Strain selection of seaweeds for improved yields in aquaculture

Dr. Antoine Fort,
Plant Systems Biology lab, NUI Galway

Co-founder, Pristine Coasts Ltd
pristinecoasts.com

Pristine Coasts
Seaweed Products Diagnostics

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SWGROW

antoine.fort@pristinecoasts.com

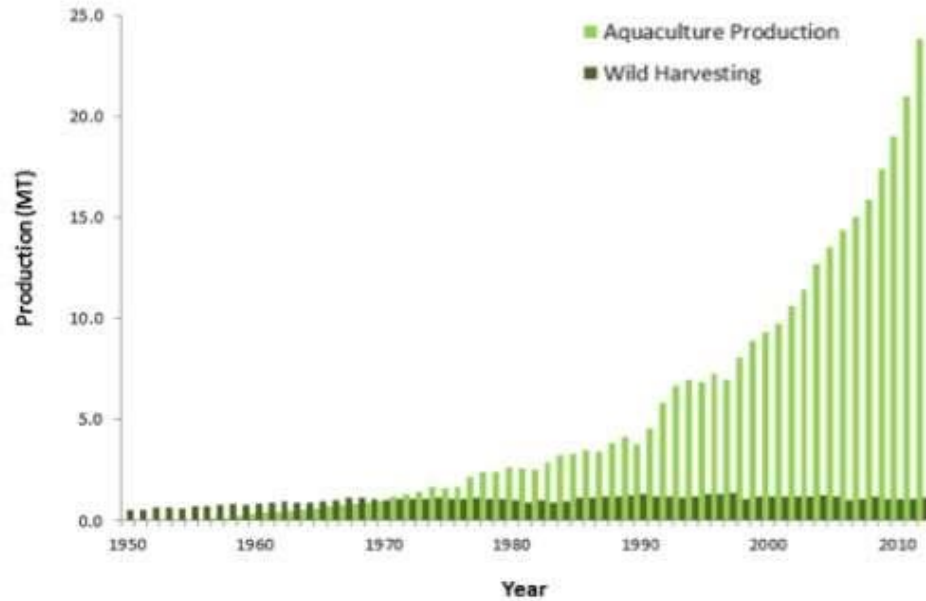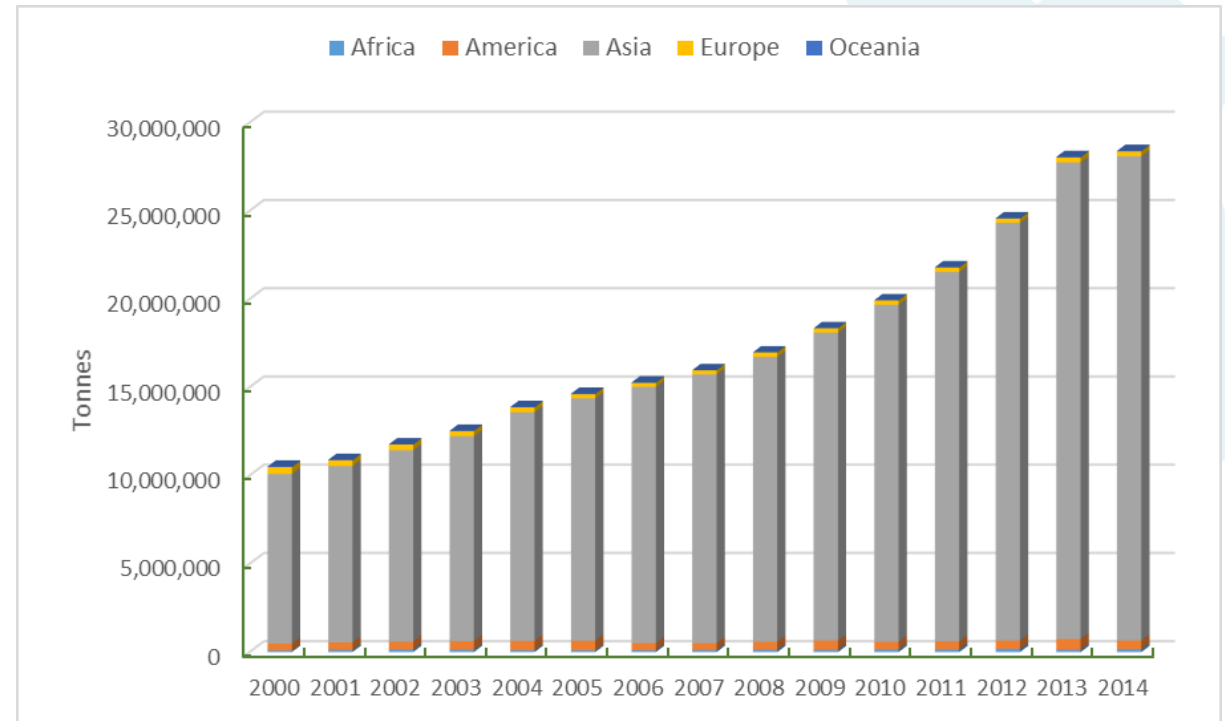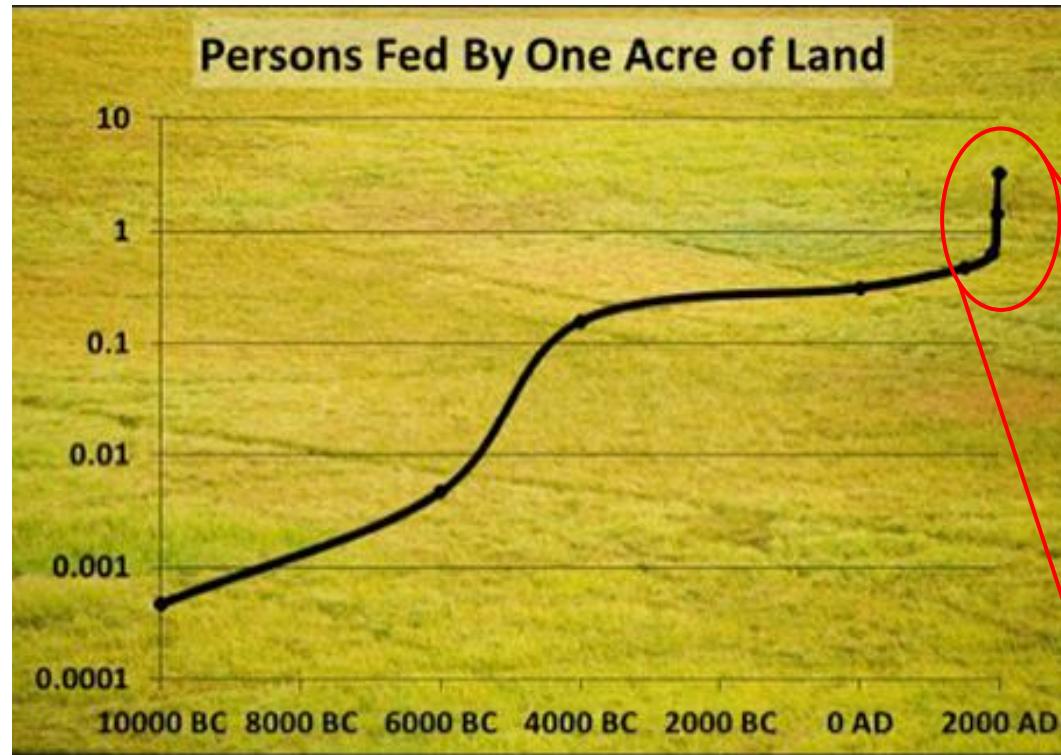# The golden age of seaweeds!

