Yield10 Bioscience Platform: Technologies for Increasing Seed Yield and Oil Content in Oilseeds

Meghna Malik, PhD, Team Leader
Metabolix Oilseeds, the Canadian subsidiary of Yield10 Bioscience

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***Under the Private Securities Litigation Reform Act of 1995**

Company Overview

Yield10 Bioscience (NasdaqCM:YTEN) is developing technologies to enhance global food security

- Headquartered in Woburn, MA USA

Metabolix Oilseeds

(Canadian subsidiary of Yield10 located in Saskatoon, Canada)

Yield10 brings extensive expertise and a track record in optimizing the flow of carbon in living systems to the agriculture sector to increase yield in key row crops

- Yield10 is targeting step-change (10-20%) increases in seed yield

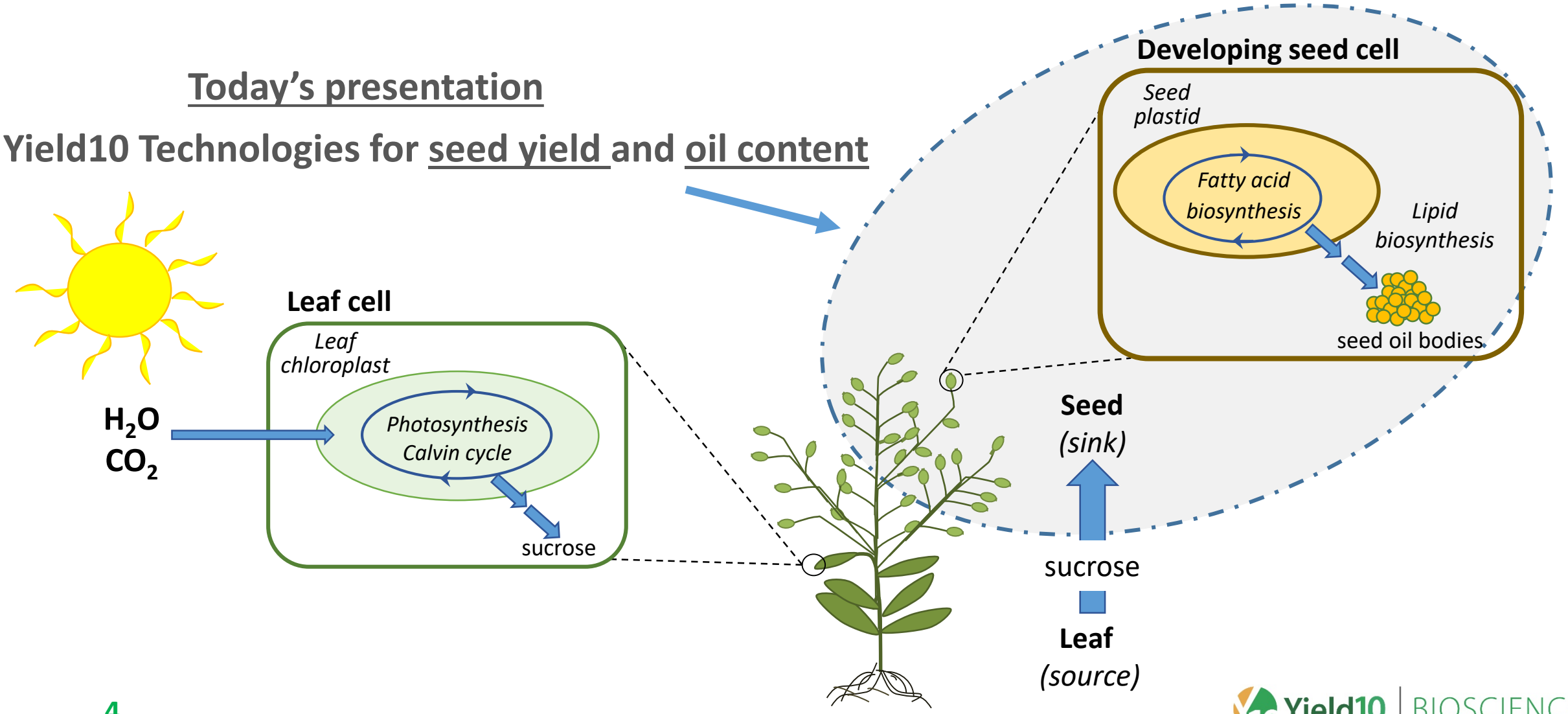
Yield10 focuses on its core strengths of advanced bioscience and innovation

