MECHANIZATION OF HARVEST AND CONSERVATION OF *MISCANTHUS SINENSIS GIGANTEUS*

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INTRODUCTION

A new crop for which nowadays much research is performed at many places, especially in Europe, is *Miscanthus*. This is a perennial C_4-grass which origins in East Asia. In Denmark a clone was recognized with high productivity called *Miscanthus sinensis* 'Giganteus' hort. (Jelitto et al, 1990). The interest in this crop is the source of new biomass or fibre. The applications under research are: Energy source, building materials, geotextile, paper, packaging material and substrate for plants on water culture. The plants are propagated by rhizome cuttings or plantlets. The research so far has been concentrated on crop production and marketing. But like most other crops the highest production costs are related to farm machinery, conservation and transport. In 1993 research on the mechanization of planting, harvesting and conservation was started. This first year was used to test different, conventional farm machines and evaluate their application in the crop *Miscanthus*. To keep all options open, the studied harvest methods were not depending on the application of the harvested material. To assure a year round delivery of product for processing, harvested material must be stored and conserved, preferably on the farm. During storage the quality of the material must be maintained. Another important aspect is transportation. Costs depend on the total volume of the material. Volume can be minimized by baling or pelleting but after compressing drying will be difficult.

PLANTING

A new crop can be established using plantlets or rhizomes. The plantlets, of tissue culture origin, can be planted with a normal planting system (Isensee et al, 1992).

Another method to establish a new crop is using rhizomes. These are pieces of root material obtained by cutting rhizomes of mother plants. Using rhizomes is cheaper than plantlets and they seem to be less sensitive for frost in winter. The rhizomes can be produced by the farmer, harvested by a flower bulb harvester after the mother plants are cut in pieces by a rotary cultivator. When the driving speed of the rotary cultivator is low (0.5 km/h) no handwork in cutting is needed. If planting is performed within a few days after harvesting and when the rhizomes are not dried out, the emergence showed to be 70 - 95%. Experiences with planting of rhizomes in Denmark are also positive (Jørgensen and Kjeldsen, 1992).

HARVESTING

The above ground crop of *Miscanthus* dies with the first frost. This is the beginning of the drying period. Depending on weather conditions the moisture content drops and harvest is possible when moisture content is 18% (wet base) or higher if drying in storage is possible (El Bassam et al, 1992). In 1993 and 1994 this moisture content was reached mid of march and beginning of april respectively. Regrowth starts when soil temperature reaches about 10 °C. In The Netherlands in 1993 regrowth started at April 23 consequently resulting in a harvest period beginning at the end of February, depending on the weather conditions, until the end of April. Existing harvesting machines can be used (Johanning and Wesche 1993) and were tested (Huisman and Kortleve 1994). After mowing three handling methods can be chosen: chopping, baling or bundling.

1) Mowing and chopping.

A chop forage harvester used for harvesting maize can also be applied in the harvesting of *Miscanthus*. In an older crop the rows are not distinguishable anymore so a row-independent mowing attachment is preferable. Experiments with a Kemper 'Champion'

3000 in combination with a Steyer 8320 machine carrier, in a 2 and 6 year old crop, gave good results. This year the material was cut at different lengths, 11 mm and 44 mm. For experimental use material was manually cut at 100 mm length, similar to the length of material harvested by a sugar cane harvester, which was not available for testing. The densities in dry matter mass of the chopped product were in the order of the tested length: 95 kg/m^3, 70 kg/m^3 and 95 kg/m^3

2) Mowing and baling.

A way to decrease transportation volume is making bales. This can be big bales (height 0.8 - 1.6 m), round bales (diameter 0.6 - 1.8 m) and compact rolls (prototype, diameter 0.3 - 0.4 m). Before baling, the crop must be mowed and put on a swath. This year tests have been carried out with a Vicon WR322 self-propelled swath mower and a Vicon pulled disctype swath mower in a 2 year old crop. The losses showed to be 10 - 30% mainly due to problems with picking up the product properly.

