JST MIRAI 未来社会創造事業

NAGOYA UNIVERSITY

KOBE UNIVERSITY

SHINSHU UNIVERSITY

Biomass innovation by elucidating the principle of hybrid vigor

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(2021.5~)

JST-mirai project "Low Carbon Society" mission area

Since the industrial revolution, we have been mining coal and oil as energy fuels without considering how we would replenish these resources.

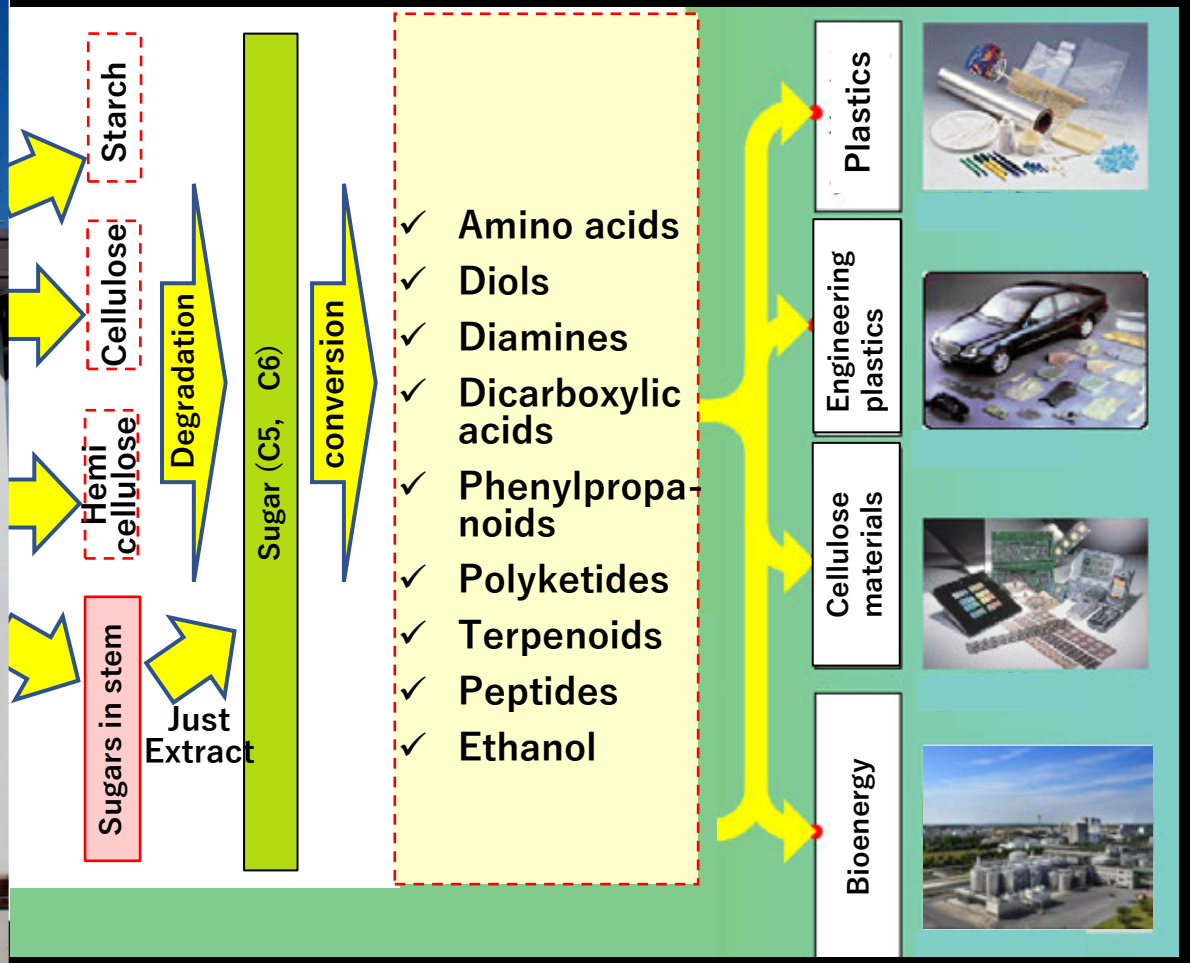
The results are obvious.

In this project, we are trying to develop

“Game-changing technologies”

for low carbon society, especially focusing on **biomass**.

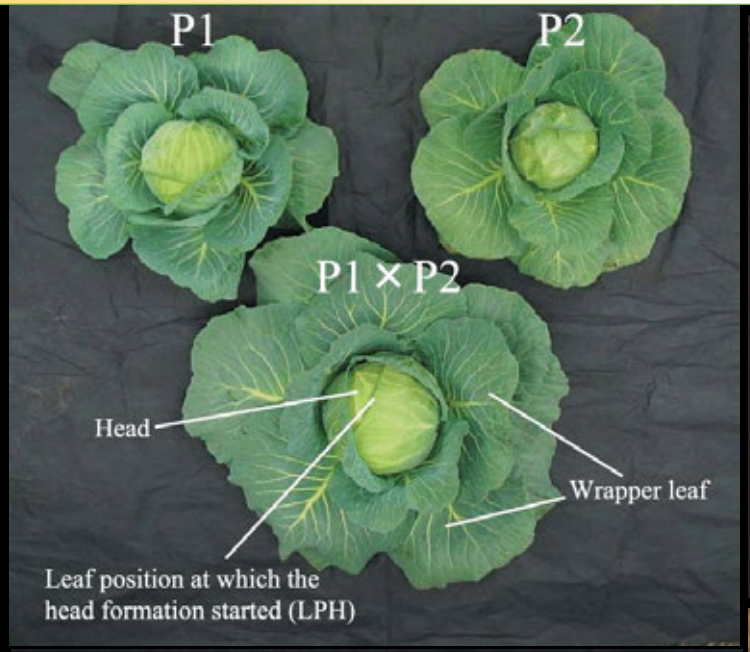
Biomass contribute to carbon neutrality in biorefineries

