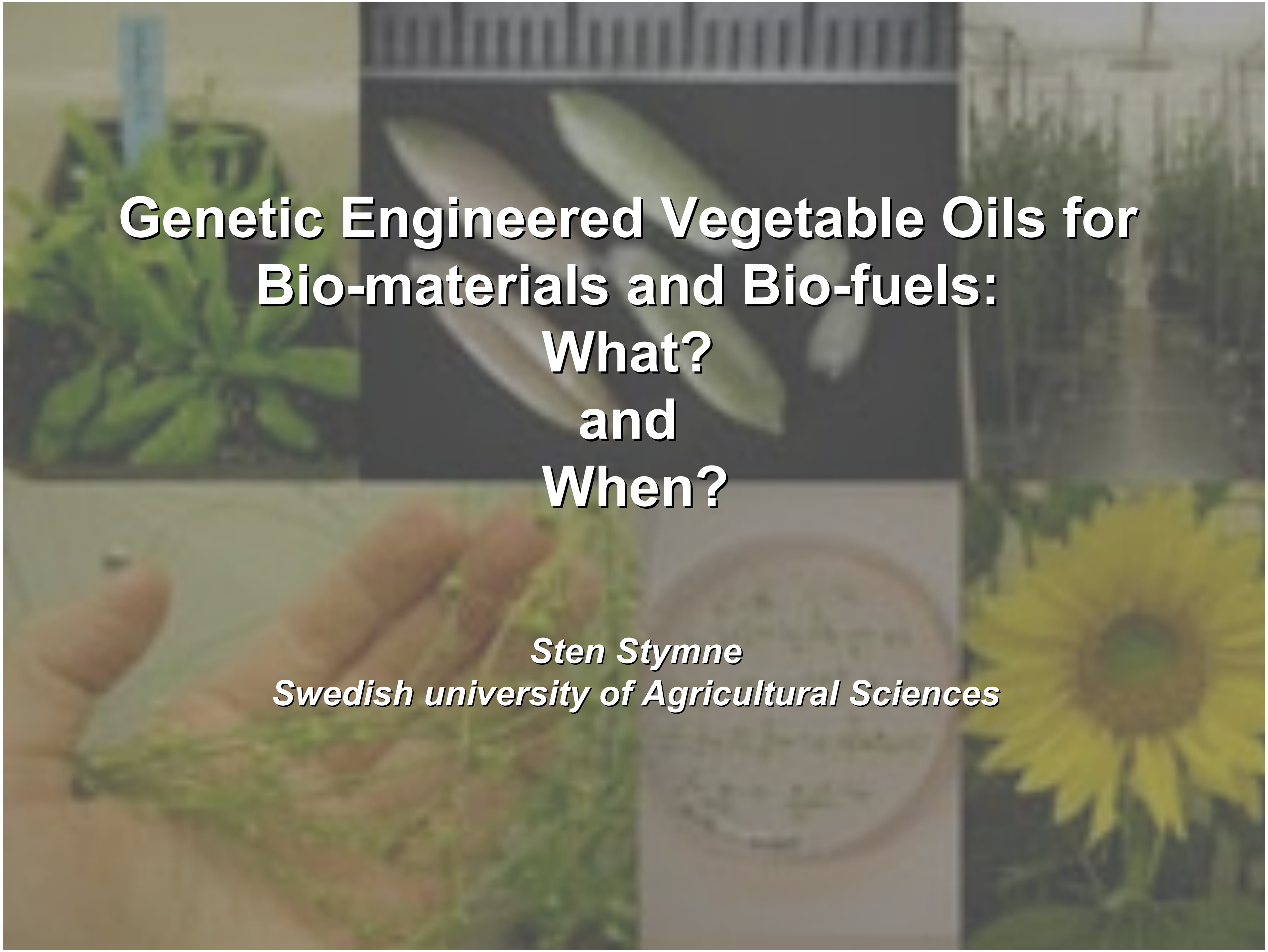


Genetic Engineered Vegetable Oils for Bio-materials and Bio-fuels: What? and When?

