

Sunflowers for Biogas – Breeding for Yield and Quality

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ABSTRACT

- In Germany biogas is starting to become a major source of energy and the acreage of plants used for biogas production is increasing. Sunflowers offer the opportunity to broaden maize based energy crop rotations. The aim of an energy sunflower breeding program is to increase the methane yield per hectare. We harvested whole plants to investigate biomass yield of lines and hybrids and investigated stems of sunflower lines for quality traits like sugar content, lignin content, and ash content.
- The total biomass yield of sunflower hybrids exceeded 200 dt/ha at some locations. Significant genotypic differences of stem quality traits of sunflower lines were found.
- The results indicate that it is possible to select sunflower genotypes with an increased digestibility of the stems and simultaneously high biomass yield.
- Only limited research is done to investigate whole plant biomass and stem quality traits of sunflower.

Key words: Sunflower, breeding, biogas, biomass, alternative use, stem quality

INTRODUCTION

In many countries renewable energies are of growing importance as alternative energy supply. In Europe and especially in Germany biogas is a key element in this segment supplying already 2.1% of the German electricity production (Biogasportal, 2011). Biogas is a product of anaerobic digestion or fermentation of biodegradable materials. It is comprised primarily of methane and carbon dioxide. Biogas can be used for the production of heat, electricity, and directly in gas distribution networks.

In addition to organic waste, an increasing amount of biomass is used to produce biogas. In Germany maize is the most widely used crop for biogas production with acreage of more than 500.000 ha. To improve maize accentuated crop rotations additional crops with high biomass yields are necessary. Sunflower could be one of these crops as a biomass yield of up to 20 t/ha can be achieved (Hahn and Ganssmann, 2008).

For biogas production a high methane yield per hectare is an important aim in energy plant breeding. The methane yield per hectare depends on the biomass yield, the amount of biogas per kg organic dry matter and the methane content in the biogas. Here sunflower offers an advantage as its oil is producing a high methane content in biogas. However, an increasing biomass yield is associated with higher amounts of sunflower stems. And in this yield fraction, compared to maize, higher ash content and larger amounts of structural substances like ADL were found. In contrast to oil, protein and soluble carbohydrates these substances affect negatively the efficiency of energy degradation of biomass. Therefore, our objectives were to (1) investigate biomass yields of newly developed hybrids and (2) estimate genetic parameters for ADL, ash and sugar content of sunflower stems.

MATERIAL AND METHODS

Biomass hybrids

In 2011 about 500 hybrids were tested in two locations in Germany (Hohenheim and Eckartsweier) and one location in the Netherlands (Ottersum). All plots were two-rowed with a length of 5 m and 0.75 m row distance. Plots were overplanted and thinned to about 7 plants per m². Plots were harvested with a chopper.

Stem quality

The study is based on a total of 147 sunflower inbred lines comprising elite and public germplasm for biomass and grain yield use. The 147 genotypes were divided into two different maturity groups. Three lines were grown as an internal check in both maturity groups. The field trials were conducted in four environments (location-year combinations) in Germany (Hohenheim and Eckartsweier in 2008 and 2009). Each trial was laid out as a randomized 15 x 5 alpha-design with two field replications. A plot consisted of one 3 m row with 0.75 m space between rows. The material was cultivated with two different sowing times. Five sunflower stems of each plot were cut manually and oven-dried at 60 °C to constant weight. The dry samples were grinded and measured with a PSS2120 spectrometer (Polytec GmbH, Germany) to determine ash, ADL, and sugar content. Statistical data analysis was accomplished with the statistical software R (R Development Core Team, 2009) using the ASREML package for the R environment (Butler et al., 2007) and a two step method proposed by Möhring and Piepho (2009).

RESULTS AND DISCUSSION

Biomass yield

Two female lines derived from genetic resources showed a high potential for biomass yield. Both lines were crossed with a range of newly developed restorer lines. The yield and dry matter content of some of the high yielding combinations are shown in table 1.

Table 1. Biomass yield and dry matter content of selected hybrids at three environments in 2011.

Location	Female	AE701		AE702	
	Male	Yield (dt/ha)	Dry matter content (%)	Yield (dt/ha)	Dry matter content (%)
Hohenheim	RE765	221.6	24.3	275.8	22.4
Eckartsweier		205.3	27.6	147.6	24.9
Ottersum		197.6	20.0	218.1	23.1
Hohenheim	RE813	225.6	23.0	250.0	23.0
Eckartsweier		64.0	35.3	143.3	26.0
Ottersum		183.7	20.5	200.2	22.0
Hohenheim	RE07-363	174.3	23.1	247.3	22.8
Eckartsweier		126.5	29.2	76.2	25.2
Ottersum		224.2	23.1	225.9	20.6

To be competitive with maize, a biomass yield of about 200 dt/ha is necessary. Some of the newly developed inbred lines are showing this yield potential in various hybrid combinations, underlining the competitiveness of sunflower as a crop for biomass production. The new inbred lines will be candidates for future sunflower biomass varieties and further inbred line improvement.

Stem quality

The mean and range values of the investigated traits ash content, ADL content and sugar content of stems of sunflower lines of the two maturity sets are given in table 2.

Table 2. Means, ranges, variance components (σ^2_g , σ^2_{ge} , σ^2_E) and heritabilities (h^2) of sunflower lines for three stem quality traits in four environments.

Trait	Mean	Range	σ^2_g	σ^2_{ge}	σ^2_E	h^2	
Early set							
ADL (%)	10.1	6.7	13.7	0.38 **	0.97 **	0.36	0.59
Sugar content (%)	8.3	0.5	28.9	8.88 **	17.55 **	3.21	0.66
Ash content (%)	10.1	4.9	15.5	0.70 **	2.50 **	0.58	0.48
Late set							
ADL (%)	10.4	6.9	14.3	0.90 **	0.84 **	0.12	0.78
Sugar content (%)	9.0	0.0	34.4	15.88 **	4.37 **	12.52	0.82
Ash content (%)	9.12	3.9	14.1	0.82 **	1.58 **	0.18	0.61

** significant at P = 0.01.

In the early set highly significant ($P < 0.01$) variances among genotypes (σ^2_g) were found for all examined traits. Estimated genotype x environment interactions (σ^2_{ge}) were highly significant for all traits. Computed heritabilities were moderate for ADL, sugar and ash content. In the late set the variances among genotypes and the genotype x environment interactions were highly significant for all traits as well. Heritabilities exceeded 0.70 for ADL and sugar content and were moderate for ash content, indicating that it is possible to select sunflower genotypes with increased digestibility of the stem.

Thus, our work shows that the methane yield of sunflowers can be enhanced by (1) increasing biomass yield and (2) applying quality oriented breeding approaches to increase the specific methane content of sunflower stems.

ACKNOWLEDGEMENTS

This study was financially supported by the German Federal Ministry of Food, Agriculture, and Consumer Protections (BMELV) via the 'Fachagentur Nachwachsende Rohstoffe e.V.' (FNR), Grant No. FNR 2010557 and the Baden-Württemberg Stiftung gGmbH, Stuttgart, Germany, Grant No. Bio08.

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