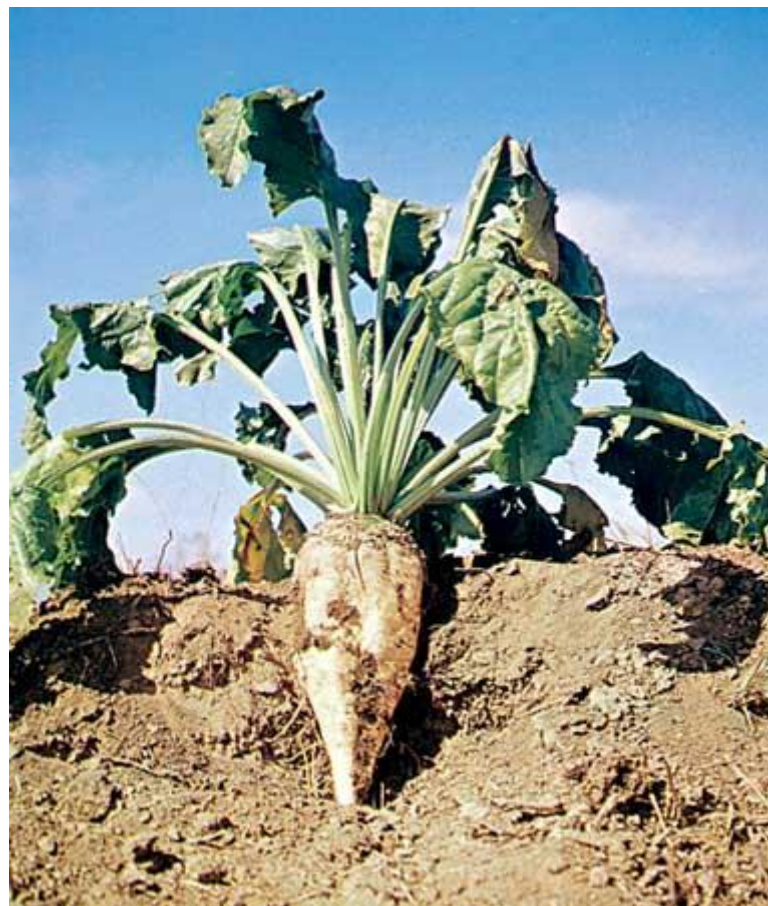




Tropical Sugar Beet (*Beta vulgaris* L.)

Potential of tropical sugar beet for bio-ethanol production

Prepared by FACT Foundation



Sugar beet (*Beta vulgaris*). photo: Grant Heilman

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1 PREFACE

1.1 Foreword

This FACT sheet is based on a Dutch report on biofuels, prepared by Wageningen University and Research in the Netherlands. FACT has translated the document from Dutch into English with the intention of making it available to the largest possible audience. Main target groups of this document are parties involved in the development of sustainable biofuels in developing countries (NGO's, small and medium sized enterprises, local entrepreneurs, local governments, local farmers and farmers groups). We hope the document helps in making well balanced decisions on new research and projects involving tropical sugar beet. Our main aim is to provide information and assist in the development of projects, either research or (semi-) commercial development, that:

- bring development to the local population,
- do not threaten food security,
- have no negative impacts on the environment and biodiversity,
- reduce greenhouse gas emissions and
- have a positive energy balance.

This document will be presented as a living document on the FACT website and will be updated when new information on tropical sugar beet becomes available.

For more information or comments please contact us or visit our website:

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1.2 Acknowledgements

This publication is made available in English by the FACT Foundation. The text is an almost literal translation of the part on tropical sugar beet in the Dutch study "Nieuwe grondstoffen voor biobrandstoffen – alternatieve 1e generatie energiegewassen", prepared by Wageningen University and Research, commissioned by Senternovem (the current AgentschapNL). It was first published in Dutch in August 2009. FACT Foundation thanks Mr. Wolter Elbersen (WUR-FBR) and Mr. Leo Oyen (WUR-PROTA), as well as Mr. John Neeft (AgentschapNL) for their approval and cooperation on this publication.