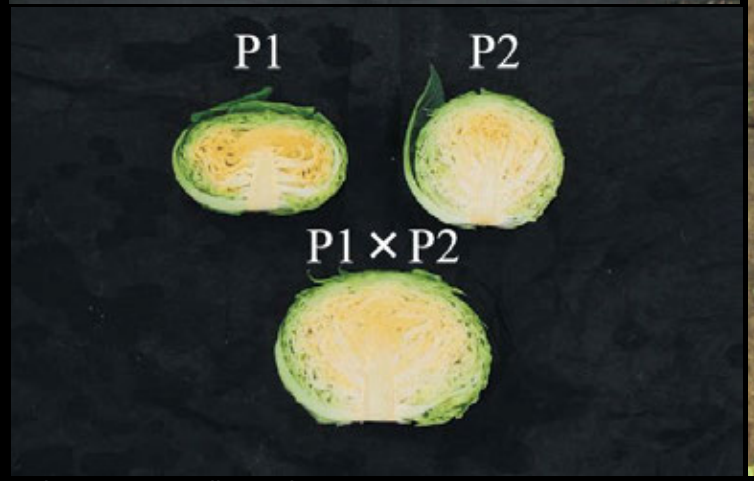


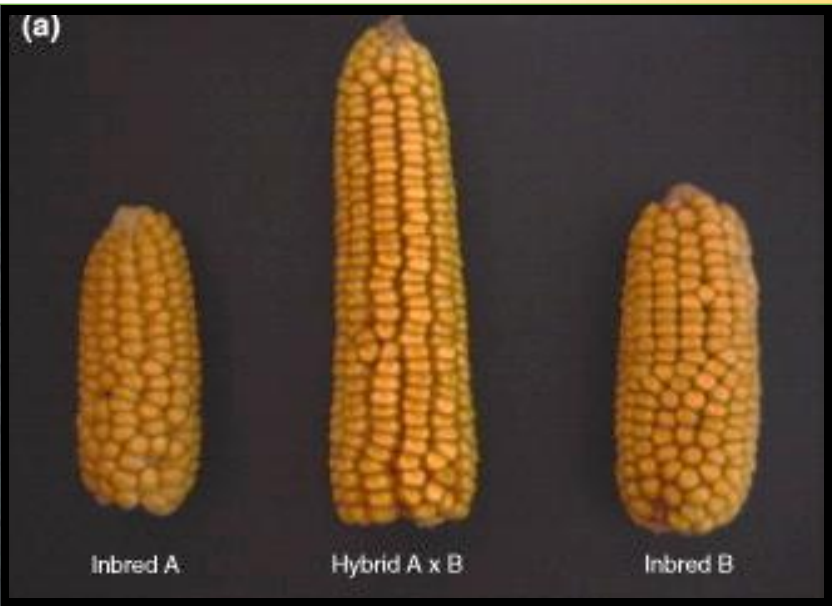
Modified from MEXT NC-CARP project

Increasing biomass is important not only for feedstock but also for sugar yield.

F_1 with hybrid vigor: a conventional, important breeding method increasing the yield







Left: Tanaka et al., 2006, Breeding Science, 56:147-153.
Upper right: Hochholdinger et al., 2007, TRENDS in Plant Science, 12:427-432.
Bottom right: Krieger et al., 2010, Nature Genetics, 42:459-463.

Biomass crop; Sorghum with typical Hybrid vigor

- Hybrid vigor of F1 is the most promising method to obtain high biomass.
- A "Key" crop for create low-carbon society.

→However,
- Principle unknown
- Needs three years to produce seeds
  → High cost

Why Sorghum ?

- Plant height = 5m
- parents =1.2m
  →Strong hybrid vigor
- High biomass (>85t/ha)
- Sweet variety (it is rarely made into edible sugar)
- Wide cultivation area (Equatorial to temperate zones)
- Established mechanical sowing and harvesting
- C4 plant
- Drought tolerance
- Diploid (Routine breeding)