Sten Stymne
Swedish university of Agricultural Sciences

Everything you can do with mineral oil, you can also do with plant oil

It is just a matter of costs!!

$17 USD

$88 USD

1997

$75 USD

$78 USD

2007

Oil seeds: The perfect chemical factory!

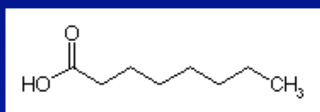
Petrochemical industry cracks carbon chains and use advanced organic chemistry to build desired products with these building blocks. Usually, this require more energy than the product contain

Plants design the complex product direct in the seeds without extra cost and energy, thereby minimizing downstream processing costs..

In many industrial applications, plant oils have successfully competeted with fossil oil despite that their price have been over five times higher.

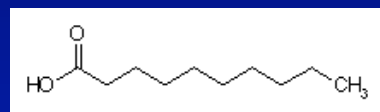
A number of wild plants have very high amount of industrial valuable fatty acids in their seed oils

73% Caprylic acid (8:0)



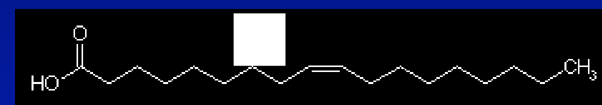
Cuphea painteri,

95% Capric acid (10:0)



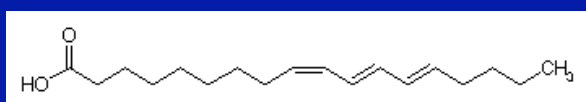
Cuphea koehneana

90% Ricinoleic acid



Castor *(Ricinus communis)*

88% α–Eleostearic acid



Aleurites fordii

78% Sterculic acid

Sterculia foetida

+ several hundreds of other fatty acid structures….

Cuphea species Castor ***Aleurites fordii*** ***Sterculia foetida***

Transferring the biosynthetic machinery for the production of unsusal fatty acids to high yielding oil crops by genetic engineering could yield production at a low price and with stable supply.

Trangenic rape with medium chain thioesterases

(Calgene reports)

	In host seed oil	GM-rape
12:0 -TE from California bay tree	60%	63%

Despite the great potentials, the industrial investments in the development of industrial oil by plant biotechnology have decreased.

This have mainly been due to following factors:

- GM plants for non-food uses are problematic
- IPR spread on many actors
- IPR positions unclear
- Public distrust in GM technology
- Volumes and prices of product not high enough to warrant investments (calculations made on substitution on existing markets and not on novel potential applications)
- Too long time frame before return of investments
- Scientific bottlenecks that cannot be solved without the input of large parts of the Scientific Community

To follow in its wake:

- Public acceptance of G plants for industrial use
- GM crops with other industrial qualities
- GM crops for food

We need an ice-breaker for industrial oil:

- A robust and safe platform crop for industrial products
- Non-toxic product with a substantial market and added value
- Substantial environmental benefits
- Development not driven by multinational companies and profit
- High probability of technical success in relatively short time frame

EU 7th frame program application

ICON

Industrial Crops producing added value Oils for Novel chemicals

Large collaborative 4 yrs project

(6 million € of EU funding, total budget 10.7 miilion €)

Called for negotiations

Third country participants:

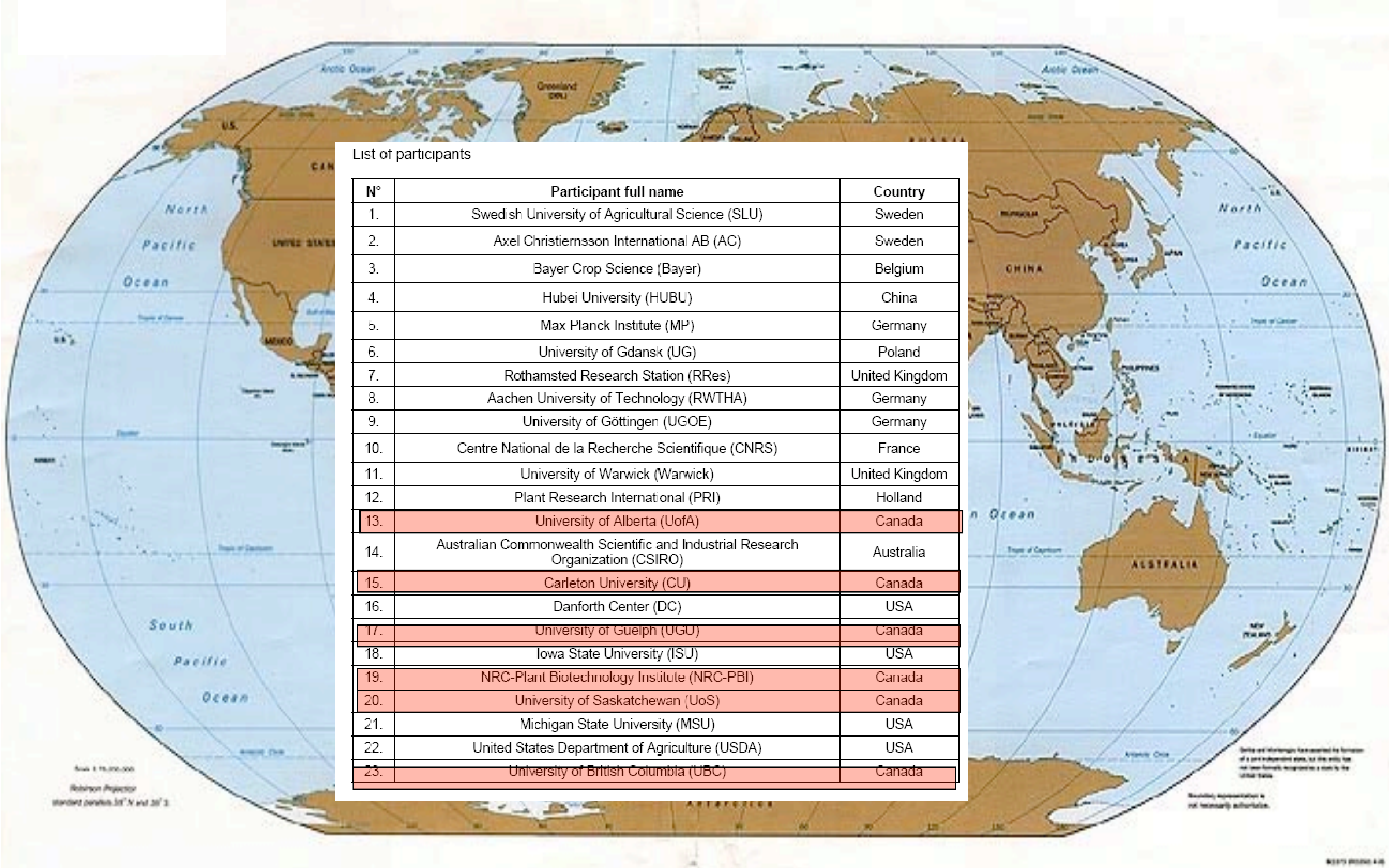
Canada

USA

Australia

China

ICON project; 23 partners



List of participants

N°	Participant full name	Country
1.	Swedish University of Agricultural Science (SLU)	Sweden
2.	Axel Christiernsson International AB (AC)	Sweden
3.	Bayer Crop Science (Bayer)	Belgium
4.	Hubei University (HUBU)	China
5.	Max Planck Institute (MP)	Germany
6.	University of Gdansk (UG)	Poland
7.	Rothamsted Research Station (RRes)	United Kingdom
8.	Aachen University of Technology (RWTHA)	Germany
9.	University of Göttingen (UGOE)	Germany
10.	Centre National de la Recherche Scientifique (CNRS)	France
11.	University of Warwick (Warwick)	United Kingdom
12.	Plant Research International (PRI)	Holland
13.	University of Alberta (UofA)	Canada
14.	Australian Commonwealth Scientific and Industrial Research Organization (CSIRO)	Australia
15.	Carleton University (CU)	Canada
16.	Danforth Center (DC)	USA
17.	University of Guelph (UGU)	Canada
18.	Iowa State University (ISU)	USA
19.	NRC-Plant Biotechnology Institute (NRC-PBI)	Canada
20.	University of Saskatchewan (UoS)	Canada
21.	Michigan State University (MSU)	USA
22.	United States Department of Agriculture (USDA)	USA
23.	University of British Columbia (UBC)	Canada

COIN

ABIP Sister applicationof ICON in Canada

(GOLDEN OPPORTUNITIES: ADDING VALUE TO CANADIAN BIO-INDUSTRIAL SEED OILS)

$5.7 M over 3.5 years for production of liquid wax esters in seeds of *B. carinata*.

WHAT?

Goals of ICON:

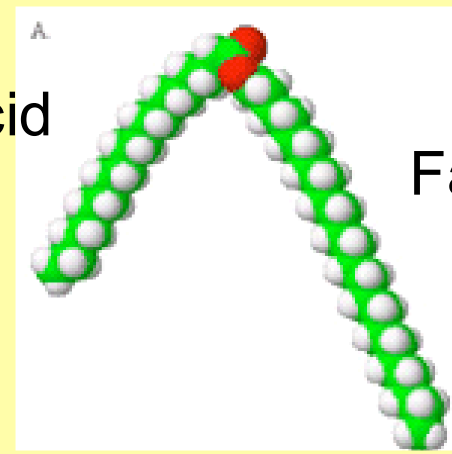
The production of kind
different wax esters
in industrial oil crops
Crambe abbysinica
and
Brassica carinata

Wax esters as those found in the spermaceti oil are excellent lubricants

From the oceans to the fields..

Jojoba *(Simmondsia chinensis)* accumulate wax esters instead of triacylglycerols in its seeds