Specialty and Niche Crops including Nutritional Oils

Specialty oil REVENUE = Oil/acre = seed yield/acre x oil content

Today's presentation

Yield10 Technologies for seed yield and oil content



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Yield10: Rich Pipeline of Trait Genes in Development

SUMMARY OF TRAITS IN DEVELOPMENT

Business Area	Current Status
Seed Yield Traits-Regulated	
C3003	Camelina, canola, soybean field trials
Seed Yield Traits-Non-Regulated	
C3004	Camelina testing underway – field trials 2019
Oil Enhancing Traits-Non-Regulated	
C3007	Camelina, canola editing underway
C3008a	Camelina non-regulated[1] status achieved; at field testing stage
C3008a, C3008b and C3009 combinations	Camelina, editing completed and submission made to USDA-APHIS
C3010	Completed in-license
Additional oil traits and combinations	Research in progress
Yield Trait Improvement Discovery Platform	
C4001	Wheat, rice underway, and corn transformation next step
C4002	Corn transformation next step
C4003	Wheat, rice underway and corn transformation next step
C4004	Editing in rice and wheat underway

Metabolic engineering traits C3003/C3004: enhance carbon flux and seed yield

Metabolic engineering traits C3007,8, 9 and 10 –increased oil content –niche oil market opportunities

Key element of the GRAIN discovery platform, Transcription factors – seed and biomass yield, stress tolerance

Many opportunities exist for licensing and/or partnerships

[1] not regulated by USDA-APHIS, could be regulated by EPA and/or FDA and/or regulated in the EU, Canada

Novel Yield Trait Gene: C3003

C3003 is a component of an algal system for increasing photosynthesis in low CO_2 conditions

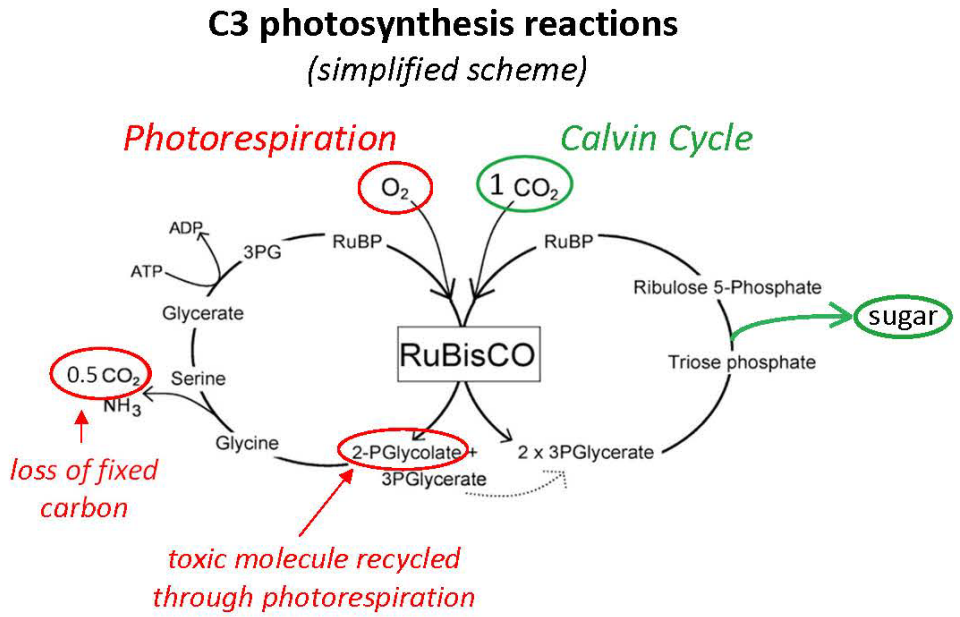
- A mitochondrial metabolite transporter licensed from University of Massachusetts
- C3003 is **believed to impact photorespiration**
- Has shown double digit increases in seed yield in Camelina and canola
- Potential to be useful in a wide range of C3 crops: Camelina, canola, soybean, wheat, rice and others

Development program for C3003

- Evaluate different constructs to optimize yield impact
- Demonstrate Camelina results translate into canola and soybean
- Execute 2018 Field Tests in oilseed crops to optimize constructs