Overview of this project

Produce varieties for Low-carbon society

F1

Reveal the principle of Hybrid vigor

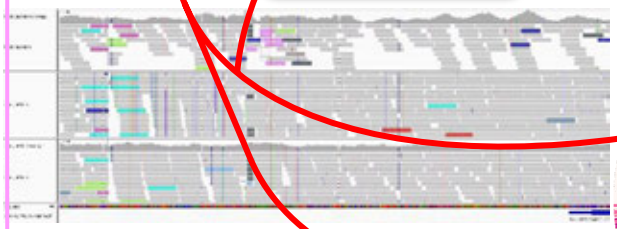
Innovation

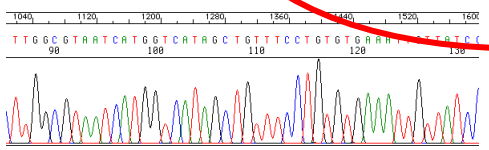
" Genome Design" new breeding Approach

- High biomass
- juicy/dry
- high Suc/Hex

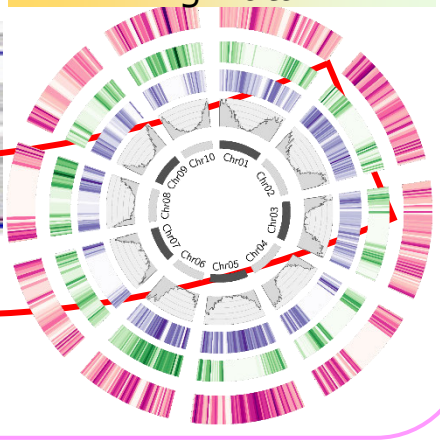
Increase of cultivated area

Genome analysis





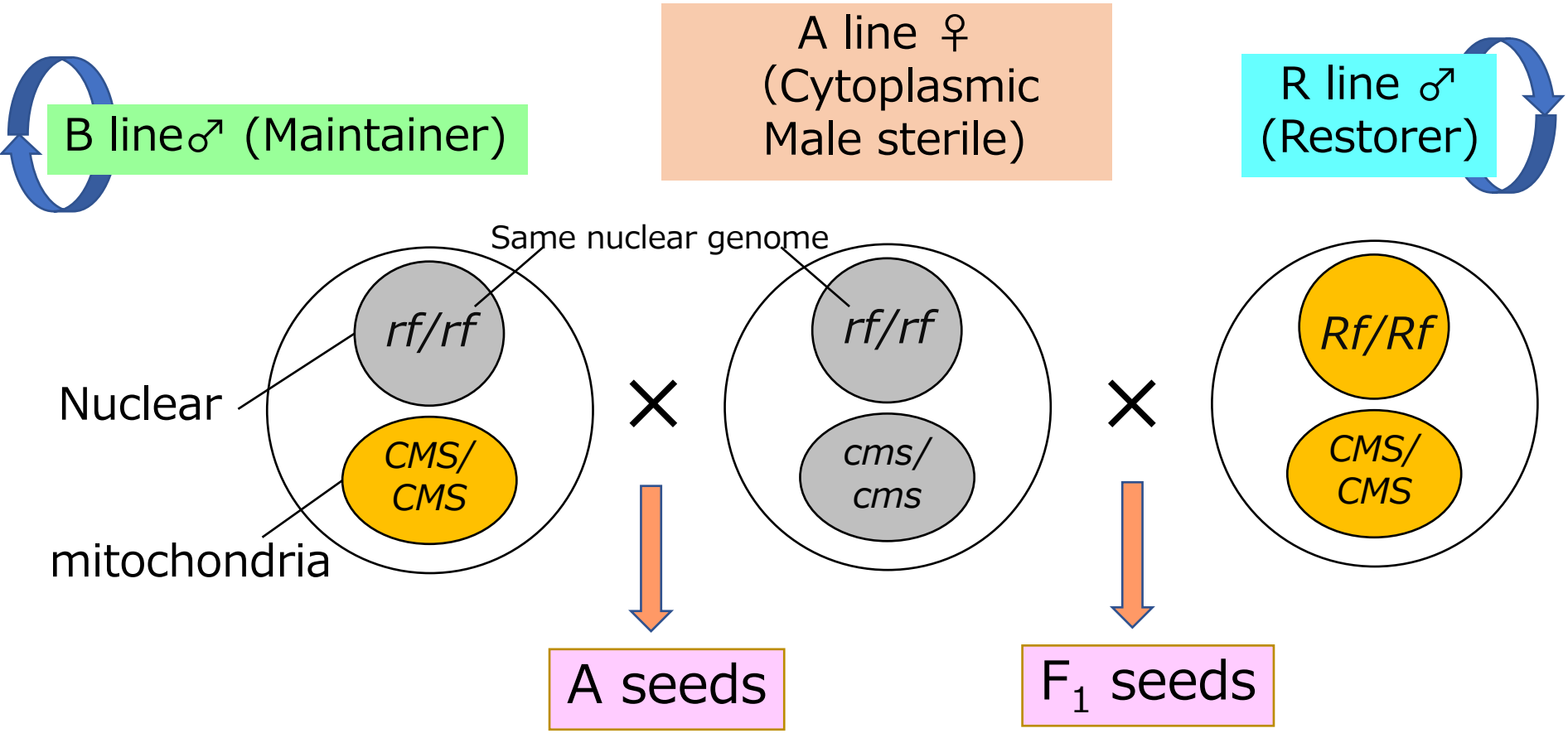
Increasing Genome Big Data



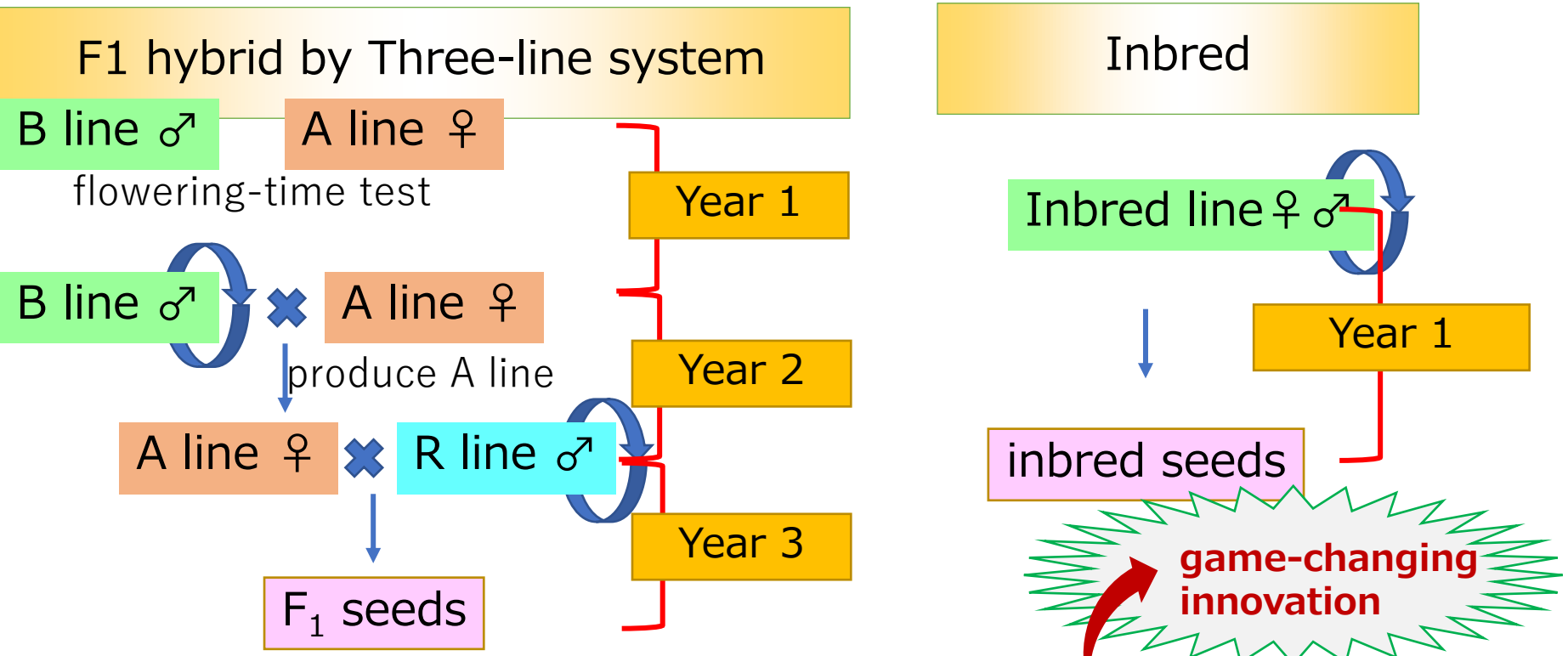
Low carbon society

Creation of a new value-chain

F1 seeds production by "Three-line hybrid system"