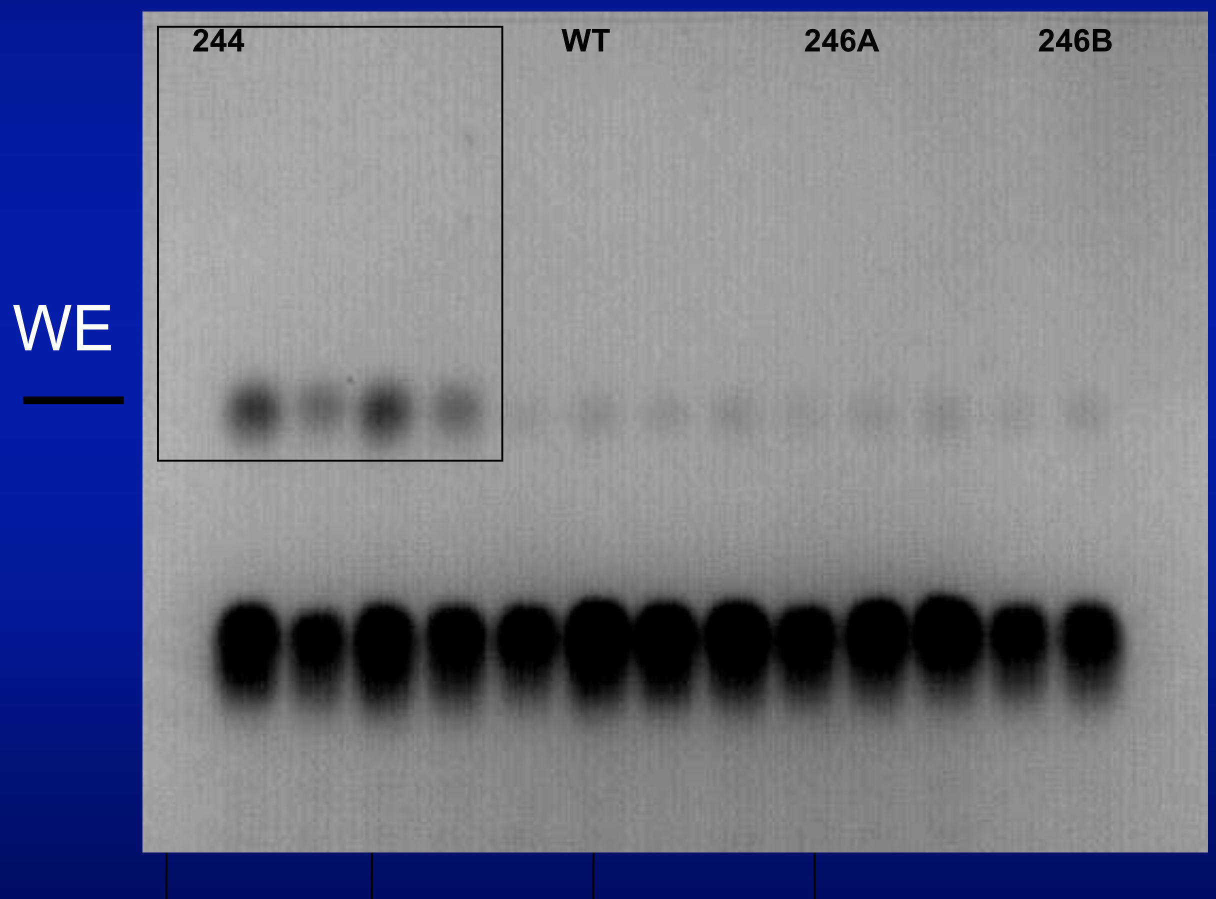
Fatty acid



Fatty alkohol

Wax ester

Lipid analysis of single seeds (T1) from transgenic *Brassica