The different types of balers will produce different densities. According to Johanning and Wesche (1993) and our experiments the densities in dry matter can vary from 140 kg/m^3 for a high pressure big baler or round baler to 300 kg/m^3 using an experimental machine called the compact roller. Experiments this year were carried out with a Deutz Fahr Gp3.612 big baler with an open press chamber. The bale size was about 0.6 x 1.2 x 2.0 m^3. The dry matter density then was: 130 kg/m^3.

It can be concluded that the loss should be reduced. This could be done by putting the crop directly after mowing in the baler.

3) Mowing and bundling

When it is necessary to harvest whole stems for the application of stems as raw material for geotextiles the appropriate harvest method is mowing and bundling. This method is commonly used in the reed and rice culture. An Agostini with binding equipment was used in the experiments. This machine was attached to the three-point linkage of a tractor. The crop is cut with a cutterbar and transported via the binding unit to the side. The density of the bundles was 140 kg/m^3, the weight 9 kg and the bundle diameter of 0.2 m.

STORAGE AND CONSERVATION

For a year round delivery, storage is necessary, preferably on the farm. It is important to preserve the quality of the product. Depending on the used harvest method the material to be stored is:

- 1) chopped (different lengths);
- 2) bigbales (square bales, roundbales and compact rolls);
- 3) bundles.

Maximum moisture content for short storage of chopped material is 25%. For a save storage during a longer period (for example one year) the moisture content must be 18% or lower (Frerichs, 1990). According to Jørgensen and Kjeldsen (1992) bigbales can be stored at 25% moisture content. Drying of bigbales is difficult. The compact rolls with the DM density of 300 kg/m^3 can not be dried anymore so moisture content of the material has to be lower than 18%.

When harvest conditions are poor and the material contains more than 18% moisture, the chopped material can be stored in any storage facility where ventilation from a floor system is possible. Tests showed that daily ventilation for 1.5 hour with ambient air during 5 weeks already reduced moisture content sufficiently. A good way of storing chopped material (11 and 44 mm) is in piles outside, covered with vapour permeable plastic (Hotz et al, 1993). However when the quantity to be stored is very large the plastic becomes costly and labour demanding. A farm building only with a roof would then be preferable.

Two experiments were done with storage in small piles. One pile had a ventilation channel and was covered with normal plastic. The other was only covered by a net to prevent the wind from blowing the material away.

After five months the covered pile still had a moisture content of 15% in the centre to 10% in the top layer. The open pile showed an increase in moisture content in the centre to 24% and in the top layer to 64%. The results indicate that a covered and ventilated pile is preferable. Notice that the open pile in this experiment was very small. Storage in a bigger open pile could give better results. The characteristics of the outside layer, such as thickness and moisture behaviour, are subject of further research to find a system to prevent rain to penetrate too deeply. The storage of the chopped *Miscanthus* in a ventilated facility makes drying possible but is compared to the other storage methods relatively expensive. Ventilation is preferable and can easily be achieved by using a ventilation tunnel. When bales are stored, the moisture content is important since drying them in storage is difficult.

Another storage method is silage, commonly used for grass, maize and also hemp. Material for silage, from a five year old crop, was harvested on the first of March 1993, with a moisture content of 40%. The material was chopped with a chop forage harvester adjusted at a chopping length of 4.1 mm. Two different moisture contents were created by adding water to one sample resulting in a moisture content of 70%. Two variants were inoculated, this means lactic acid bacteria (Lactomol) were supplemented. The four variants were stored in preservers. After 1.5, 3, 6 and 21 days the preservers were opened for determination of pH-value and acids with HPLC-analysis (High Performance Liquid Chromatography). Results from these silage experiments show that the glucose available in the basic material was rapidly converted to mainly lactate. The material contained just enough sugars to decrease pH-value to values of 4.1 and 4.2 for the 40% moisture content and 4.1 and 4.5 for 70% moisture. The inoculated silages showed the lower values. Just the not inoculated, 70% moisture content silage was not stable and pH increased to 6 after 1 year. Harvest dates later than March 1 will result in less sugar in the material and most likely give higher pH-values in silage, thus making additives like molasses necessary.