Figure 1. Global seaweed aquaculture production (1950-2014). FAO (2015)

The seaweed industry is expanding, mostly in Asia
 > Can we help develop the seaweed industry in Ireland?

How do we increase aquaculture yields?

Persons Fed By One Acre of Land

Beginning of agriculture → Present

X1000 of food production / acre in 10,000 years

The large increase in food production over the last 10,000 years is due to the emergence of agriculture

Two aspects of this:

- Creation of **better farming techniques**

- Selection and amplification of elite varieties / strains of crops and livestock
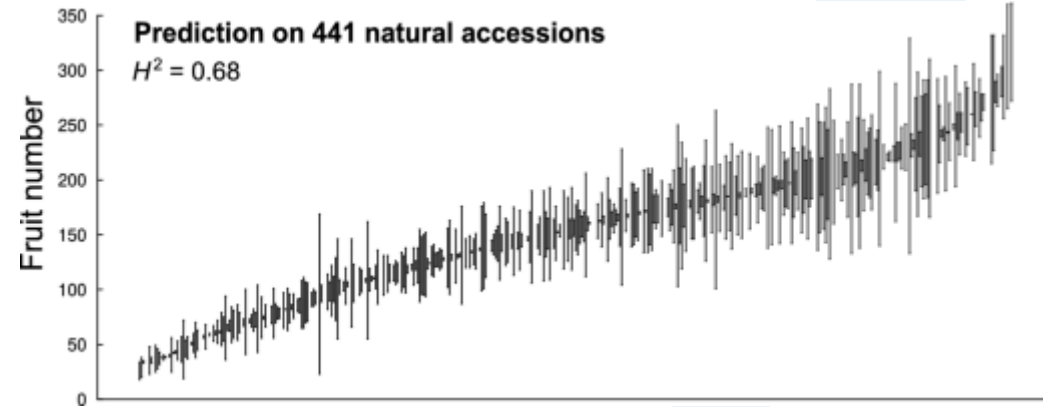 **-> Domestication/ Artificial selection**

Growth/yield is influenced by the genetic makeup of the individual

Prediction on 441 natural accessions
$H^2 = 0.68$

Each individual is unique, as it contains its own **"blend" of genetic information**

This unique blend can make an individual **better for growth and yield**
> Selecting individuals with the best performance can **drastically increase yields**

The expanding seaweed industry doesn't rely on selected strains

While the industry is booming, the strains used in the various farming systems in Europe have **not been selected for high growth**

The growth of seaweeds itself is a **poorly understood phenomenon**

- **Is there genetic variation affecting growth?**

- **Can strains be selected for higher yield?**

> Ensuring reliable and high yields will require the selection of "elite" strains/varieties

Strain improvement programme for *Ulva*

How?