juncea with WS and FAR genes*



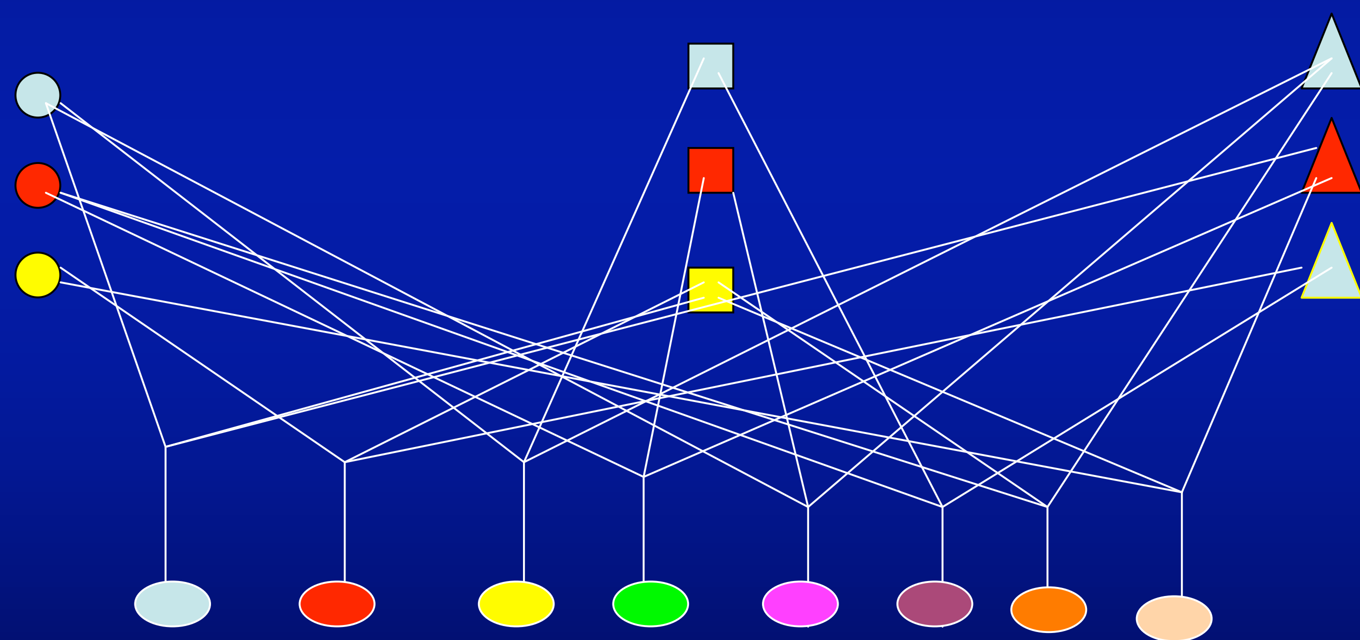
Results from Jaworski, Cahoon et al. Danforth center, US, 2007

