



Breeding Research and Aquaculture Industry of *Pyropia* (Gim) in Korea



2024. 8. 22.

National Institute
of Fisheries Sciences

Dr. Mi-Sook Hwang



Contents



Biology of *Porphyra/Pyropia*



Breeding Research of *Pyropia*



Aquaculture of *Pyropia* in Korea

Biology of *Porphyra*/*Pyropia*

Ecology and Taxonomy

- ◆ More than 140 species, distributed from subtropic to arctic/antarctic
- ◆ Growing from intertidal to subtidal zone
- ◆ Taxonomy

홍조식물문(Rhodophyta)

김파래강(Bangiophyceae)

김파래목(Bangiales)

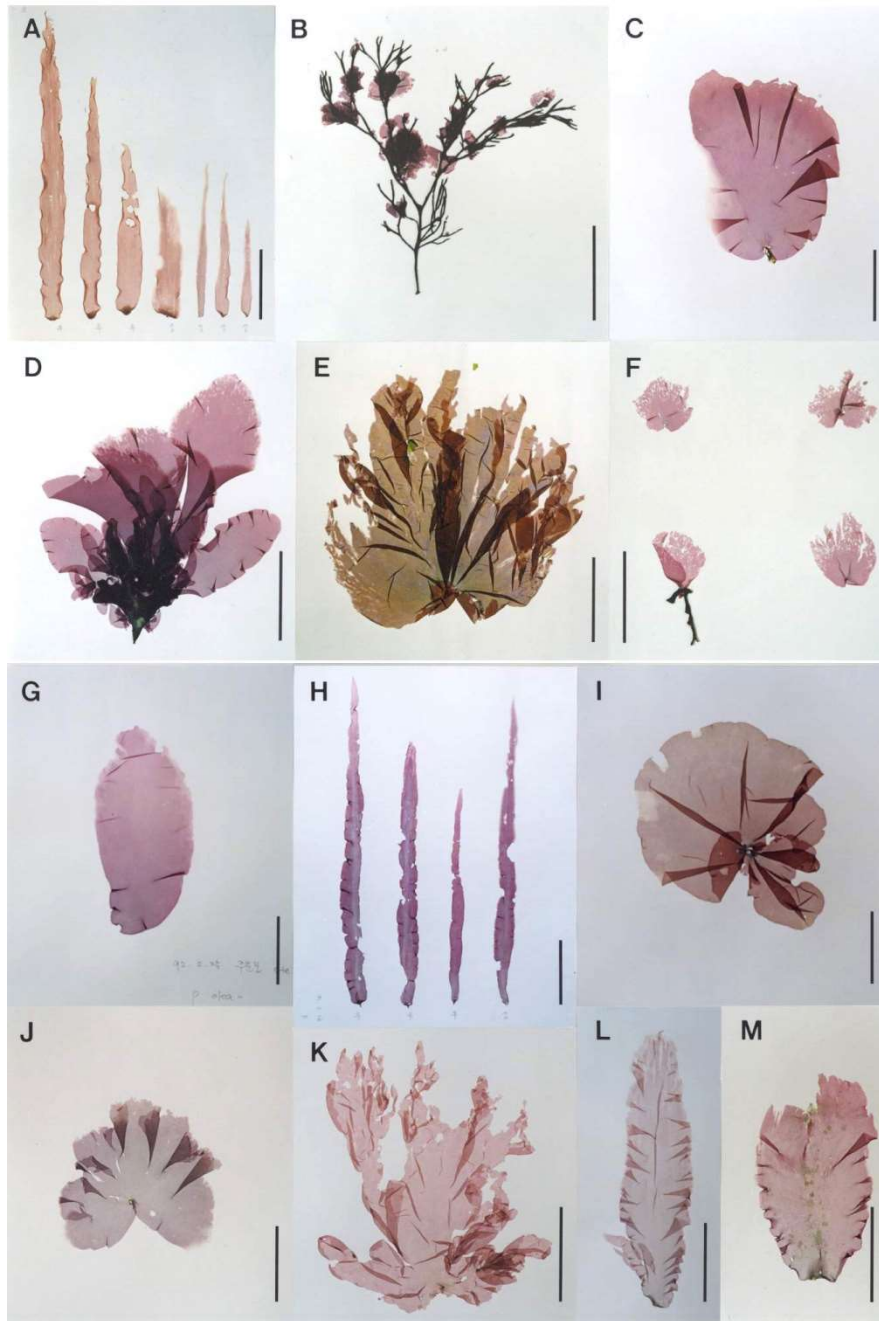
김파래과(Bangiaceae)

김속(*Porphyra* → *Pyropia*)

* Genus *Porphyra* were divided into 8 genera such as *Porphyra*, *Pyropia*, *wildemania* etc. by Sutherland *et al.* (2011).