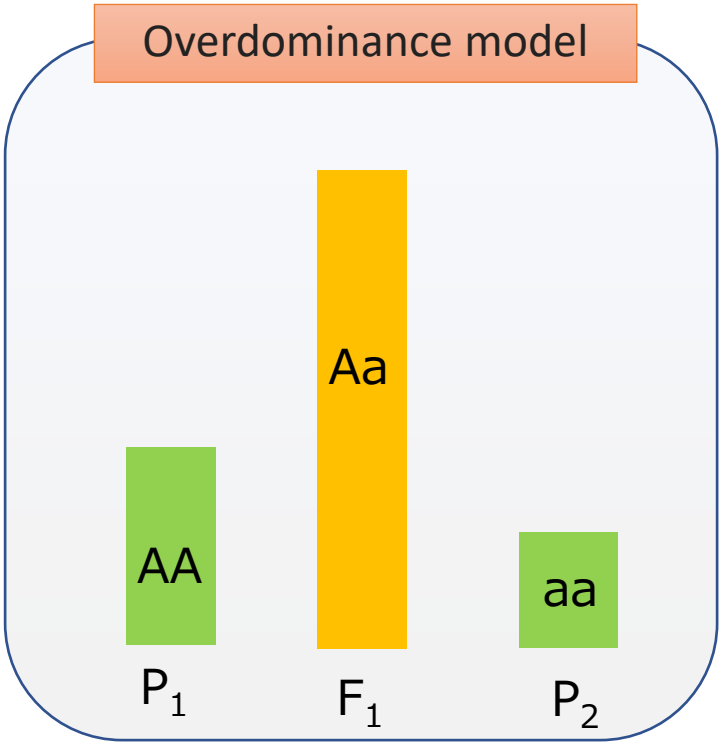
Seeds production



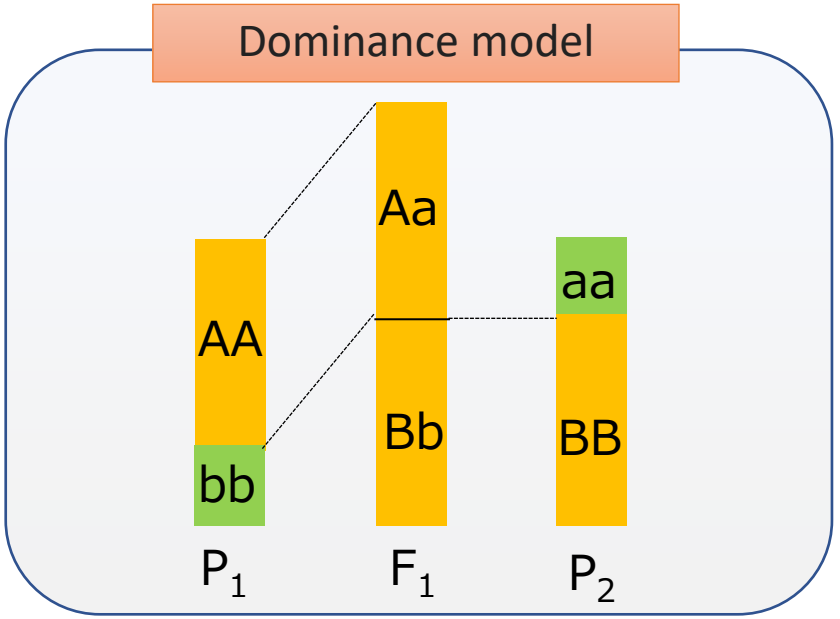
	F1 hybrid	Inbred
High biomass	◎ (Hybrid Vigor)	believed to be impossible
Cost	▲(Three times)	◎
Time	▲(Three times)	◎
Risk (natural disaster)	▲(Three times)	◎
Effort	▲(Three times)	◎

Models for hybrid vigor

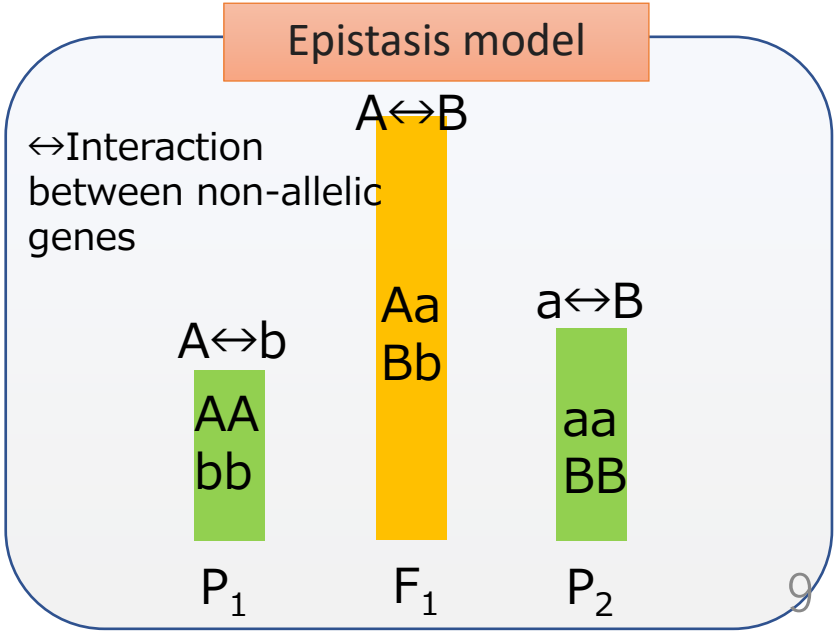
①



②



③



Path-breaking result

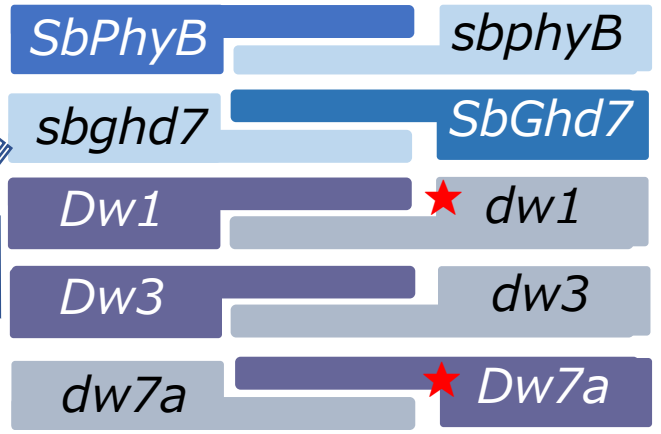
Five genes control the hybrid vigor!

revealed !

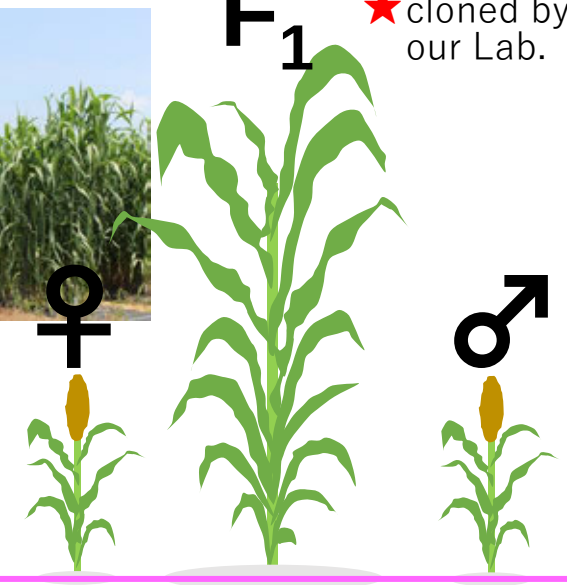
Hashimoto et al. Sci. rep. (2021)

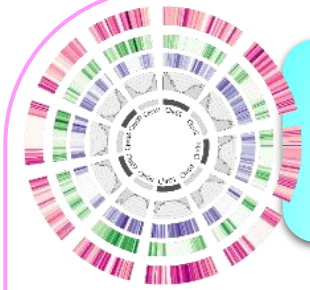
Until now: breeding by chance
From now : genome design based on the principle!