Fast and efficient strain selection method
> To screen hundreds of strains and assess various growth/yields traits

Safeguard the best performing strains, and reuse year-on-year

Strain collection

250+ individual laminar *Ulva* specimens from Ireland, the Netherlands, Scotland, France, Spain and Portugal

A

B
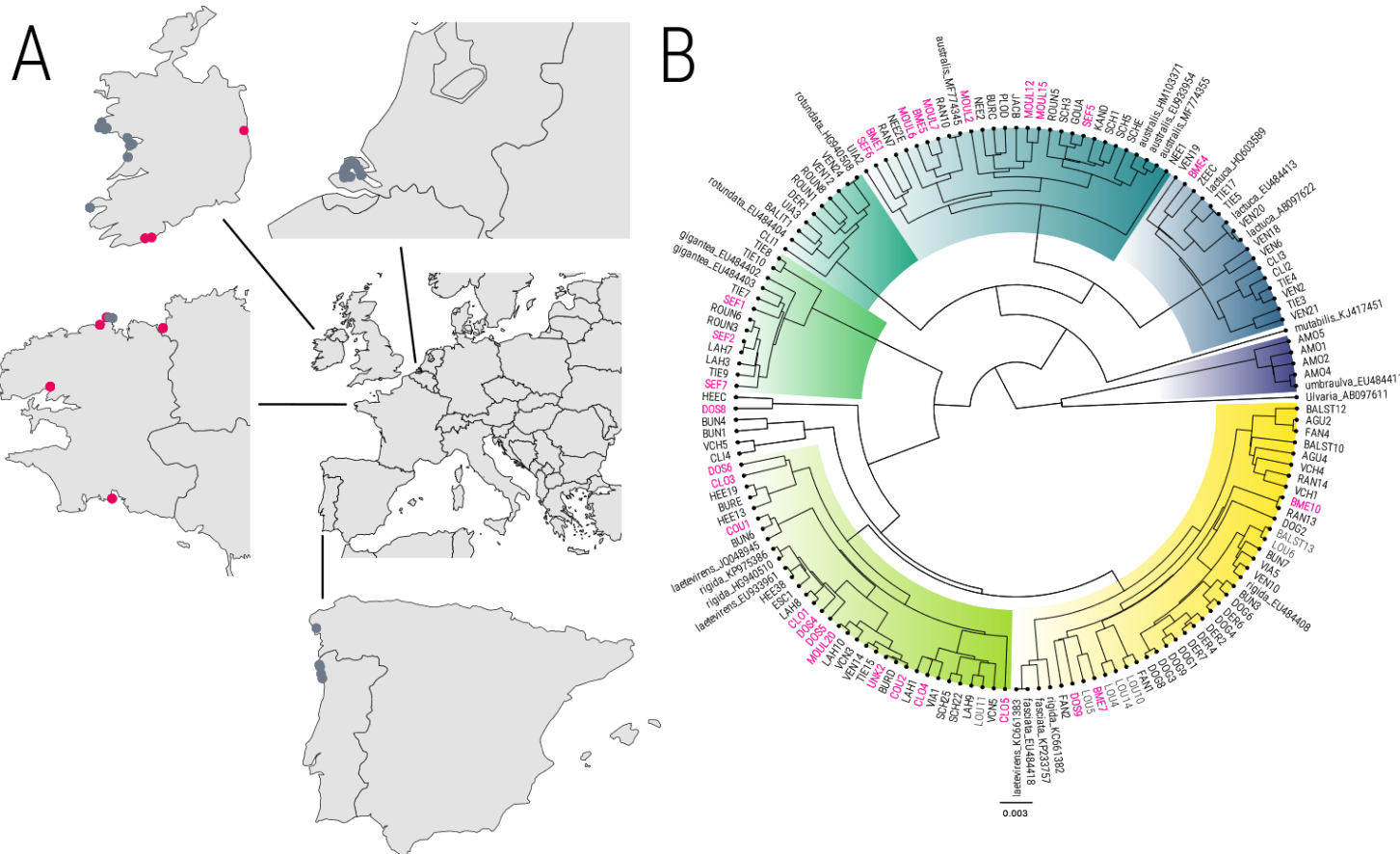
7 *Ulva* species represented

At face value, all samples have similar morphology, and no indication as to their growth/biochemical content

# Lab/hatchery-based phenotyping system

Currently:
- 9 remote-controlled Raspberry pi computers
- Image capture every 2 minutes during daylight
- Discs of *Ulva* thallus
- Artificial seawater + nutrients
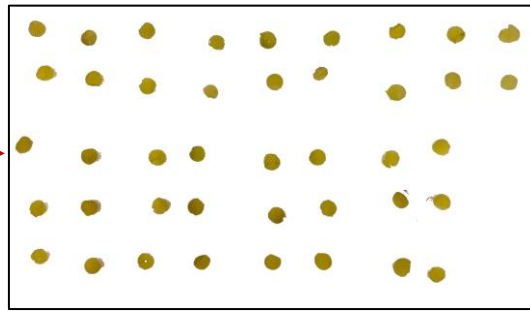- Can change environmental conditions