By combining various fatty acid modifying, FAR and WS genes, a huge number of wax esters with different compositions can be achieved

Fatty acid modifying genes
e.g. medium chain thioesterses
RNAi FAD2, hydroxylases

Wax synthase genes with different specificities

FAR genes with different specificities



Wax esters of different compositions

Crambe abyssinica might fullfil the criteria for a robust and safe platform oil crop for industrial products

- Not a food crop (60% erucic acid in its oil)
- Not outcrossing with other oil crops & few wild relatives
- Reasonable oil yield per hectare (same as spring rape)
- Some experience as an agricultural crop
- Excellent fatty acid composition of oil for the conversion into wax esters (due to the 60% erucic acid)

Crambe abyssinica might fullfil the criteria for a robust and safe platform oil crop for industrial products

But:

No efficient transformation protocol is available

Brassica carinata as an alternative industrial oil crop

- Efficient transformation protocol available (at PBI)
- Drought resistant

Brassica carinata as an alternative industrial oil crop

But:

- Some outcrossing with other *Brassica* species
- Limited seed yield

When?

2011 Field trials with GM- crambe or *B. carinata* with at least 20% very long chain wax esters and lubrication tests

When?

Beyond ICON and COIN………

My guess:

2015
Field trials with *Crambe* and *B. carinata*
with 60% wax esters

Field trials with other types of wax esters at a level of 20%.

Commercial production:

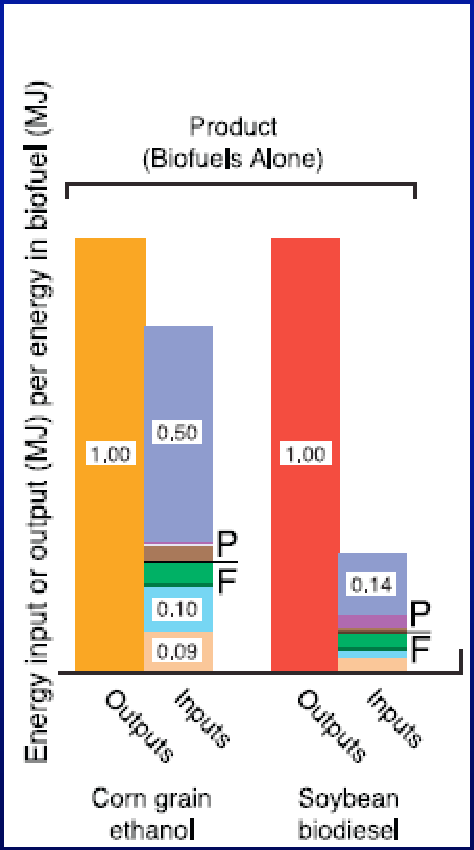
When?

I do not dare to speculate…

What can plant biotechnology do in the biofuel area?

Major losses in energy occurs in the conversion of sugars into biofuels (no matter if it comes from starch, cellulose or sucrose)

Converting plant oil into biodiesel involves only a small energy loss



PNAS | July 25, 2006 | vol. 103 | no. 30 | 11207

Plants direct sugars to biofuel (*i.e.* oil) much more energy efficient than any *ex-planta* process.