1.3 Original publication data

Title: Nieuwe Grondstoffen voor Biobrandstoffen. Alternatieve 1e Generatie Energiegewassen

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2 SUMMARY

English name: Tropical sugar beet (TSB)

Other names: Tropische suikerbiet (NL), Zuckerrübe (Ge), Betterave sucrière (Fr)

Latin name: *Beta vulgaris* L.

Plant Family: *Chenopodiaceae*

Sugar beet is the largest sugar crop in the world after sugar cane. It is mostly grown in temperate and drier areas of the world. Sugar beet requires a soil that is not too stony or clayey. It has a relatively high tolerance of saline and alkaline soils and has a relatively low water use. Sugar beet is grown as an annual crop and multiplied by seed. It has a thickened taproot that accumulates sugar. Under tropical conditions, the growth cycle is about 6 months. This makes it possible to grow 2 crops per year. Keep in mind that sugar beet requires crop rotation of not less than 1 to 3. Consequently, sugar beet can be grown in the same land only once in 3 years to prevent pests and diseases. This results in longer transport distances to the processing plant since continuous monoculture cultivation close to the factory (such as possible with sugar cane) is not possible.

In the tropics, sugar beet is still a crop of marginal significance. It has been grown in higher regions (> 1500 m) or in dry or saline conditions where sugar cane is no option. In the past 10 years, Syngenta® has developed new varieties with better disease resistance, and improved cultivation techniques. These varieties are being introduced in India, South America (Colombia and Brazil) and Africa (Kenya, Sudan and South Africa). The first projects with tropical sugar beet in India and in Colombia (in 2009) mainly produce bioethanol. The world average yield of sugar beet is 46 tons per ha (fresh). For the new Syngenta® varieties, yields from 60 to 80 tons per ha (fresh) are expected corresponding to 9.5 to 14 tons of sugar, and equivalent to 5000 to 7500 liters of bioethanol. This is slightly higher than the current bioethanol yields of sugarcane in Brazil. Please note that sugar beet has a growth cycle of 6 months, while sugar cane has a cycle of 12 months.

Beneficial properties of tropical sugar beet are the high yield per hectare (leading to efficient land use). The need for crop rotation can contribute to diversification of crops. Production of by-products (leaves and pulp for animal feed or energy) is limited but can contribute to reducing the ecological footprint. Sugar beet has a low water use (50% lower) per unit of sugar (or bioethanol) as compared to sugarcane. The by-products are difficult to use as fuel (heat and electricity) for bioethanol production as is the case for sugar cane residues. Sugar beet is a high input crop that requires good knowledge and sufficient inputs such as fertilizers, pesticides, and good seed. Tropical sugar beet demands good soils and has high costs of inputs and therefore seems less suitable for marginal areas with the exception of saline land, widely present in irrigated areas. Because of the knowledge-and capital-intensive nature, sugar beet cultivation is probably not an option for small farmers in the tropics. Tropical sugar beet will not so much be a competitor of sugar cane, but rather a complementary sugar crop. Processing of sugar beet in a sugarcane factory is possible up to 20% and can extend the operational period of the factory or limit the negative effect of cane shortages leading to better utilization of infrastructure. Furthermore one can grow sugar beet between two monoculture sugar cane cycles and thus reduce disease pressure. Tropical sugar beet will have to prove its value as an energy crop without the current intensive supervision and support of the seed industry in the coming years.