Pyropia in Korea



A. 잇바디돌김 (*P. dentata*)

B. 패돌김 (*P. ishigecola*)

C. 카타다돌김 (*P. katadae*)

D. 비단잎돌김 (*P. koreana* Hwang et Lee) new

E. 쿠니에다김 (*P. kuniedae*)

F. 갈래잎돌김 (*P. lacerata*) unrecorded

G. 오카무라돌김 (*P. okamurae*)

H. 긴잎돌김 (*P. pseudolinearis*)

I. 모무늬돌김 (*P. seriata*)

J. 둥근돌김 (*P. suborbiculata* f. *suborbiculata*)

K. 넓은둥근돌김 (*P. suborbiculata* f. *latifolia*)

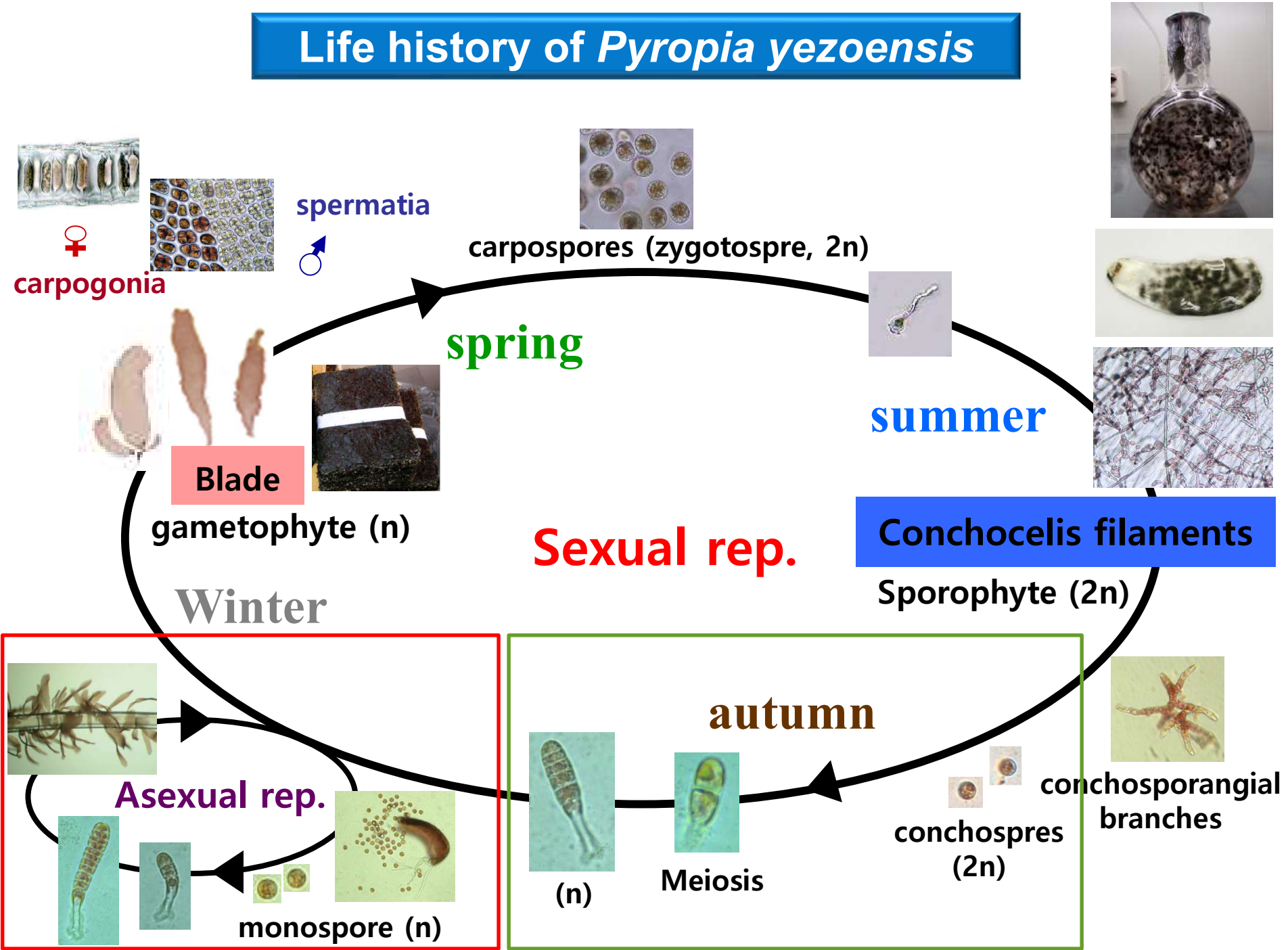
L. 참김 (*P. tenera*)