Redirecting the reduced carbon in plants from sugar based polymers to oil would dramatically increase the economy of biofuels.

Converting high starch crops into oil crops

-

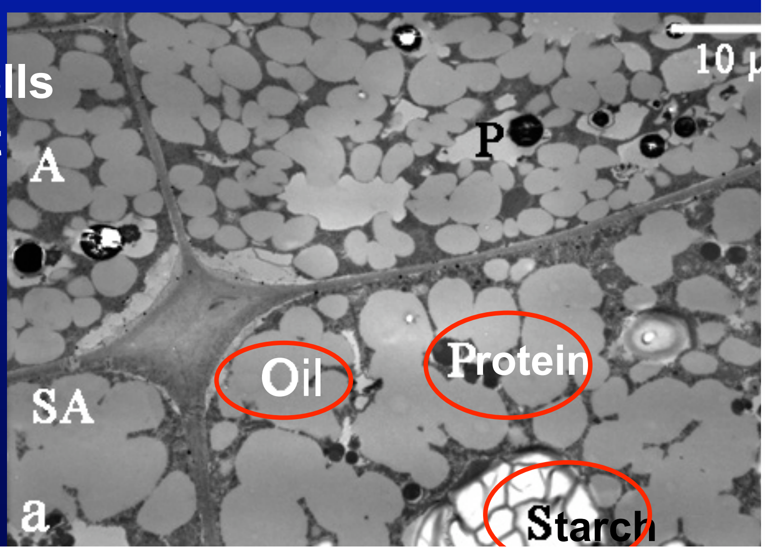
Is this possible?

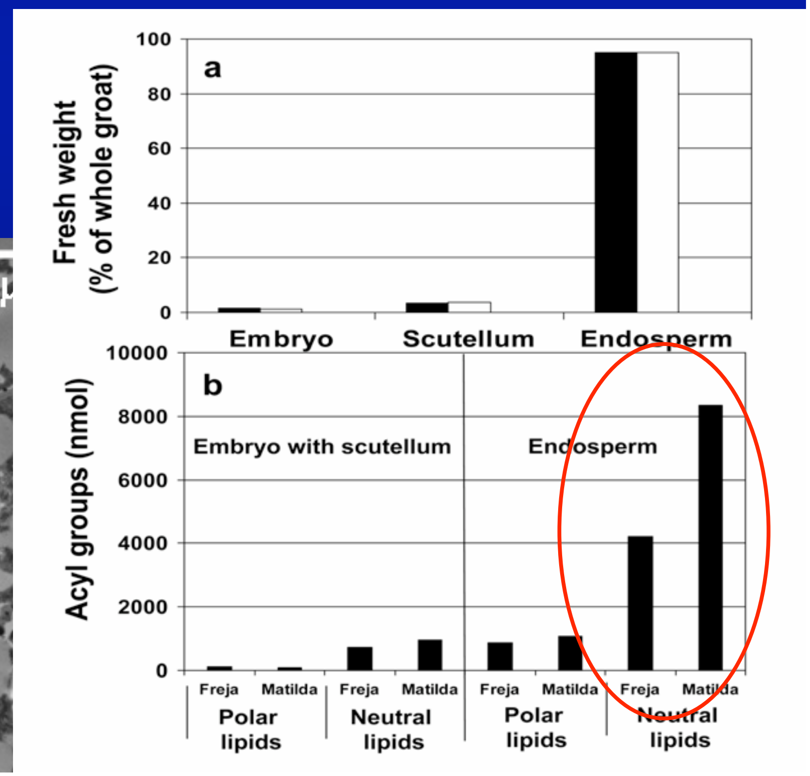
Oat as a model plant for converting cereals into oil crops

Oat is unique among cereals having the major part of the oil in the endosperm.