Scientific progress provides new insights on mechanism

- Expression of C3003 in Camelina induces the expression of the novel gene C3004



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2018 Field Tests Underway for C3003 Traits

Metabolix Oilseeds

Conducting Field Tests of C3003 in Camelina and canola

Bulking-up soybean seed

Generate technical data and determine the best way to deploy C3003 in canola and soybean

- Test C3003 Gen 2.0 and Gen 2.1 in Camelina
- Test C3003 Gen 1.0 and Gen 2.0 in canola
- Grow C3003 Gen 1.0 and Gen 2.0 soybean to generate field grown seed for 2019
- Multiple sites in Canada
- Data expected beginning in fourth quarter 2018

Gen 1, expressed throughout plant

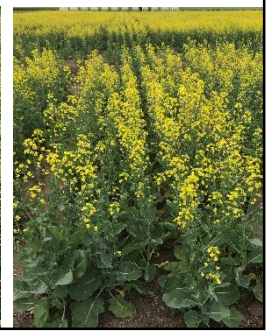
Gen 2, seed specific

2018 C3003 Field Tests

Drone View

Camelina

Canola



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Photorespiration: a Major Yield Drag in C3 Crops

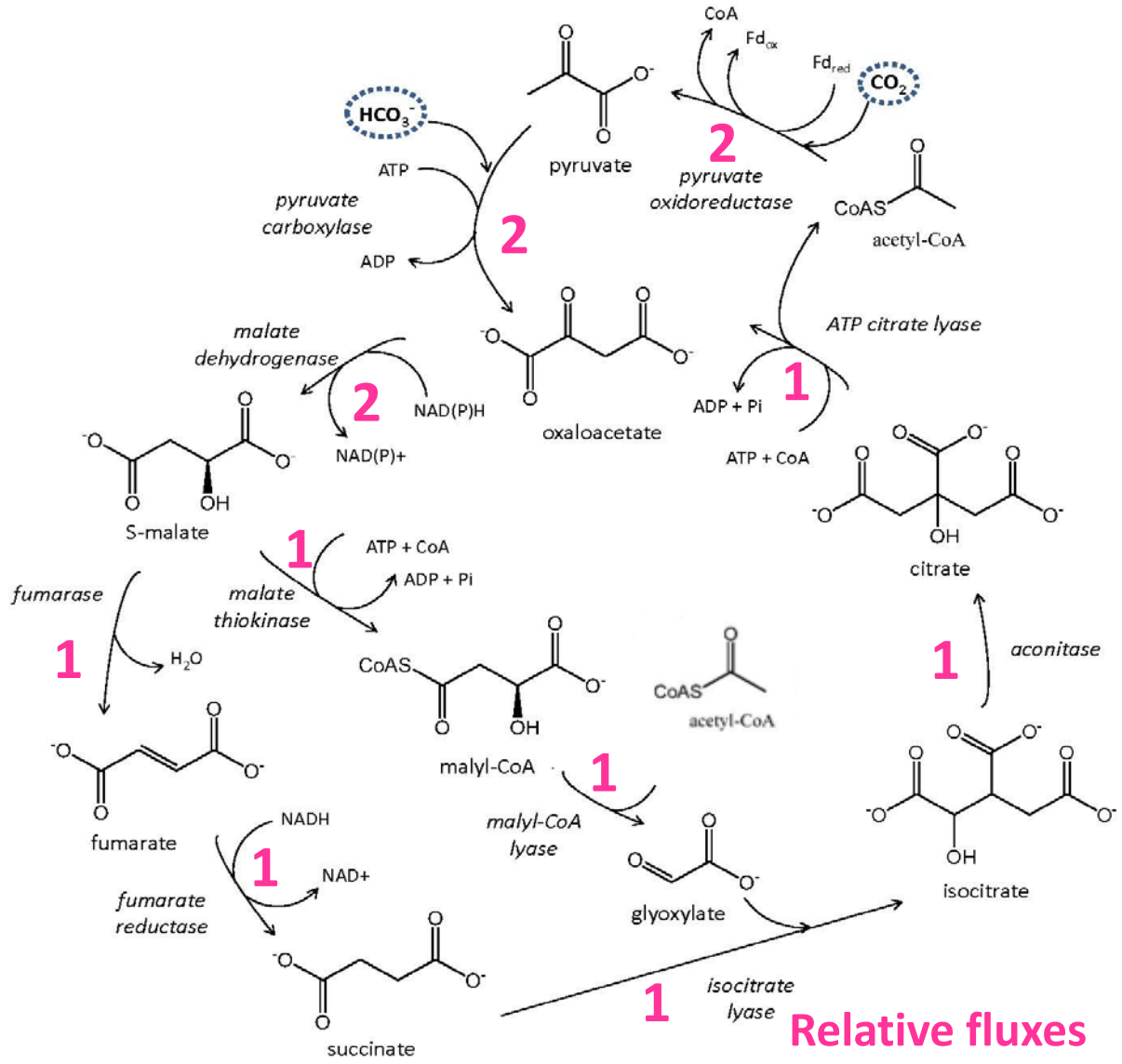
C3003 is believed to impact photorespiration