M. 방사무늬김 (*P. yezoensis*)

❖ adding new species by phylogenetic researches

❖ 25 species (as of 2024)

Life history of *Pyropia yezoensis*



Breeding Research of *Pyropia*

Plant Variety Protection in Seaweeds (2012)

♣ Additional target plants

감귤	Mandarin	<i>Citrus unshiu</i> Marc.
나무딸기	Raspberry	<i>Rubus allegheniensis</i> Porter <i>Rubus coreanus</i> Miq. <i>Rubus lociniatus</i> Willd. <i>Rubus thyrsoides</i>
딸기	Strawberry	<i>Fragaria</i> spp.
블루베리	Blueberry	<i>Vaccinium angustifolium</i> Aiton <i>Vaccinium corymbosum</i> L. <i>Vaccinium formosum</i> Andrews <i>Vaccinium myrtilloides</i> Michx. <i>Vaccinium myrtilillus</i> L. <i>Vaccinium simulatum</i> Small <i>Vaccinium virgatum</i> Aiton
양앵두	Cherry	<i>Prunus avium</i> L. <i>Prunus cerasus</i> L. <i>Prunus × gondouinii</i> (Poit. & Turpin) Rehder
해조류	Seaweed	김, 미역 등 (<i>Pyropia</i> , <i>Undaria</i> , etc.)