Oil content of oat grain can vary from 2-10% and The differences is due to the oil content of the endosperm

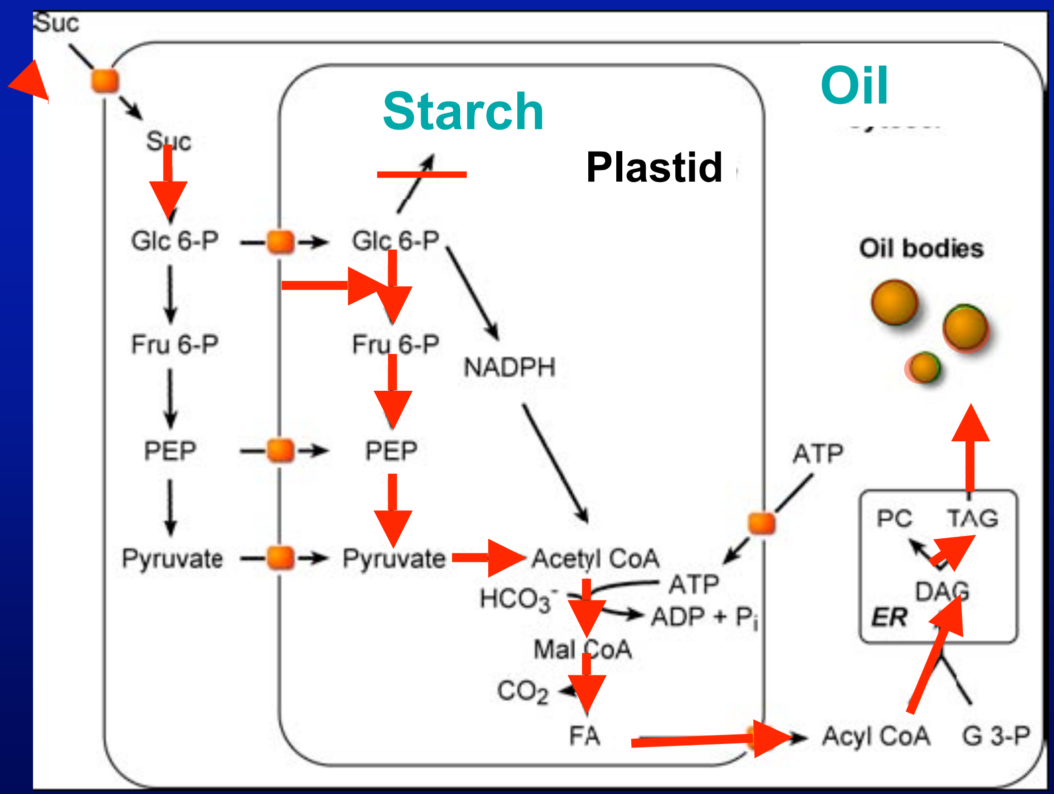
Endosperm cells of high-oil oat





Identifying the genetic switch between oil and starch synthesis in oat endosperm cells open the possibility to create high oil cereals.

A Chevron sponsored collaborative project between UC-Davis (Katie Dehesh) and Swedish University of Agricultural Sceinces (Sten Stymne)



Nut sedge (Cyperus esculentus) tubers as a model for oil accumulation in roots and tubers

(e.g. sugar beets and kassava)

Composition:

26% Oil

21% Sugars

12% Fiber

6% Proteins

31% Starch

The photosynthetic capacity to produce reduced carbon is usually much higher than what the sink accumulate.

Plant Biotechnology Journal (2007) **5**, pp. 109–117

doi: 10.1111/j.1467-7652.2006.00224.x

Doubled sugar content in sugarcane plants modified to produce a sucrose isomer

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Received 1 June 2006;
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Summary

Sucrose is the feedstock for more than half of the world's fuel ethanol production and a major human food. It is harvested primarily from sugarcane and beet. Despite attempts through conventional and molecular breeding, the stored sugar concentration in elite sugarcane cultivars has not been increased for several decades. Recently, genes have

Thank you!