A 5% reduction of photorespiration in soybean and wheat would add ~$500 million/year of economic value in the US
(Walker et al., 2016, Ann. Rev. Plant Biol. 67:17.1 – 17.23)

What other metabolic approaches can be used to reduce photorespiration ?

The Reverse Glyoxylate Shunt (rGS)

- **What if we could use a novel microbial reverse glyoxylate shunt (rGS) pathway to eliminate the impact of photorespiration altogether ?**
- **Potential NET Impact: 2 CO_2 + 2 HCO_3^- → OAA**
- **Flux modeling:** predicts a **112% increase in seed yield** with new pathway under photorespiratory conditions
- **2 vectors** were constructed to express **12 transgenes** encoding **10 enzyme activities** from a seed specific promoter and transformed into Camelina



Malik, M.R., Tang, J., Sharma, N. et al. *Plant Cell Rep.* (2018). https://doi.org/10.1007/s00299-018-2308-3

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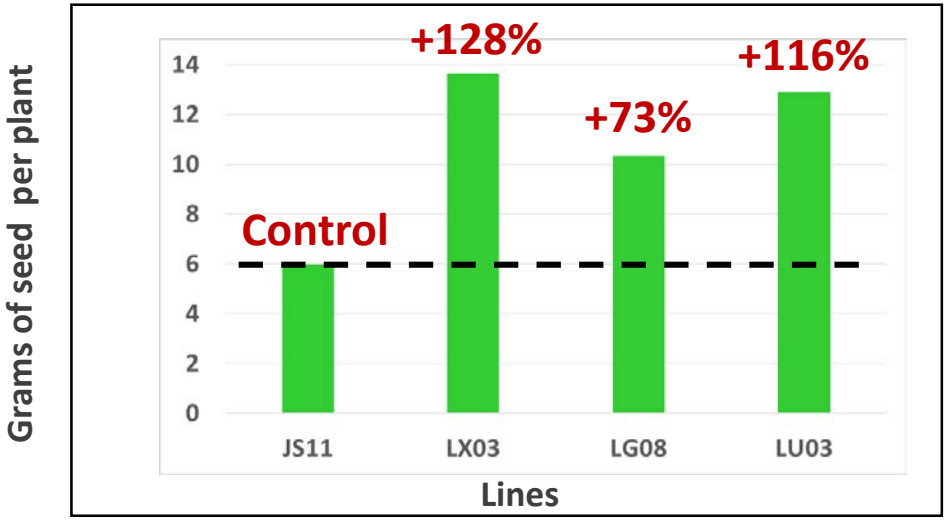
Yield10 rGS data Suggests Potential to Double Seed Yield

New pathway engineered into Camelina to increase seed yield

- Metabolix Oilseeds experimental results (12 transgenes) shows seed yield increase of up to **128%**
- Experimental multigene system too complicated for regulatory approval and commercialization
- What's the maximum yield with the minimum number of gene changes?



Camelina greenhouse study: Seed yield in best plants

Malik, M.R., Tang, J., Sharma, N. et al. *Plant Cell Rep.* (2018). https://doi.org/10.1007/s00299-018-2308-3

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Update on C3004 Trait in Camelina

Generated Preliminary Greenhouse Results for C3004 in Camelina; Field tests Planned for 2019