The harvested bundles were stored outside. Two different kinds of bundles were tested. Some bundles were tight bound and others had a loose binding. Two variations were made, covered with plastic and non covered. The uncovered bundles became wet completely and deteriorated. The loose bound bundles will dry after rainfall, but not enough. Storage of plastic covered bundles outside is very well possible.

LABORATORY EXPERIMENTS

In 1993 research has been carried out to find out how long it takes before stored material, under different temperature and Relative Air Humidity (RAH) conditions, gets mouldy. Also the sorption isotherms of 10 °C and 20 °C were measured.

Determination of sorption isotherms is of great importance for research on storage and drying of *Miscanthus*. These isotherms show the relation between equilibrium moisture content of the material and the Relative Air Humidity (RAH) for a specific storage temperature. This gives information on the behaviour of stored material under certain storage conditions and is a parameter in drying models. It is also reversible, when material from storage is being examined, forecasting is possible about the air condition in the storage and the risk of mould building.

The experiments on mould growth were done at three temperatures (10, 20 and 30 °C) and two RAHs (80 and 90%). Chopped material at the lengths 11 mm, 44 mm and 100 mm were used. The different RAHs were created by salt solutions in conical flasks which contained baskets with *Miscanthus* just above the salt solution.

In 1993 only the adsorption isotherm of the three different chopped *Miscanthus* material (11 mm, 44 mm and 100 mm) was determined. The material was stored in stainless steel barrels under vacuum, so equilibrium moisture content was reached earlier due to lower resistance in water exchange. The barrels were placed in climate controlled rooms for three weeks, enough to reach an equilibrium moisture content.

Table 1 shows the results of the mould growth experiment. It is clear that mould will appear only under extreme storage conditions. After 10 days at 30 °C and 90% RAH filamentous fungi were clearly visible. After a few phases in which different moulds appeared and also disappeared one mould dominated after 45 days. This mould most likely affected the cellulose in the

Table 1 Days before getting mouldy in relation to Relative Air Humidity and Temperature.

Temp [°C]	RAH 90%	RAH 80%
	Days before getting mouldy	
30	10	75
20	45	300
10	90	>300

material. Under the other storage conditions only a small contamination of filamentous fungi was detected. Storage conditions with a low RAH and temperature show that mould building will take longer than 300 days.

The results of the determination of the adsorption isotherms are presented in figure 1. The difference in equilibrium moisture content between the three kinds of material was very small.

