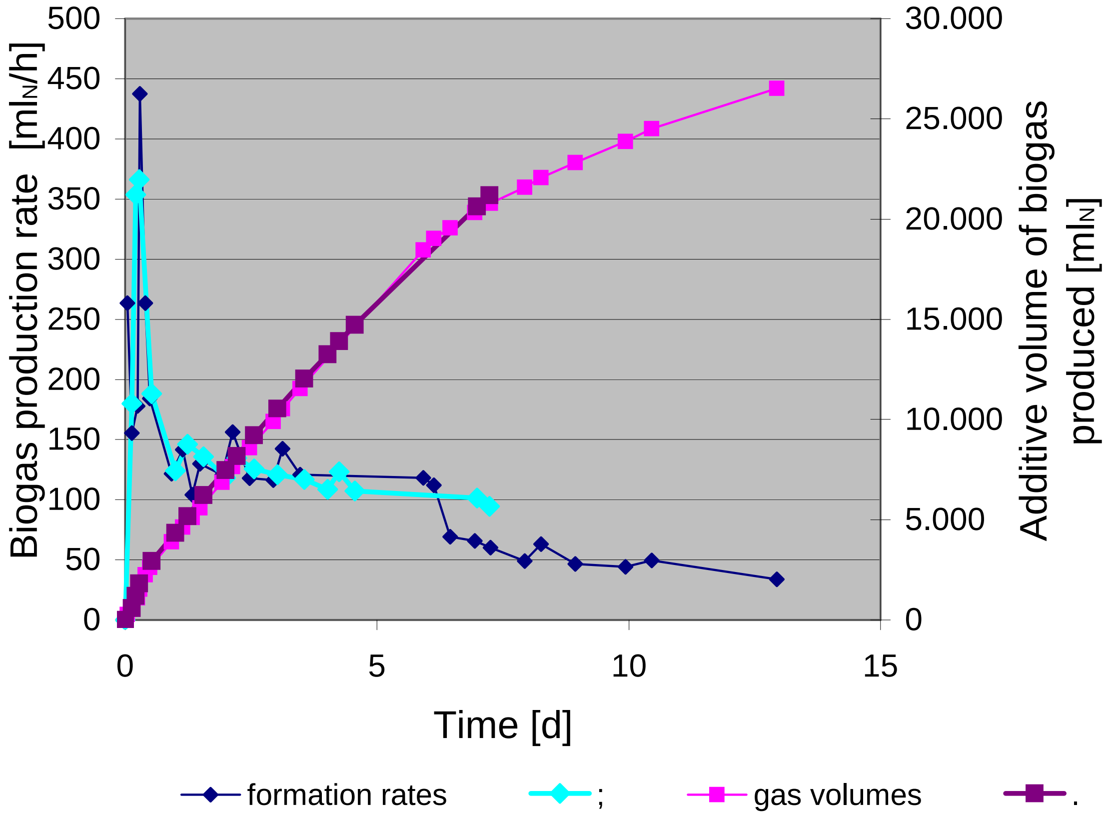

Fig. 3: Time courses of two fermentation experiments using Vetiver grass as substrate (input: clone Texas, 160 g in 2.1 l working volume; 36 °C; 80 min^{-1})

Methane content in biogas estimated by gas chromatography was higher than expected as shown in Figure 4. Methane accounted for around and partially far above 60% over large time of fermentation. These data are far above the methane content calculated and indicate a high energy potential of Vetiver, much higher than that of other grasses reported elsewhere.

Conclusions

Vetiver grass is a potent versatile plant used for soil conservation, slope stabilisation, improvement of water quality, pollution control, bioremediation and other environmental applications. Native in India it is spread nearly world wide in different climates. Cultivation of Vetiver grass is in many aspects advantageously.

The application of the Vetiver system and its use for bioengineering was not studied in details north of the Alps before. With this project could be shown that Vetiver may be cultivated even under northern climatic conditions. The use and breeding of cultures that are winter resistant are one important prerequisite in the moment. Growth conditions must be studied more in detail on different sites and soil textures. Global warming and climate change will offer new applications for Vetiver grass and in the same manner Vetiver grass can contribute to mitigate negative effects connected with.

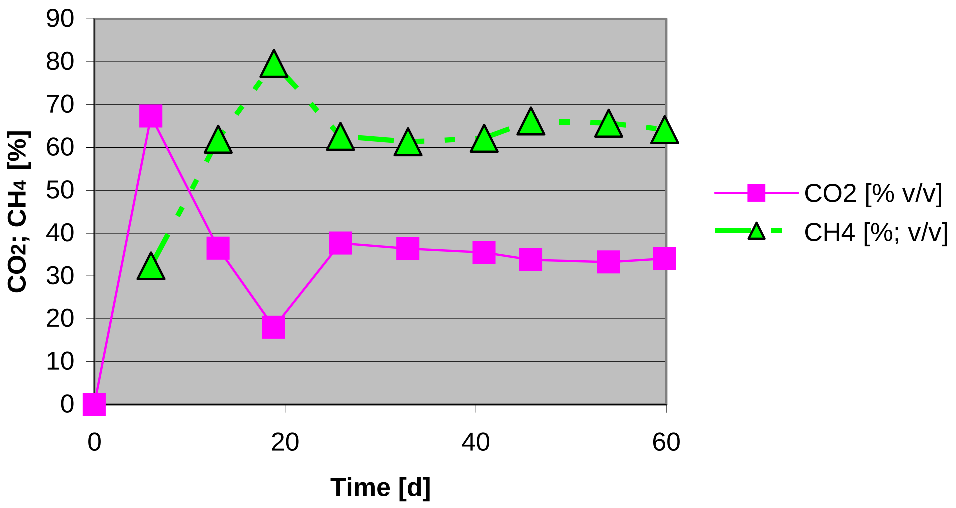

Fig. 4: Methane and carbon dioxide content in biogas produced using Vetiver grass (clone Texas) as substrate

Bioengineering applications of Vetiver grass will be the most recent important basic principle. Generation of a transportable energy carrier – biogas – might become the next basic principle. Vetiver grass may be used as single substrate in liquid biogas fermentation on the basis of cow manure. Both yields and quality of biogas produced are of high level. Much more research work has to be carried out to conduct high efficient processes as repeated batch. The application of such processes will deliver energy on the one hand and qualify waste material to high efficient fertilisers too on the other one.

References:

Greenfield, J.C.: Vetiver Grass: The Hedge against Erosion. The World Bank, Washington, D.C. 1987

Anonymos, *Institute of Pacific Islands Forestry:* Pacific Island Ecosystems at Risk (PIER) 2007: http://www.hear.org/pier/index.html

Maffai, M., ed.: *Vetiveria*. The genus *Vertiveria.* Taylor & Francis, London 2002

TRUONG, P.: The vetiver plant. In: Vetiver systems application – proven and green environmental solutions. P. TRUONG, T.T. VAN, E. PINNERS, eds. The Vetiver Network International 2008

VDI 4630: Vergärung organischer Stoffe Fermentation of organic materials. Verein Deutscher Ingenieure, Düsseldorf 2006.

Abbreviations used:

a.k.a	also known as
d.m.	dry matter
f.m.	fresh matter
ml_N	volume of dry biogas in normal state (T_0 = 273 K; p_0 = 1013 hPa)
o.d.m.	organic dry matter