3 BIO-ENERGY POTENTIAL OF TROPICAL SUGAR BEET

3.1 Center of origin and climate and soil requirements

Wild forms of *Beta vulgaris* occur along the Mediterranean coast, with offshoots as far east as Indonesia, and westward along the coasts of the Atlantic to the Canary Islands and southern Norway. *Beta vulgaris* was initially grown for its leaves in the eastern Mediterranean and as such is also mentioned in Mesopotamian literature in the 9th century BC. The use of the thickened root is of much more recent date. Recipes for the roots of beet date back to the 3rd century, while garden beet is only known since the 16th century. Fodder beet was known for its sweetness and around 1750 it was discovered, in Prussia, that sugar could be extracted from beet juice after which, in 1801, the first factory for processing sugar beets was built. When no cane sugar was available in Europe due to trade embargoes in the Napoleonic era, a sugar beet-based sugar industry developed fast. In the Netherlands, the cultivation of sugar beet became really important only after 1860 when the dye 'Rose madder' or 'Madder lake' was replaced by chemical dyes and the cultivation of common madder or dyer's madder (*Rubia tinctorum*), a plant that produces the dye, was no longer necessary. Common madder was important in the crop rotation system because it required deep tillage resulting in good weed control for the whole rotation. Sugar beet proved an excellent replacement. Besides cultivated beet and wild beets in the Netherlands locally also populations of 'ran wild' - or weed beet occur. As a crop, sugar beet is particularly important in the temperate regions of Europe, North America and Japan. In Southern Europe and North Africa, sugar beet is sometimes grown in the same areas as sugar cane. This is important because the active period and the productivity of sugar factories are increased. Adaptation of sugar beet to tropical conditions is a very recent development. In 1997, Syngenta® began investigating the possibilities to develop tropical sugar beet varieties, mainly by improving disease resistance. In 2007 the first new Syngenta® sugar beet varieties were harvested on a commercial scale in tropical India. Note that at higher altitudes in the tropics sugar beet has been cultivated for a long time: in Ecuador since 1990 approximately 500 hectares are cultivated with yields comparable to those in the Netherlands. Despite the deep root system of sugar beet, periods of drought lead to a marked reduction in root yield. Also, wet periods are harmful. Because of the high production and thus high biological activity, the root system requires large amounts of oxygen. In wet periods, there is often too little oxygen in the soil for maximum growth. The structure of the soil can also negatively affect growth. The relatively low water consumption is one of the advantages of the crop under tropical conditions. The crop is relatively tolerant to saline conditions, a trait which could be further developed by plant breeding or genetic modification.

In sugar beet varieties grown in the Netherlands, the optimum temperature for growth of the plant is 17-24°C, for sugar production however, this is around 17°C. In varieties adapted to tropical growing conditions, the optimum temperature range is higher.

3.2 Current distribution and status as an energy crop

World production of sugar beet approaches 250 million MT per year, and sugar production hereof is approaching 60 million MT per year. This makes it the most important sugar crop worldwide after sugar cane. In the tropics sugar beet has been a marginal crop, which is a result of its susceptibility to pests and diseases and the availability of sugar cane as an alternative. Breeding of sugar beet has long been focused on increasing the sugar yield. Later, breeding increasingly focused on selecting and crossbreeding of resistance to pests and diseases.

Recent breeding research from Syngenta® has resulted in varieties that are suitable for commercial cultivation of sugar beet in tropical lowlands. The program that took

approximately 10 years has resulted in tropical sugar beet cultivars Posada, Hi 0064 and Dorotea. Besides disease resistance the major effort was in improving the ability to store sugar in the beet at higher temperatures. Seed production of tropical sugar beet is done outside the tropics and therefore obstacles to seed production (cold requirement and photoperiod sensitivity) do not need to be overcome.

The new tropical varieties are now rapidly being introduced in the market especially for bioethanol production. First launch is expected in India followed by Colombia, Brazil and (South) Africa. Especially in Brazil there is great potential in addition to sugarcane. Specifically cultivation of sugar beet after sugar cane is considered. This will break the sugar cane cultivation cycle and can compensate shortages of sugar cane when this is not available. This enables a more efficient and continuous use of the sugar factory and related infrastructure.