Network Raspberry pi Pi Camera
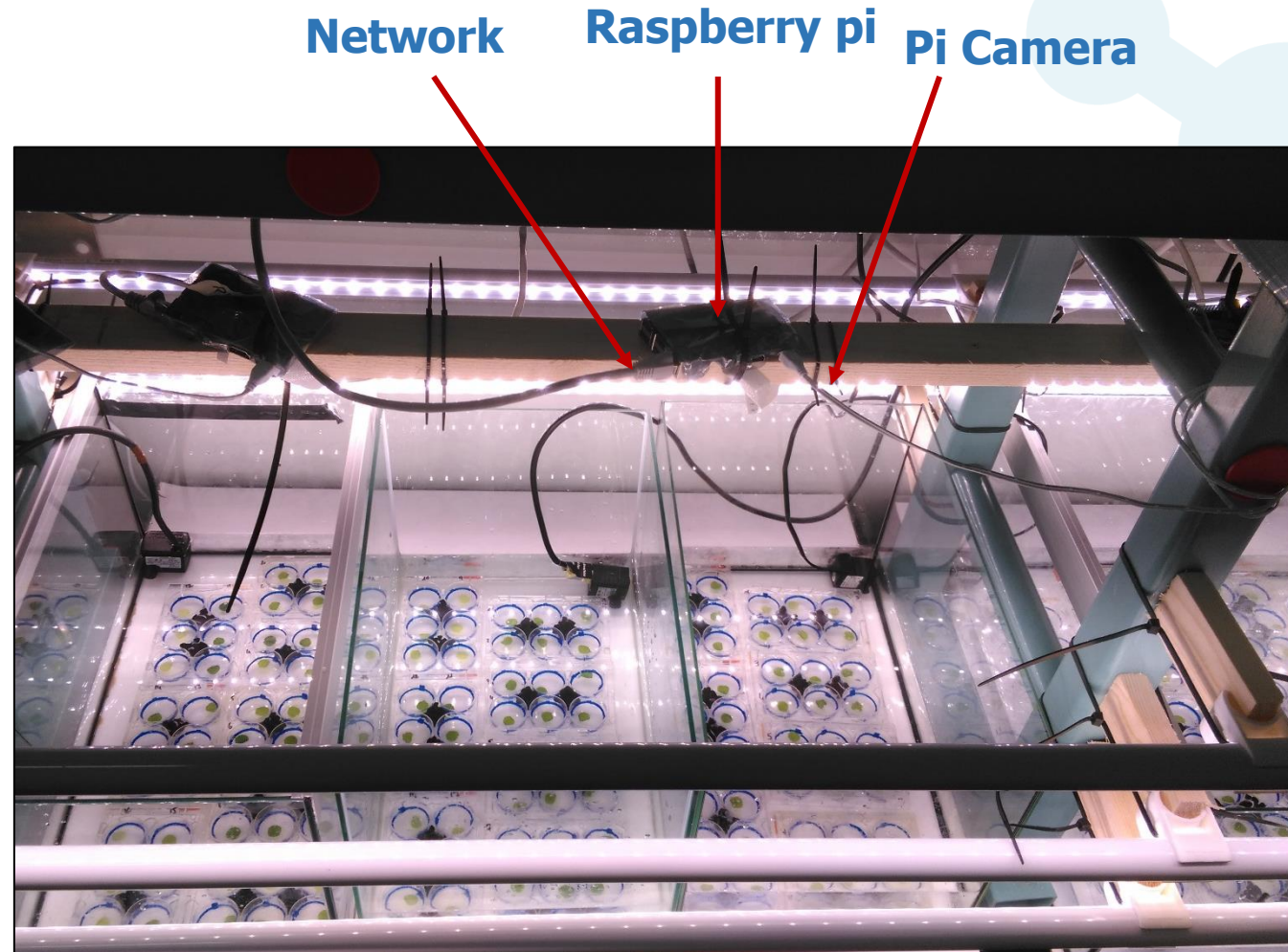
Fort et al, Plant physiology 2019