Principle



★cloned by our Lab.





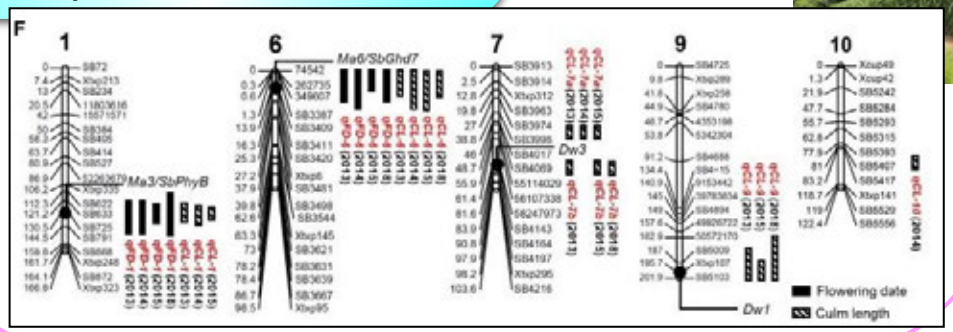
brand-new genome big data

QTL analysis

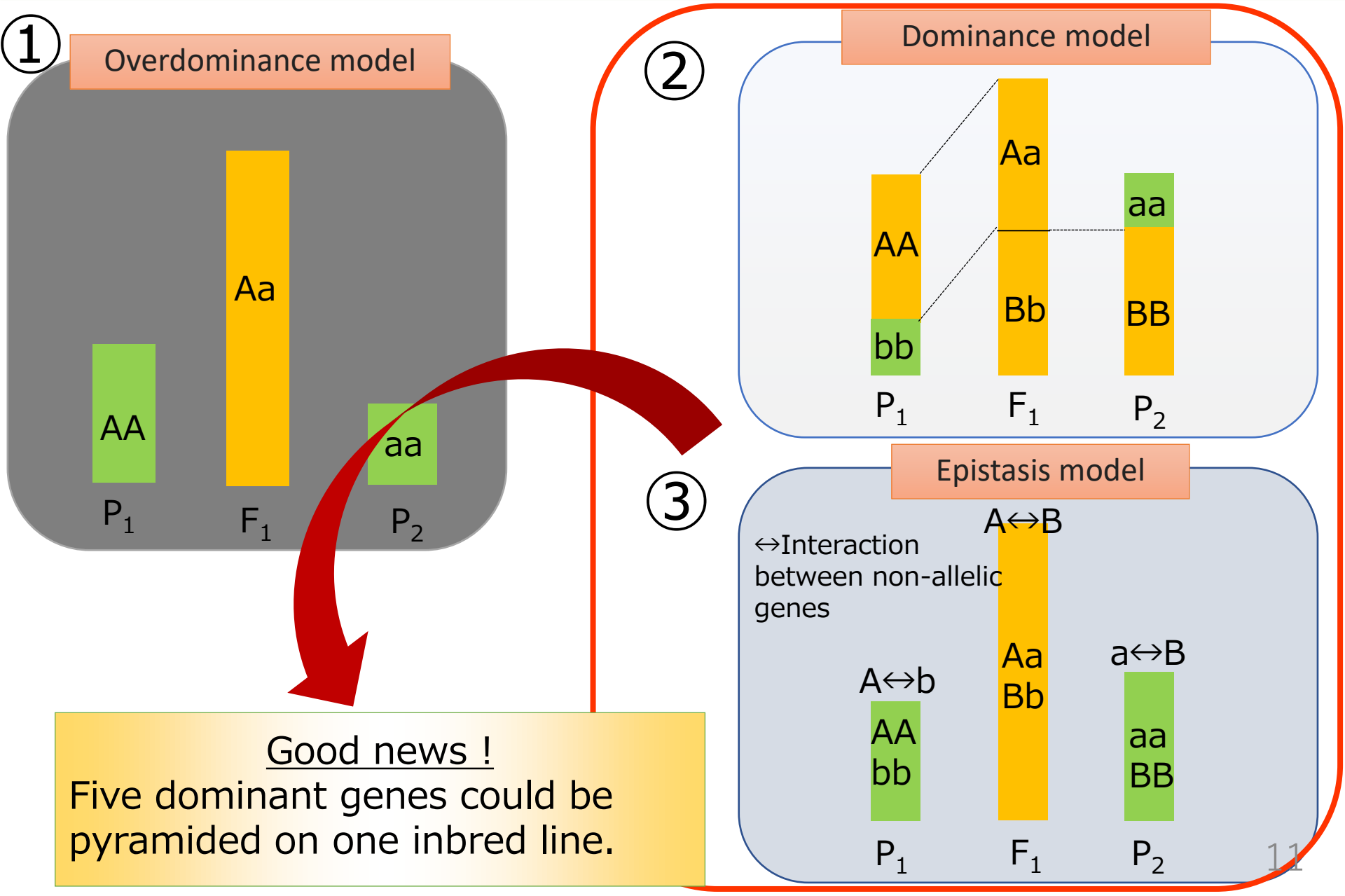
Over 9years

Phenotyping in the field, and Genotyping, DNA analysis

>10,000 plants



This hybrid vigor mostly fits “Dominance model”



Good news !

