Breeding of sunflower as a biogas substrate

Volker Hahn[1], Martin Ganssmann[2]
[1]University of Hohenheim, State Plant Breeding Institute, Research Station, 77731 Willstaett, Germany, E-mail: vhahn@uni-hohenheim.de,
[2]KWS SAAT AG, Grimsehlstr. 31, 37555 Einbeck, Germany, E-mail: m.ganssmann@kws.com

ABSTRACT
The acreage for energy crops will increase during the next years. Biogas offers the possibility of producing a high amount of energy per hectare. To enhance the methane yield of sunflower as a biogas substrate, we investigated the biomass yield, oil content, oil yield and ash content of total sunflower plants. In the mean, biogas hybrids showed greater biomass production, oil content and oil yield than oil hybrids. Some recently developed experimental biogas hybrids derived from non adapted germplasm and genetic resources exceeded the best biogas hybrids in biomass and oil yield. Ash content was high for all investigated sunflower types.

Key-words: ash content – biogas – biomass yield – energy – methane yield – oil yield.

INTRODUCTION
Biogas is a product of anaerobic digestion or fermentation of biodegradable materials such as manure or sewage, municipal waste, and energy crops. It is comprised primarily of methane and carbon dioxide. Biogas can be used for electricity production, space-, water- and process heating and in local gas distribution networks. If compressed, it can replace natural gas for use in vehicles, where it can fuel an internal combustion engine or fuel cells. According to a recent study (Trend: research, 2007) the number of biogas plants will be increasing during the coming years, not only in Germany, but also in many European countries especially France, Italy, and Spain. To feed these biogas plants, the acreage and efficiency of energy crops for biogas production has to be raised.

Sunflower is a well-known oil crop. However, the high genetic variation in habit type, rapid growth, and seed oil content offers the possibility of breeding for biogas types to be used as entire sunflower plants in biogas reactors for the production of methane. In general, 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 produces a higher methane content in biogas than other biogas crops.

Only a few results are available on the prospects of sunflower as biogas substrate. Therefore, we investigated sunflower varieties and newly established biogas hybrids for their total biomass yield, oil yield and ash content.

MATERIALS AND METHODS
In 2007 we conducted three experiments to investigate the biogas potential of sunflower. In experiment 1 we tested 22 oil hybrids, four biogas hybrids, and four populations (OPV) at the German locations Eckartsweier (South West), Hohenheim (South), Bonn (West) and Rostock (North East) in a 6x5 alpha design with two replications for their plant height, biomass yield and dry matter content. Oil content was investigated from samples of Eckartsweier, Hohenheim, and Rostock. In experiments 2 and 3, one oil hybrid, three biogas hybrids and 46 or 26 experimental hybrids (EH), respectively, were investigated at Eckartsweier and Rostock for biomass yield and dry matter content in a 10x5 or 6x5 alpha design, respectively. For experiment 2, additionally, oil content and plant height were measured at Eckartsweier. Ash content was examined from the samples of Eckartsweier and Rostock for experiment 1 and Rostock for experiment 2. In experiment 1 the plots consisted of four rows with harvesting of the two center rows. In experiments 2 and 3 the plots consisted of two rows. All rows were 5 m long with row spacing of 0.75 m. The plots were harvested with choppers. Samples of about 2 kg fresh weight were taken and dried to quantify the water content. The dried samples were milled. Oil content was determined by investigation of five subsamples of about one gram with a Bruker minispec. One gram of the samples was reduced to ashes in an oven by heating to 1,000°C.

The experimental hybrids of experiment 2 were developed by crossing a biogas sterile female line with pollen from single F_3 plants derived from crosses between non adapted or elite oil lines. The experimental hybrids from experiment 3 were developed by crossing the same female line with pollen from single F_3 plants derived from crosses between elite oil lines and genetic resources.