Image processing

Raw image (every 2') Segmentation Merging every 10' 10' merged image
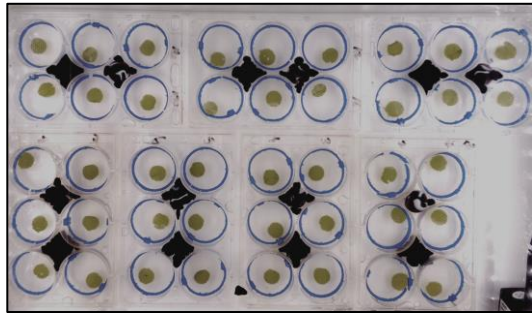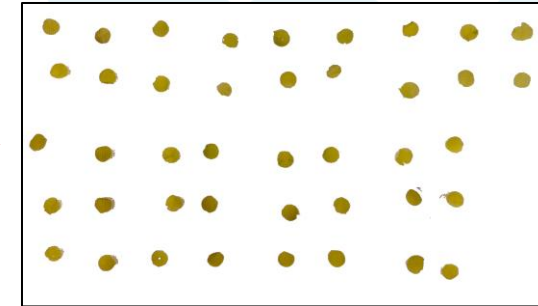
PlantCV
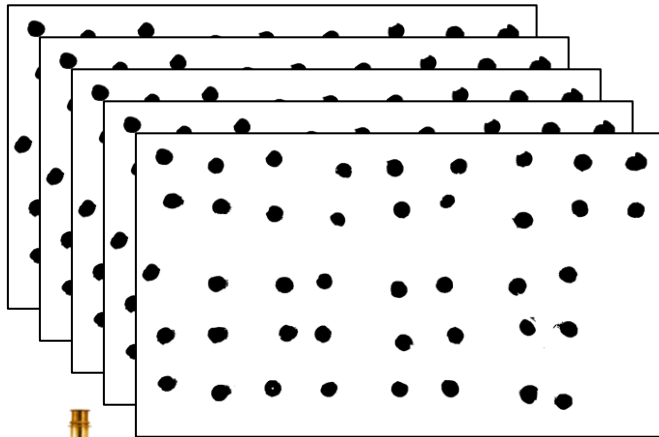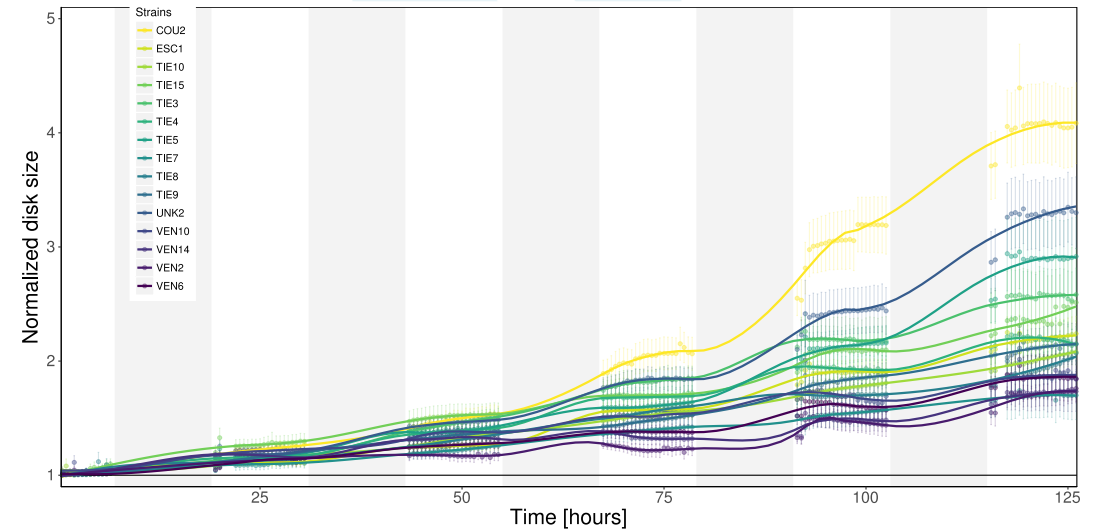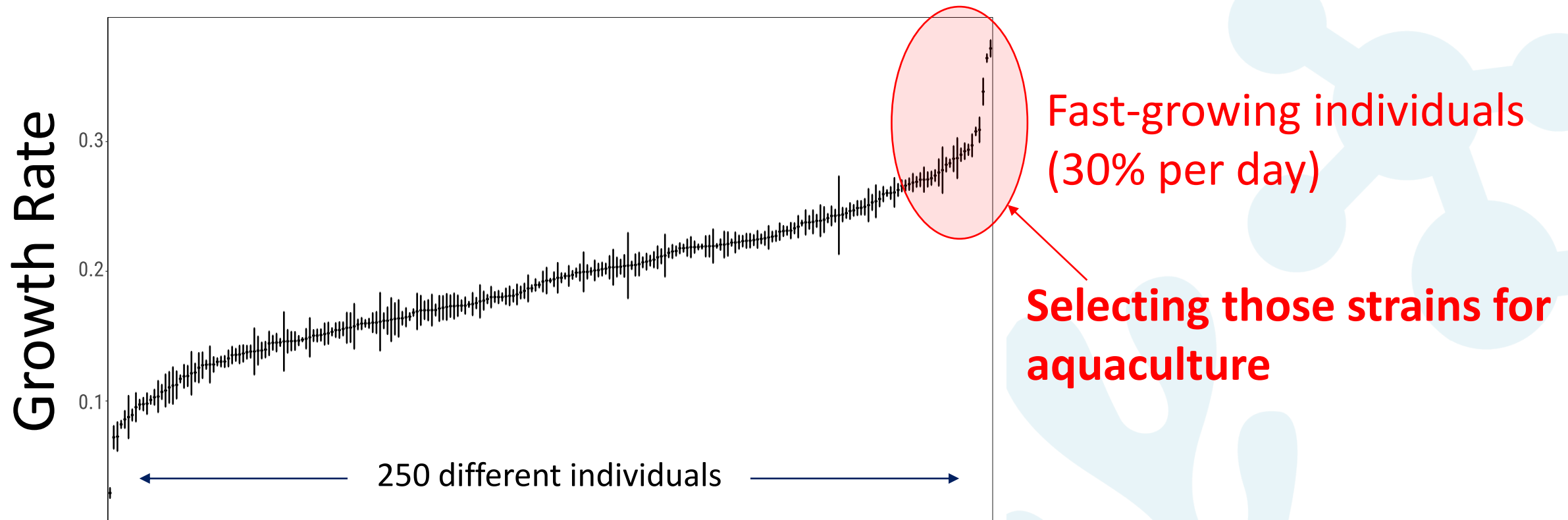Plant phenotyping using computer vision
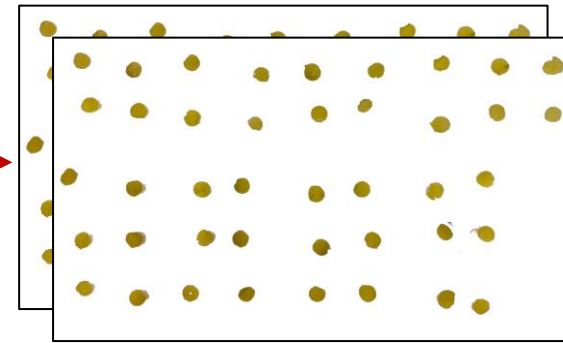
ImageJ time-lapse Stacks
(7 days-worth)

Data analysis

Fort et al, Plant physiology 2019

Different individuals show drastically different growth

Fast-growing individuals (30% per day)

Selecting those strains for aquaculture

Growth Rate

250 different individuals

When grown in the same conditions, *Ulva* individuals show ~5 fold-differences in growth rate

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Different individuals show drastically different protein content

High protein individuals (20%+ of biomass)