Five dominant genes could be pyramided on one inbred line.

Application for the breeding

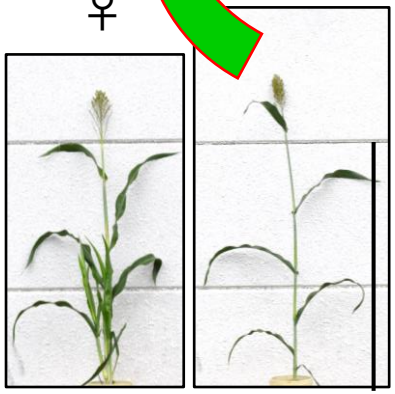
Pyramiding the five dominant genes on an inbred line

Five genes make plants so huge!

Pyramiding by crossing

No GMO

♀ ♂



1m

Pyramided inbred

mimic!

F_1

1m

Seed production

F1(3 lines system)

Complicated, and needs long time

A line

R line

B line

cross

cross

F1 seeds

◎ Pyramided inbred

Just harvest the seed.

inbred plant → inbred seeds

drastic decrease in time, cost, and efforts!

⇒On going!

On going

Future plans for create of “Low Carbon Society” by sorghum

Nagoya Univ.
Shinshu Univ.

Who will produce the seeds?

① Utilization of abandoned farmland （domestic)

Biomass → Livestock feed

②Intercropping with sugarcane, expansion of cultivated zone

Sugars → Bioethanol Bioplastic

③Preventing desertification

robustness → cultivated land

On going

Future plans for create of “Low Carbon Society” by sorghum

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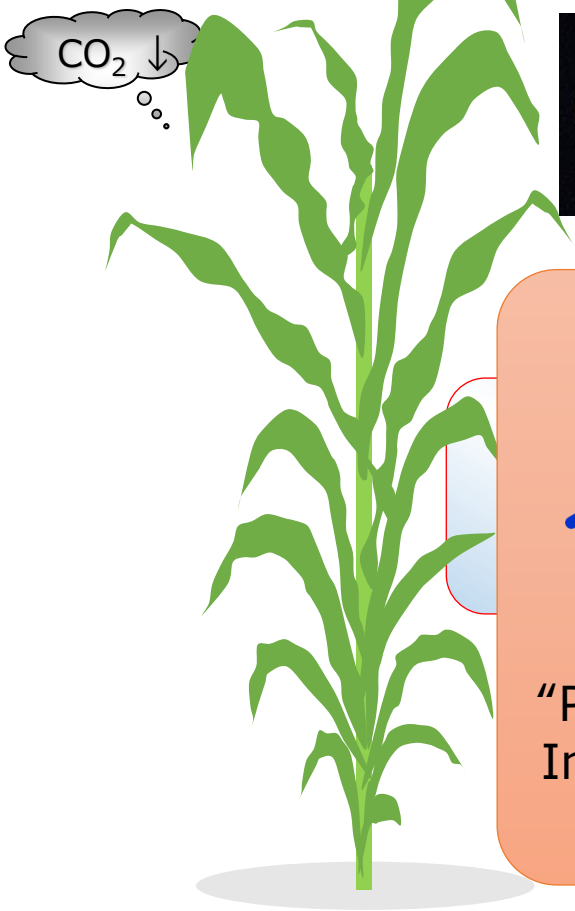
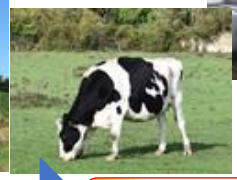


Nagoya University Startup:

PLANT OPEN INNOVATION

“Plant Open Innovation” (POI)

① Utilization of abandoned farmland （domestic)



Biomass → Livestock feed

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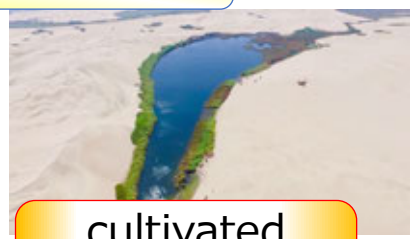
Sugars → Bioethanol Bioplastic

③Preventing desertification



robustness → cultivated land

Biorefinery; a key of low-carbon society

round bale

fermentation

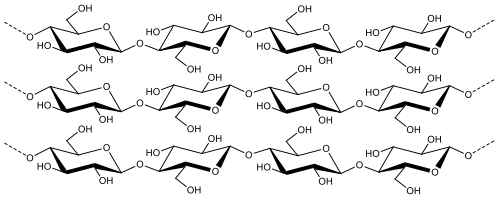
Forage

squeezing

Juice

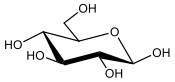
separation

bagasse



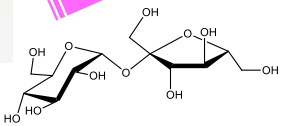
cellulose

hydroly-zation & fermen-tation



glucose

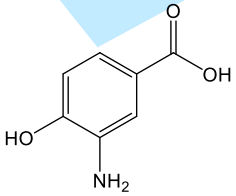
Fermen-tation



sucrose

High-performance plastics

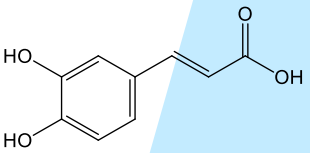
Zylon® (TOYOBO; $460/ kg)