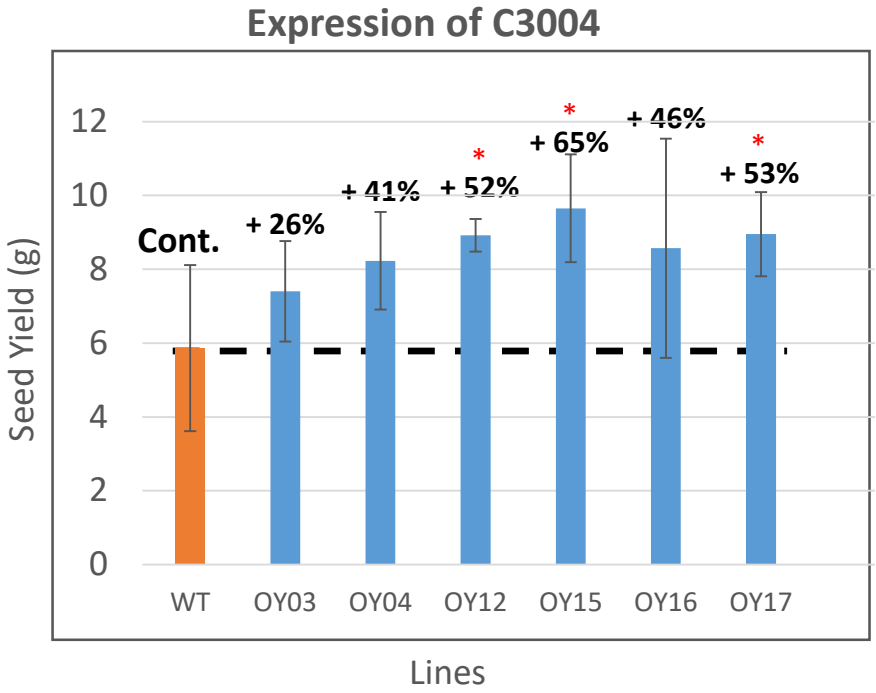
Background on the C3004 Yield Trait

- C3004 has altered expression in Gen 1 C3003 Camelina plants
- C3004 may be linked to transport of fixed carbon to seed?

Key Questions

- Is C3004 responsible for the smaller seed size in Gen1 C3003 in Camelina, canola and soy?
- Is C3004 a good target for genome editing?
- What is the right combination of C3004 with C3003 to maximize the increase in seed yield?

Expression of C3004 in Camelina Increases Seed Yield



*Student's t-test, *p<0.05; Data average of 3 to 4 plants per line*

Control (WT) Line OY12 (C3004)

- Up to 65% increase in seed yield observed in C3004 plants compared to control
- Field testing planned for 2019, accelerate C3004 trait into soybean and canola
- Develop data for C3004 + C3003 combinations
- Develop the best strategy to create non-regulated versions of C3004 for key crops

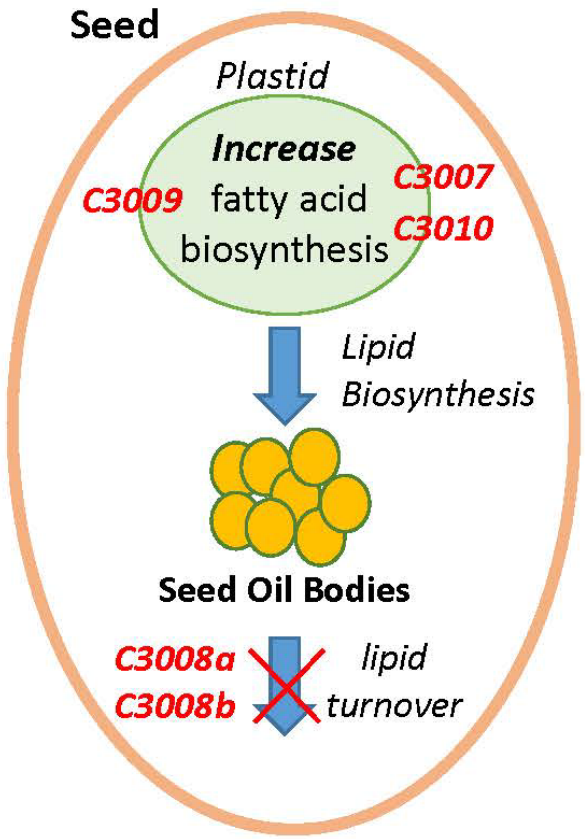
Genome Editing Targets for Increasing Oil Content

For niche oils: cost of goods is driven by harvested oil/acre (= seed yield/acre x seed oil content)