Selecting those strains for aquaculture

250 different individuals
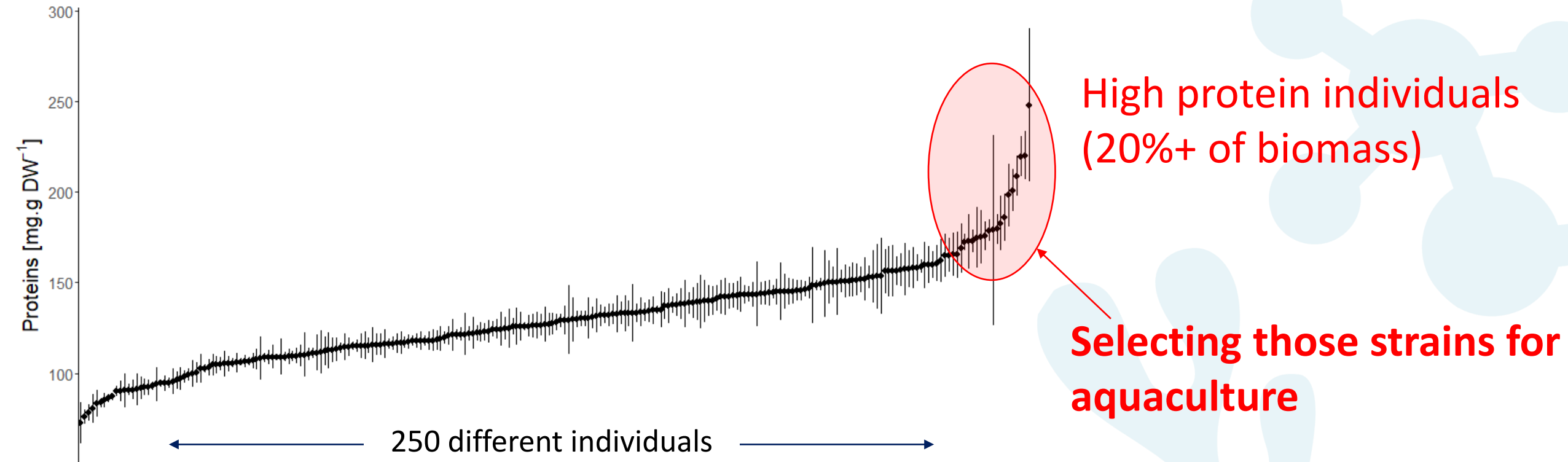
When grown in the same conditions, *Ulva* individuals show ~4 fold-differences in protein content. **Similar range with carbohydrates, pigments, etc.**