3-Amino-4-hydroxy-benzoic acid (3,4-AHBA)

Starting material

$2,460/kg



Caffeic acid

Antioxidant, immunomodulatory and anti-inflammatory effects

$1,850/kg

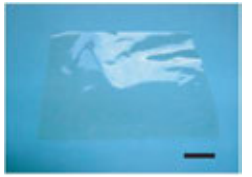
Cosmetics

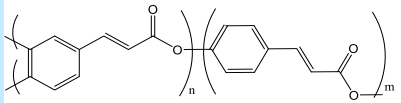
Vitamin CE Caffeic Silk Serum 16+2 (FutureDerm; $89, 30 ml)

Medicines

Bioplastics

(thermostable, biodegradable)



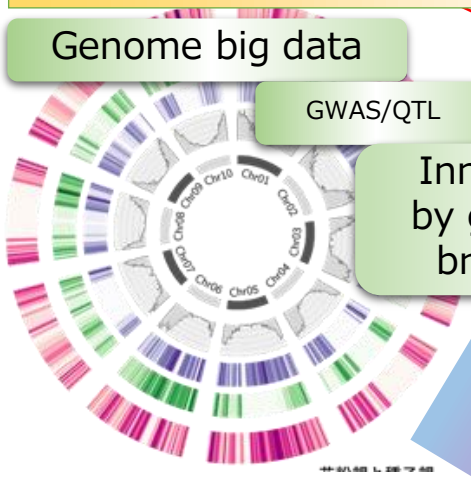


Kaneko, et al. (2006) Nat Mater. 5(12): 966-970.

Summary: a sustainable society using sorghum

Genome big data

GWAS/QTL



Innovation by genomic breeding

New varieties supported by JST

CO_2↓

harvesting

Bioplastics (degradable)

biofiber

Biorefinery

Bioethanol

KU

JST-MIRAI project

Juice (sugar)

biomass

Biogas Power Generation

Biomass power generation

CNF

Livestock feed

NU startup; POI

- Seed production
- Agribusiness consulting

Companies (Decarbonization Business)

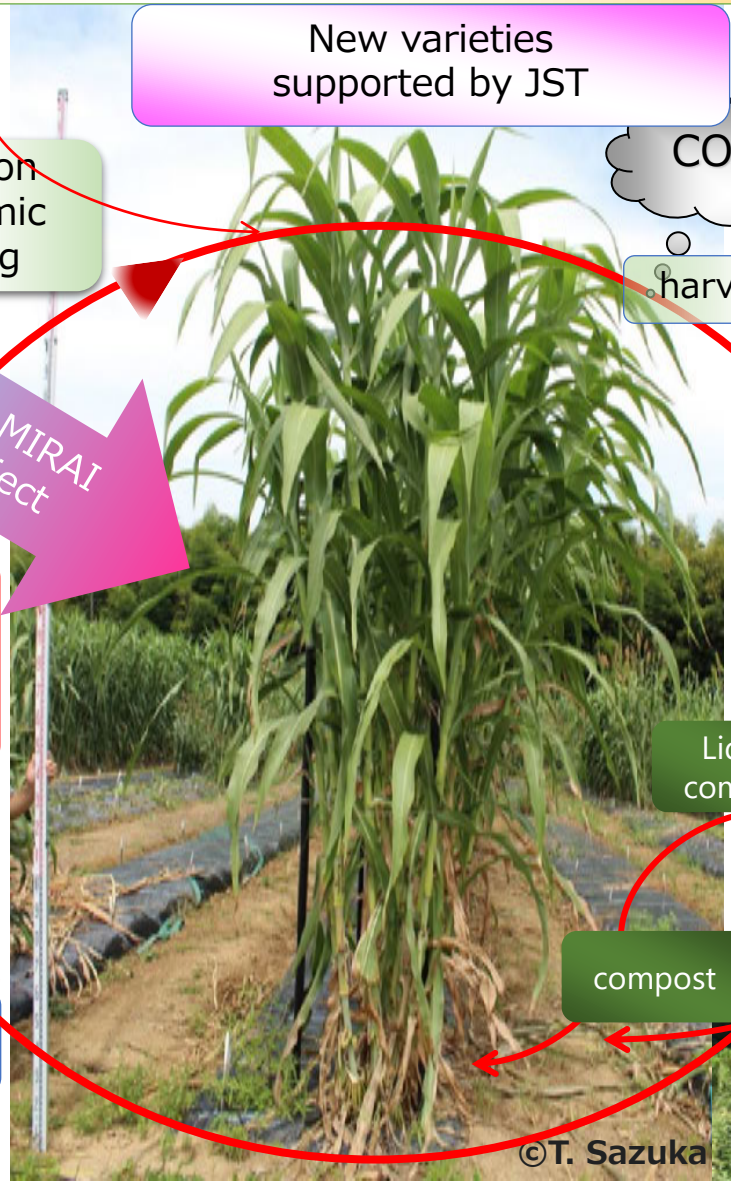
Joint research ・R&D

Development of new businesses

NU, SU

Liquid compost

compost



C recovering, N, P, K recycling

Thank you for your attention

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