※ 농림수산식품부고시(제2011-178호, 2011. 11. 2), 2012. 1. 7일부터 시행

'War of Seaweed Seeds'...
Competition to develop & secure
excellent varieties

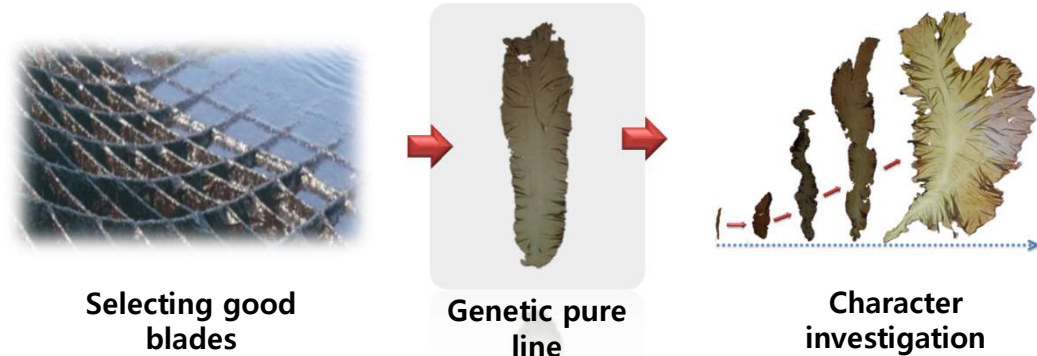


Using more than 20%
of Japanese varieties

Need to develop and
distribute new Korean
varieties

Breeding Technology of *Pyropia*

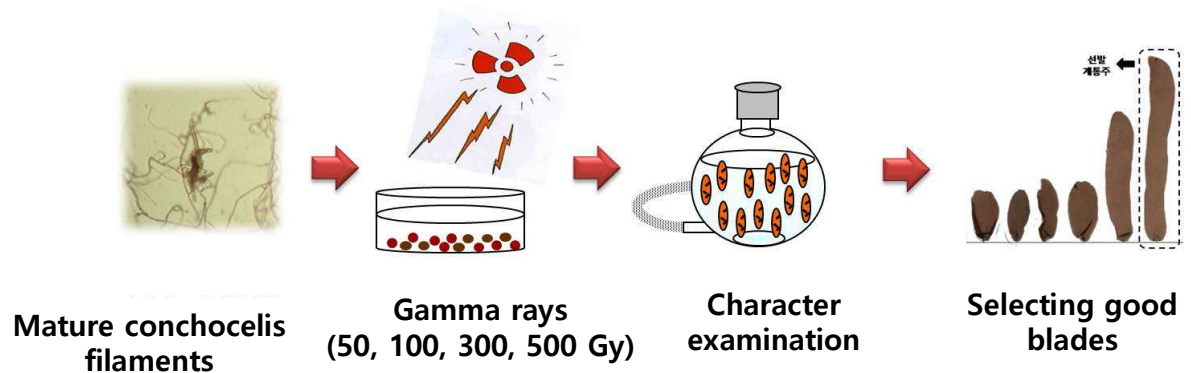
1. Isolation



2. Hybridization (DNA markers)

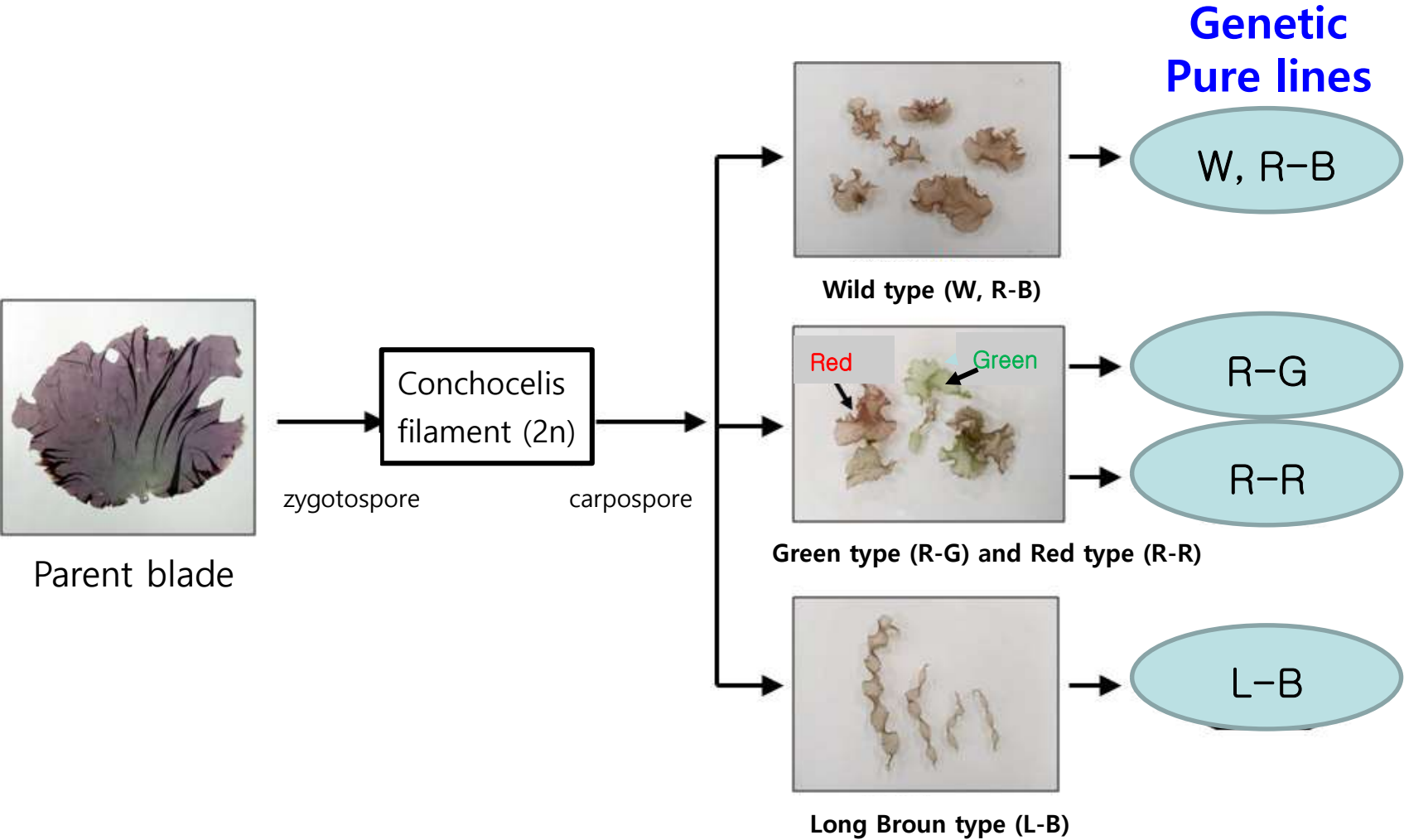