Some areas may contain more promising individuals
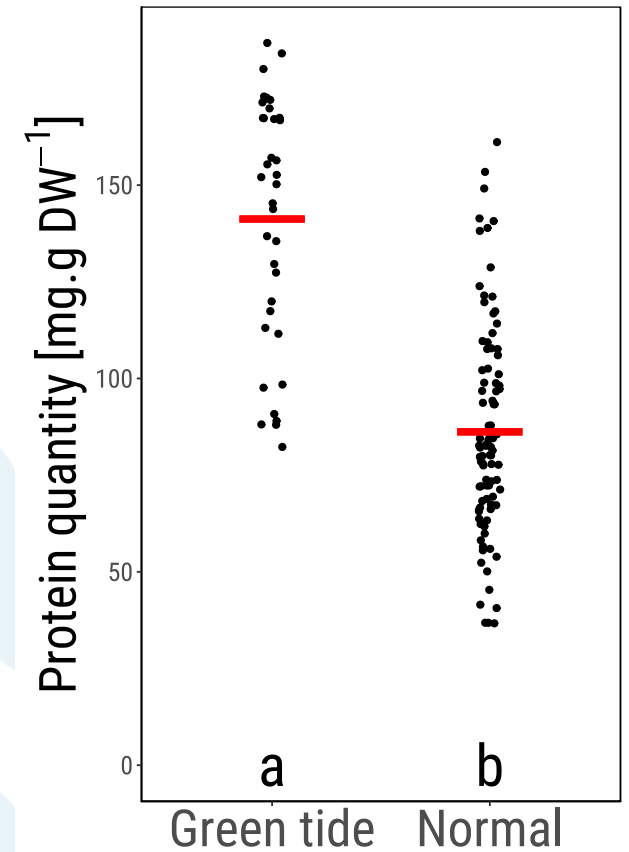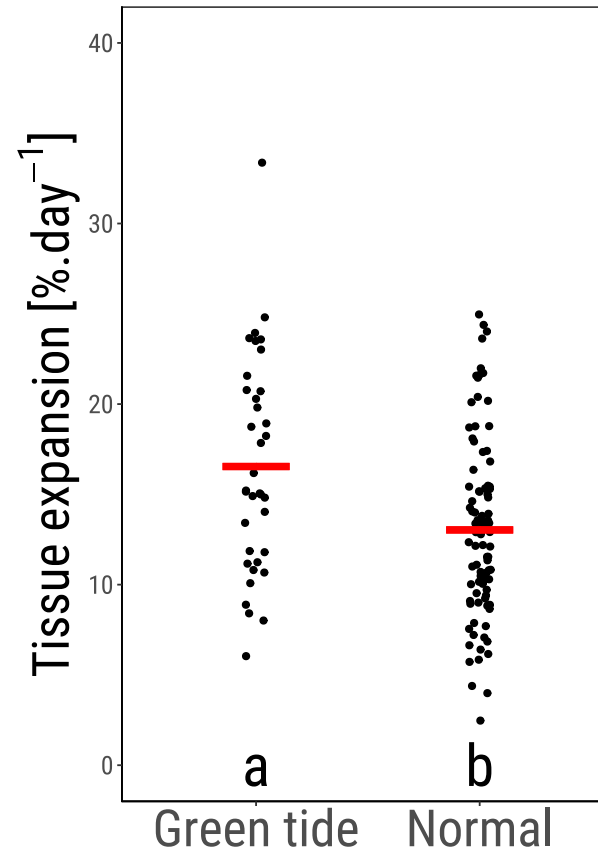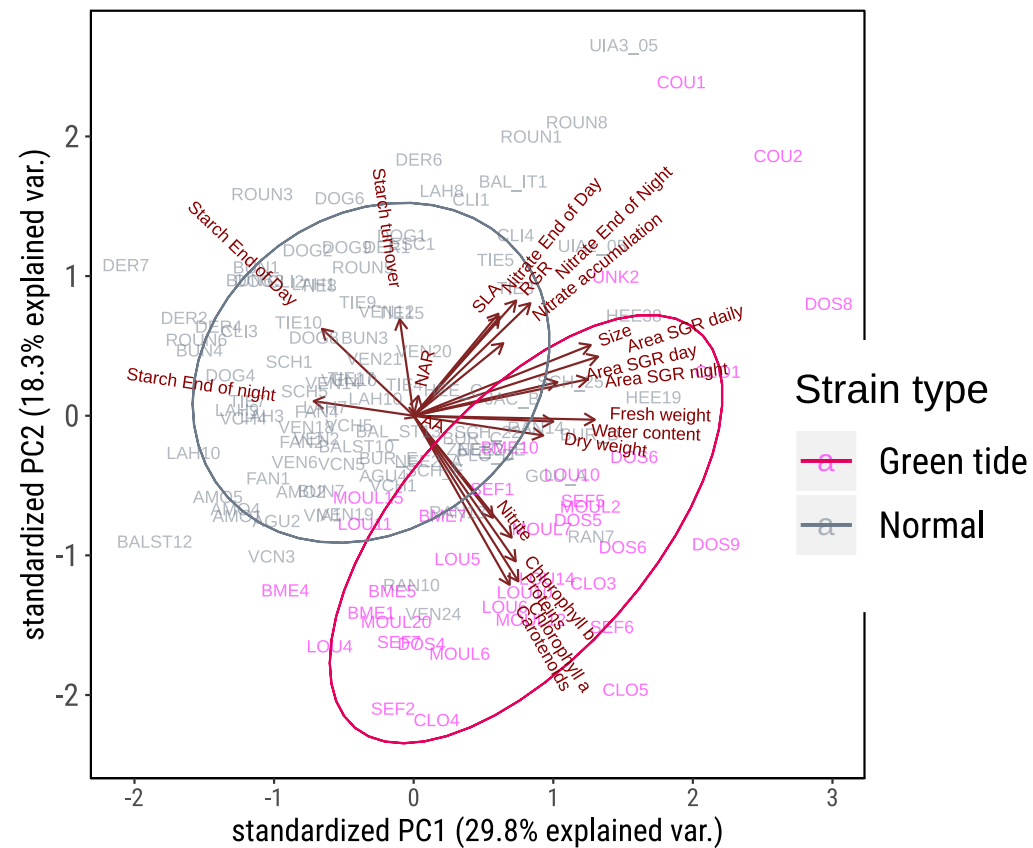
Fast growth, high protein and low carbohydrate content in green tide strains could make them important for aquaculture.

Strain selection can be performed on any seaweed

Saccharina latissima sporophytes from six different individuals

How do deploy such methodology?

> Prior (lab-based) and/or during large-scale cultivation

> Measure the growth (or any other characteristics) of a population of individuals from the local area.

   - The "test" conditions should as closely as possible reflect real-world conditions in the aquaculture site.

   - Doesn't necessarily require the use of fancy equipment, flasks containing different individuals can be enough, and strain selection can be performed in the aquaculture site itself.

   - Select the most promising individuals and use those (or their offspring) for large scale cultivation.

How do deploy such methodology?

- Use the local population for the growth season

- Towards the end of the season,
select the most promising individuals based on
desired characteristics

- Bring the selected individuals in the hatchery

- Induce reproduction, and maintain and
use the offspring for Year 2 cultivation

**- Repeat year on year, or until the overall growth
and characteristics of the cultivated population
is uniform**

How do deploy such methodology? Vegetative propagation

Unlike Kelps, *Ulva* and some red algae can be maintained in vegetative growth, and do not require reproduction to create new individuals.