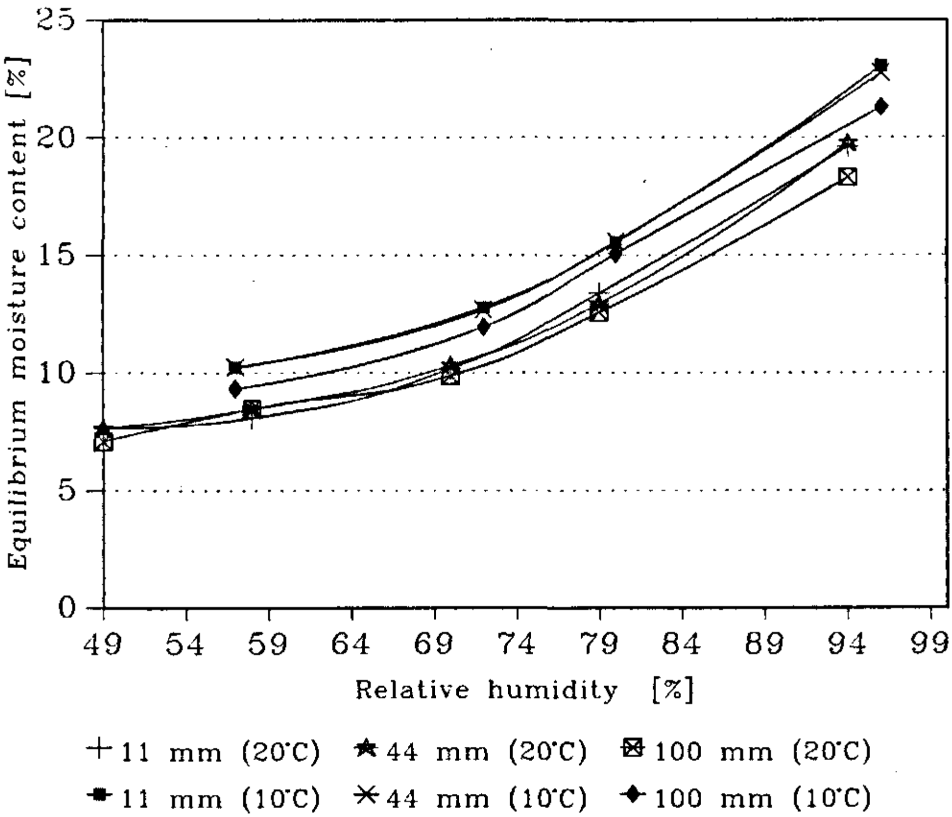

Figure 1 Adsorption isotherm of *Miscanthus* at 10 °C and 20 °C.

According to Frerichs (1990) moisture content must be lower than 18% for long term storage. The sorption isotherms show that at 10 °C and RAH of 80% equilibrium moisture content is 16% and at 20 °C it is 14%.

TIMELINESS

The harvest of *Miscanthus* takes place between January and May because there is a decrease of moisture content in the crop, depending on weather conditions (temperature, precipitation, radiation and wind). When a specific moisture content (= threshold) is reached harvest can start (t_{begin}) and continue until the threshold is crossed again. The threshold level depends on the harvest method. For instance for chopping, a higher moisture content can be accepted than for compacting since artificial drying is possible with chopped product. The costs for drying will decrease in time, as will the damage to the field and also the crop yield of the next year(s) due to field traffic under too wet conditions.

When the temperature increases in spring new sprouts will emerge. The harvest must be finished (t_{end}) prior to the date after which unacceptable damage to the sprouts will occur as a result of field traffic. Too much damage or cutting off will result in a decreased yield in the following year(s). The amount of damage depends on the harvest method since each method causes a different field activity.

The period of the harvest between t_{begin} and t_{end} is called the 'harvest window'. Harvesting within this window means minimization of timeliness costs. Machine costs can be high in case of a 'short' 'harvest window' because of large machine capacity requirements. The moment within the 'harvest window' at which the actual harvest will start depends on the workability. The workability depends on the harvest method (field activity), crop moisture content and the soil conditions due to weather conditions.

In order to assess the total costs precisely, it is needed to develop simulation models in relation to the weather conditions of a specific location and for the different harvest methods. This includes models of drying of the *Miscanthus* crop in the field, of drying in storage, of soil conditions and their effect on yield. With historical weather data the models can calculate historical cost courses. With these data the workability and so timeliness costs can be calculated for the various moisture thresholds for the years the weather data were used. With the assumption of no climate change the future workability can be statistically described. The model for drying in storage is needed to predict the possibilities of drying by natural ventilation and the cost of artificial drying. Such research has been started recently. Cooperation with research institutions on various locations with different climate conditions are necessary.

Preliminary cost calculations showed that machine costs of harvest and field transport also vary with the length of the 'harvest window'. When the 'harvest window' lasts two months (March + April) machine costs are at minimum, about Dfl 700 for the chopping chain and about Dfl 900 for the other methods. In case of a 'harvest window' of 1 month (April) these costs are Dfl 800 and Dfl 1200 respectively. Total production costs will not only also depend on timeliness costs but also on tranportation costs from farm storage to processing plant. The density of the product then becomes very important. The product in the form of compact rolls with their high density of 300 kg/m^3 will give lowest transportation costs, since the maximum transport weight of a truck will be reached then.

Total estimated yearly costs of the production of 1 ha of *Miscanthus* at the farm are Dfl 1578 and are based on:
Plant propagation material, from rhizomes, harvested by the farmer: Dfl 0.25 per rhizome. Plant density: 1 per m^2. Plant growth period: 10 years. Weed control: only in year 1 and 2: Dfl 90 per ha. Yearly costs per ha for: fertilizer Dfl 465; harvest and storage Dfl 1000; costs of labour and rent of land etc. Dfl 2000. In case a set aside subsidy can be gained of Dfl 600 then the costs of 1 ton dry matter of *Miscanthus* delivered at the farm will be Dfl 163.

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