3. Mutation (low level gamma rays)



Isolation

◆ 4 genetic pure lines of *Pyropia tenera*



◆ **Development of 4 varieties as genetic pure lines**

→ 1 variety (Sugwawon 101) : patent, PVP (breeder's) right

→ 2 varieties ((Sugwawon 102 and 103) : PVP (breeder's) rights



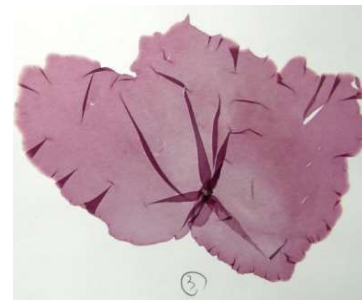
Wild type (W, R-B)



Sugwawon 101



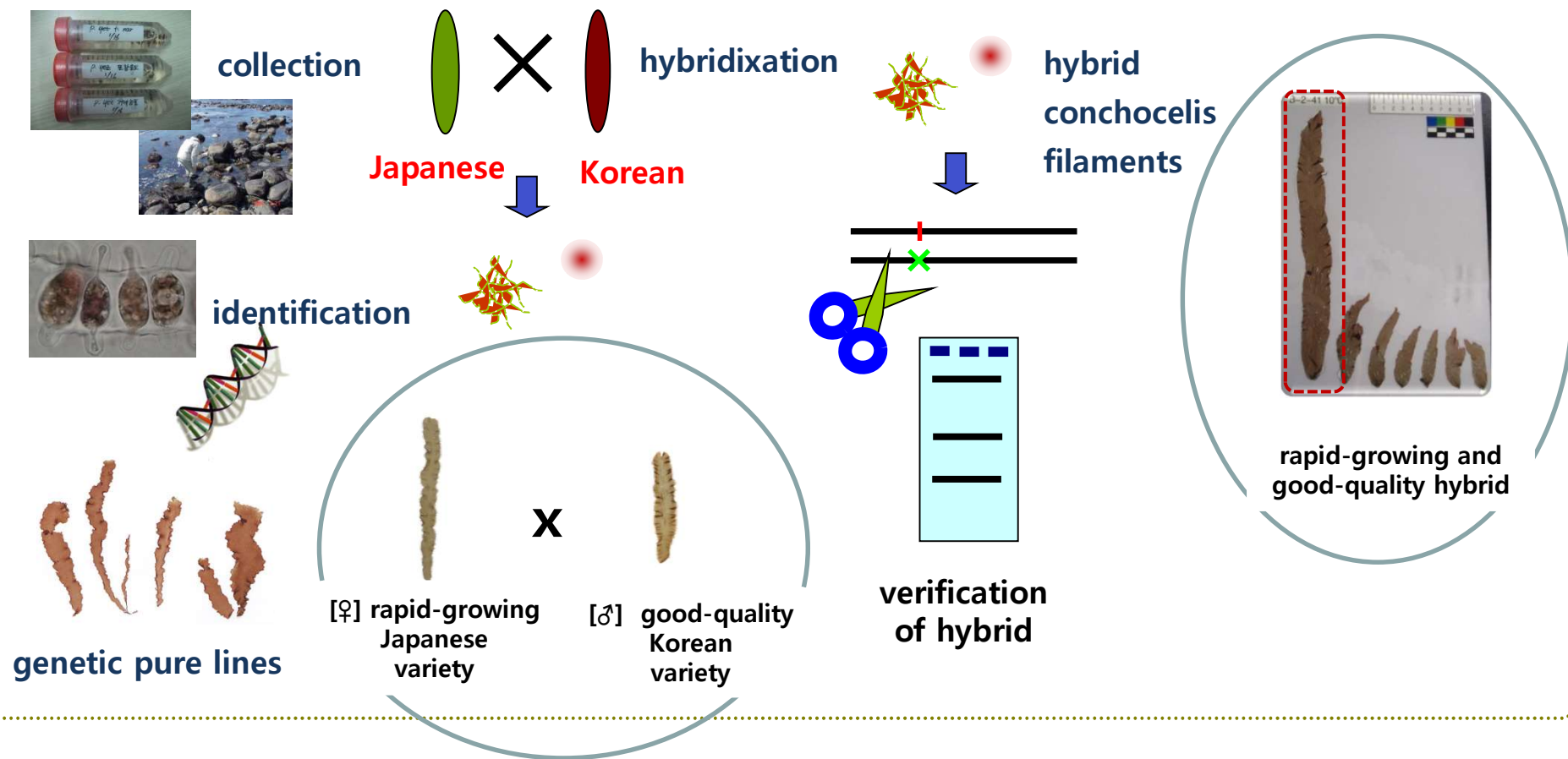
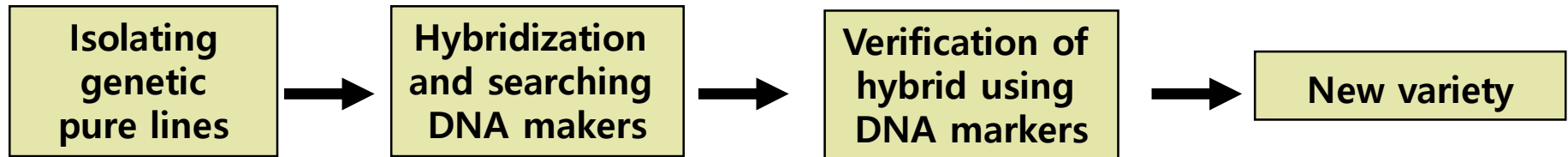
Sugwawon 102