The methodology is similar, but the biomass from the selected individuals can be split into several batches and kept in the hatchery for year-on-year use
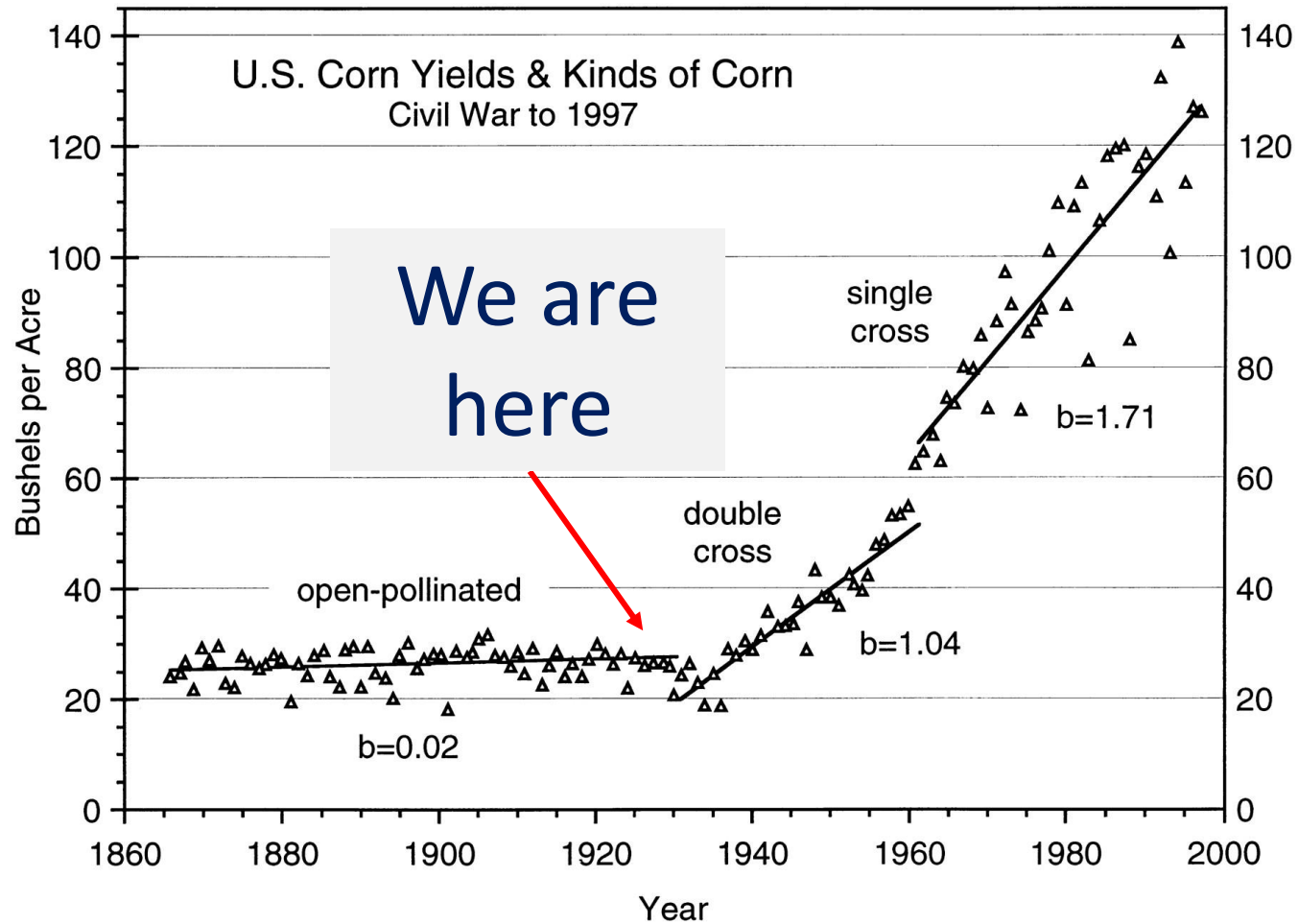
Alternatively, most seaweeds can be kept at ultra low temperature for **long-term storage (cryopreservation)**
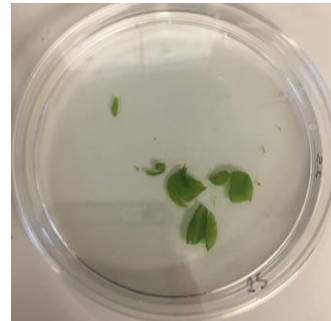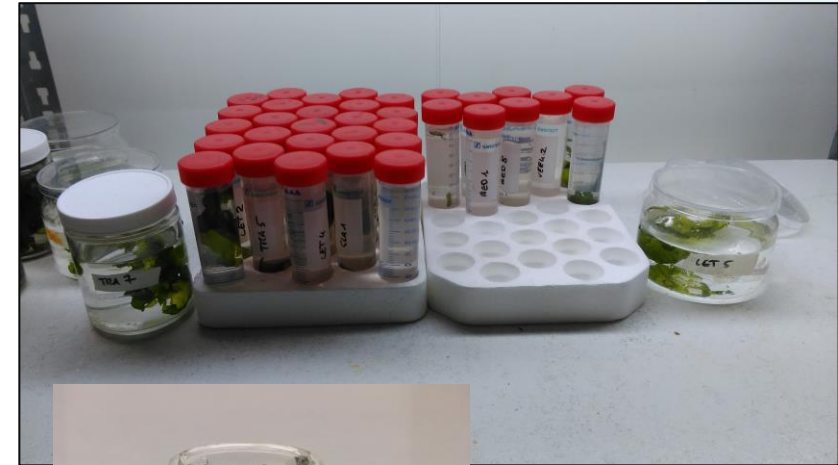
Ulva strain two weeks after storage for > 1 month at -195 °C

Strain selection as the first step towards elite cultivars

Selection and breeding of elite varieties and cultivars led to the explosion of the yield increase year on year in crops

Starting strain selection in seaweeds will lead to the same results as for plants!

Summary

- Seaweeds contain enough genetic diversity to render most individuals unique

- Each individual has different growth/biochemical characteristics
    ~4-fold differences among *Ulva* individuals

- Selecting the "right" individual(s) for large scale cultivation is likely to dramatically increase yield(s)

- Strain selection can be performed in the lab prior to cultivation, or *in-situ*.

- With increased and reliable yields through strain selection, the seaweed production in Europe is likely to expand.

Thank you for your attention

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