RESULTS

In experiment 1, the biogas hybrids showed the highest mean biomass yield (Table 1), lowest dry matter content, and tallest plants; the oil hybrids showed the highest oil content and the lowest ash content. The populations showed the lowest biomass yield, lowest oil content and highest ash content. In experiments 2 and 3 the biogas hybrids again showed the highest mean biomass yield. However, in both experiments, some experimental hybrids produced more biomass than the best biogas hybrids, especially when F_3 plants with a genetic resource background were used.

Table 1. Results of the field trials[1].

		E 1			E 2			E 3		
Trait		Oil hybrids	Biogas hybrids	OPV*	Oil hybrids	Biogas hybrids	EH*	Oil hybrids	Biogas hybrids	EH
	n	22	4	4	1	3	46	3	3	26
Biomass yield (dt/ha)	Mean	110	146	89	94	133	119	98	156	147
	Min	86	134	72		131	72		140	109
	Max	138	153	137		135	179		170	231
	LSD*		30,7			32,7			58,2	
Dry matter (%)	Mean	29.8	25.3	29.0	52.7	25.3	27.6	49.2	32.1	30.9
	Min	25.7	24.0	23.8		23.3	22.2		27.8	32.3
	Max	35.8	25.8	33.3		27.9	40.0		36.9	39.7
	LSD		5.0			6.7			10.3	
Plant height (cm)	Mean	195	217	207	185	209	200	183	208	204
	Min	167	210	157		205	175		195	178
	Max	249	222	280		215	238		215	225
	LSD		30,2			16,6			20,8	
Oil content (%)	Mean	10.3	10.1	6.7	11.0	9.3	9.2	11.5	12.2	9.7
	Min	1.2	9.2	4.1		8.7	6.3		10.5	6.4
	Max	13.0	10.8	9.7		9.7	11.4		13.9	15.2
	LSD		3.4			3.3			3.0	
Oil yield (dt/ha)	Mean	10.9	14.1	5.2	10.3	12.4	11.0	8.0	13.8	10.6
	Min	1.3	11.5	3.2		11.6	6.6		11.8	5.0
	Max	16.5	15.7	8.1		12.8	17.2		15.4	14.7
	LSD		5.2							
Ash content (%)	Mean	8.6	9.2	10.3	7.3	8.0	8.1			
	Min	7.9	8.1	8.5		7.7	5.9			
	Max	10.7	11.0	11.5		8.4	11.1			
	LSD		2.6			2.6				

[1]E = Experiment, OPV = open pollinated variety, EH = experimental hybrid, LSD = LSD 5%

DISCUSSION

A high biomass yield is a prerequisite for a high methane yield of a crop. In this research project we selected sunflower lines which showed a superior biomass production in hybrid combinations. Those biogas hybrids were compared with hybrids used for oil production. Most of these oil hybrids produced significantly less biomass than our newly developed biogas hybrids. For a further increase of the biomass, we selected tall lines with high lodging resistance, derived from either non adapted germplasm or genetic resources and crossed them with our elite biogas lines. To get an idea about the potential of this material we produced experimental hybrids. Although, on average the experimental hybrids produced less biomass than the biogas hybrids, some of them showed a pronounced biomass yield. Thus, using non adapted germplasm or genetic resources allows a further increase in biomass yield.

A high methane yield also depends on the specific methane yield of a substrate. As oil achieves high methane rates, we investigated the oil content of the tested hybrids. The highest mean and maximum oil content were found for the oil hybrids. But the oil yields of the biogas and experimental hybrids were comparable with the oil yields of the oil hybrids. This means that a high biomass yield can be achieved without loss of oil yield.

High ash content decreases the specific methane yield of a substrate. In our primary investigations we generally found a relatively high ash content in the biomass of sunflower. But, as there are differences between genotypes, selection for lower ash content seems possible.

Currently, biogas production from energy crops is mainly based on the anaerobic digestion of maize. Sustainable biogas production must include a whole system of sustainable and environmentally friendly crop rotations. Sunflower has shown to have the potential to be one partner of a biogas crop rotation.

ACKNOWLEDGEMENTS

We thank the NCRPIS, USDA, USA for seeds of the genetic resources and the Federal Ministry of Food, Agriculture, and Consumer Protection of Germany for financial support (Project number FNR22013104).

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