Objective: Develop the best combination of gene edits to maximize oil/acre

C3008a

- Successful editing of all three copies of C3008a in Camelina
  - Camelina is an allohexaploid; each gene expected to be present in 3 copies
  - Received confirmation in 2017 that line is not regulated by USDA-APHIS
  - US field tests in progress, data in Q4



C3008a, C3008b, C3009

- Completed editing of three distinct genes of Camelina designed to increase oil
  - Simultaneous editing of 9 genes (3 target genes present in 3 copies each)
  - Submitted “Am I regulated?” letter to USDA-APHIS in second quarter

C3007 (BADC) and C3010

- Completed exclusive license to IP from University of Missouri (C3007 and C3010)
  - C3007 is a novel negative regulator of ACCase a key enzyme in fatty acid biosynthesis
  - Metabolix Oilseeds is currently editing the C3007 gene in Camelina and canola

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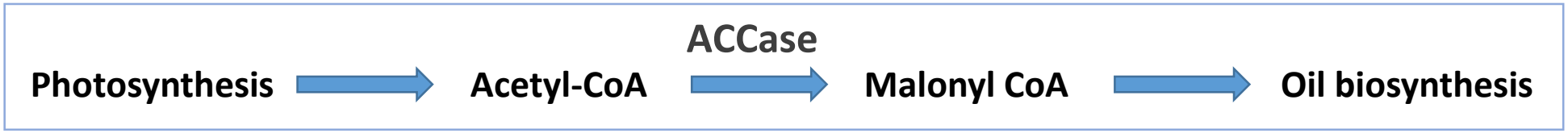
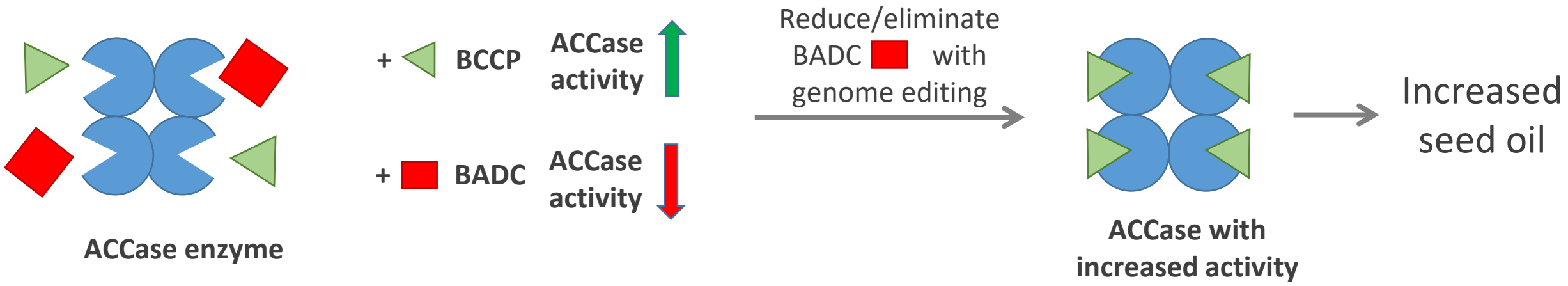
C3007 Trait: A Negative Regulator of a Key Enzyme in Oil Biosynthesis

- Acetyl-CoA carboxylase (ACCase) - a key enzyme in oil biosynthesis with a complex, multi-subunit enzyme structure
- BADC (C3007), a key negative regulator of ACCase *(Salie, M. et al., 2016, Plant Cell)*
- Use genome editing to reduce/eliminate availability of BADC (*red squares*) to increase the activity of the key ACCase enzyme to increase carbon for fatty acid biosynthetic pathway





BADC = biotin/lipoyl attachment domain containing proteins
BCCP = biotin carboxyl carrier protein

Summary

- Yield10 and Metabolix Oilseeds are progressing traits to increase seed yield and oil content in oilseed crops
  - Metabolic modeling and research results suggests potential for achieving significant increases in seed yield
  - Field work in progress with C3003 in Camelina, canola and soybean
  - Recent C3004 seed yield results driving accelerated path to field testing in Camelina in 2019 growing season and translation into canola and soybean
  - Using CRISPR-Cas9 genome-editing approach with oil boosting traits for use in canola and niche oils
- Employing both GMO and genome-editing approaches to achieve goals
- Many opportunities exist for licensing, partnerships, and/or collaborations

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