3.3 Botanical description of the crop

Sugar beet is a robust, biennial plant with a thickened taproot and deep and extensive root system. In the first year it forms a rosette of leaves and in the second year a large inflorescence (for sugar, the plant is harvested in the first year). Leaves in the rosette have long leaf stalks and large oval shaped leaf blades. On the flowering stem, leaves are positioned opposite and are much smaller. The inflorescence is up to 1.5 m long, with groups of small green bisexual flowers. The fruit is a nut, usually several (3-4) clustered together in a ball of cork-like material. Seed is 1-3 mm in diameter. In the first year, 30-40 (-60) leaves are formed as well as a thickened taproot in which carbohydrates are stored. In winter after the first year flowering is initiated and in the second year the plant flowers and produces seed. In the transition from vegetative to generative phase both temperature and day-length play a role. In the Netherlands the maximum amount of foliage is reached around early August. Thereafter, the number of leaves slowly decreases. Since it takes quite some time before the crop foliage covers the soil, the ability to compete with weeds is small. Weed control therefore plays an important part in crop management. The increase in root weight starts rather slowly, but continues during the first year at a steady rate. Only in October, the maximum dry matter yield of the root is reached. In autumn this amount barely decreases.



3.4 Cultivation

Under tropical conditions sugar beet is an intensive crop that requires considerable amounts of inputs and knowledge, but also provides a high yield. In the tropics the crop is typically sown at the beginning of the rainy season.

Weed control in sugar beet is a very intensive operation, particularly in the first part of the growing season. The development of varieties that are resistant to diseases and the development of crop protection strategies against pests and diseases have been crucial for the adaptation of sugar beet to tropical conditions. In the cultivation of sugar beet numerous

diseases may occur, such as leaf diseases caused by *Cercospora*, powdery mildew, or root diseases such as rot caused by *Rhizoctonia solani* and rhizomania, a viral disease. Damage may also be caused by nematodes and larvae from insects such as lined click beetle (*Agriotes lineatus*) and the beet beetle (*Atomaria linearis*) that eats the beet plants. Crop rotation is the most important measure to prevent diseases.

In temperate regions, chemical weed control is usually applied; this requires 3 to 7 sprayings per year. The major producers of sugar beet seeds have genetically modified varieties on the market which are resistant to the herbicide glyphosate which leads to yield increase of about 10%. It is expected that also tropical sugar beet varieties with these qualities will become available.

In nutrient management of sugar beet, nitrogen fertilization plays a crucial role. For the growth, especially of the leaf, large amounts of N are needed. During the formation and filling of the beetroot, N hardly plays a role and excessive quantities during this stage may even reduce sugar content. The distribution of Nitrogen applications over the growing season is therefore very important.

3.5 Yields and conversion to biofuel

The world average yield of sugar beet is 46 MT per ha (fresh) per crop cycle (with in temperate zones one cycle per year) which corresponds to about 8 MT of sugar from which about 4000 liters of bioethanol can be produced. In the Netherlands, typical yields are 64 MT per hectare and 11 MT of sugar per hectare, while yields up to 80 MT per ha (fresh) can be achieved in the EU. For the new tropical varieties, Syngenta® predicts yields of 60 to 80 MT per ha (fresh), which is equivalent to 9.5 to 14 MT of sugar or 5000 to 7500 liters of bioethanol. This is slightly higher than the current bioethanol yields of sugarcane in Brazil. PLEASE NOTE: Sugar beet has a growth period of 6 months until harvesting while sugarcane has a cycle of 12 months. One advantage is that the sugarcane bagasse can be used for energy production in the factory. However the residues of sugar beet (dried pulp and leaves) are also of value and can be used for biogas production. Research has shown that 340m³ biogas can be produced per MT of organic dry matter of leaves (Cosun magazine, June 2010).



Photo: Tropical Sugar Beet towards processing
- Syngenta ®

In the tropics sugar beet must be processed within 48 hours after harvesting. In areas where the growing season is not limited by cold, beets can be harvested over a longer period and sugar or bioethanol plants can be used more efficiently. In the factory the beets are washed and sliced. The sugar is extracted from the chopped beet with hot water. The resulting raw juice is first purified by adding lime that later can be used as agricultural lime. Then the juice is concentrated, and upon further thickening the sugar crystals are formed. To encourage the formation of crystals a bit of powdered sugar is added. By centrifugation the crystals are separated from the remaining syrup, which is called molasses and is sold separately, such as

for the production of alcoholic drinks. The granulated sugar is dried and stored in silos. During the year the sugar is packed and transported. The remaining pulp from which the sugar has been extracted is used as animal feed or can be a raw material for biogas production.

The production of bioethanol from sugar beet in itself is a simple process. However, innovations occur, for example extruding the sugar beet and directly ferment it into ethanol. An important option is processing of the sugar beet in a sugar cane factory. Reportedly up to 20% of sugar beet can be processed in a sugar cane factory with limited adjustments. This allows partial integration of sugar beet in the sugar cane production system which for a country such as Brazil offers great prospects.

The data presented so far show that the new tropical sugar beet varieties produce more sugar per hectare than sugar cane, in about half the time and with less water. In some countries in the tropics and particularly in India (2008) the first projects for the commercial cultivation of tropical sugar beet have successfully started and the first factories for the production of bioethanol from sugar beet have been built.

3.6 Traditional uses

As mentioned above, different varieties of sugar beet are grown as a sugar crop, forage crop, root vegetable, leafy vegetable and stem vegetable. Sugar beet is grown almost exclusively for the production of sugar. Besides use as food and in the food industry, sugar has key industrial applications, particularly as raw material in the chemical industry. After processing pulp remains that is used as cattle feed. An alternative is to use the pulp for biogas and energy for the bioethanol production process. Also, beet leaves and heads may be used as fodder.

3.7 Economics

Relatively little is known about this in the public domain. Syngenta announces production costs of \$ 900 to \$ 1800 per hectare and a net output 35% higher than for sugar cane. The crop should be seen as a high input, as well a high output crop. The costs of seed, tillage and weed control are high but the benefits as well. Furthermore, the crop will often be grown under irrigation.

3.8 Sustainability

Good sustainability analyses and life cycle analyses (LCA) of bioethanol production from tropical sugar beet are not known. LCA studies that compare bioethanol production from sugar cane in Brazil and sugar beet in temperate regions are always much more favorable for sugar cane, particularly with regards to energy balance and greenhouse gas emissions. This is mainly explained by extra bagasse (crushed stalk) that is available in sugar cane and is used as fuel for processing and ethanol distillation. Sugar beet produces far less by-product that is also less suitable as fuel. Furthermore, sugarcane is a perennial crop which saves inputs. We expect that the incorporation of indirect land use impacts in the sustainability analysis will lead to a better appreciation of sugar beet because of its high productivity per hectare. If tropical sugar beet can realize its high productivity in a short growing season under commercial farmers' conditions, this will raise the sustainability score in comparison to sugar cane.

Despite the lack of good data on tropical sugar beet, it is possible to consider its sustainability more generally:

- Tropical sugar beet appears to have a very high yield per hectare which is beneficial in light of efficient land use.
- At the same time it is produced on fairly good soils that are also suitable for food crops which can be considered as competition with food crops.

- The amount of byproducts is limited, although leaves, pulp and heads of the beets may serve well as animal feed and/or can be used for energy through biogas production.
- Tropical sugar beet seems to make efficient use of inputs such as water (50% less than sugar) and nutrients, associated with high productivity. For a good yield, the crop requires sufficient chemical control of pests and diseases. Good cultivation practices are necessary to prevent the pollution of air and water.
- The crop is grown in rotation and goes through its productive cycle from seed to harvest in six months making it efficient in use of land. The crop must be grown in rotation and in this way can contribute to diversification of crops in a cropping system.
- Tropical sugar beet can be harvested over a longer period than in temperate areas and thus allows a more efficient and cheaper system.
- Sugar beet requires intensive soil tillage each year.
- Tropical sugar beet seems to be less suitable for marginal areas because of the high input costs and soil requirements. An exception may be the case of saline soils that have developed as a result of poor irrigation.
- Due to the relative high knowledge and capital intensive type of farming and the need for large-scale processing close to the sugar beet fields, it is probably not an immediate option for small farmers in the tropics. Unlike with sugar cane, the labor requirements in the cultivation system will not quickly lead to seasonal employment. Also, burning of the leaves as is often done in sugarcane, leading to air pollution, are not required.