Sugwawon 103

Hybridization

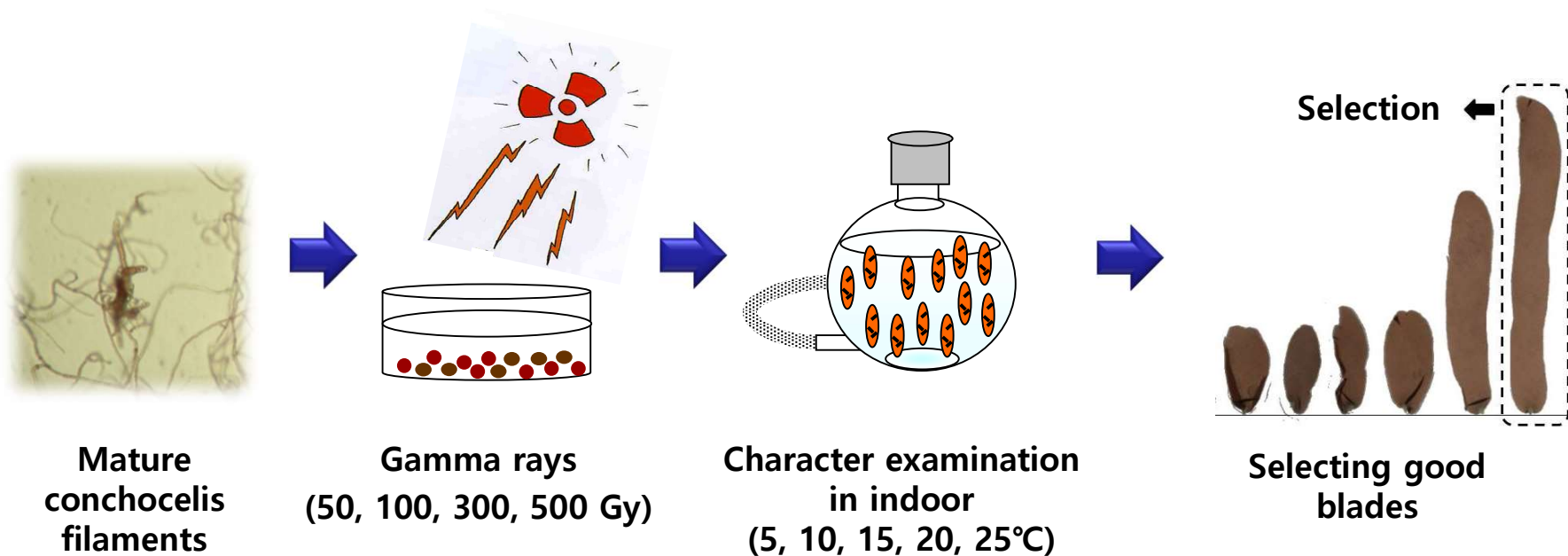
Hybridization using DNA markers



Mutation

◆ Antioxidant, high-temperature tolerant or rapid-growing varieties

- Jeonsu No. 1 (2015): Antioxidant
- Gold No. 2 (2017): high-temperature tolerant
- Sugwawon 115 (2019): rapid-growing

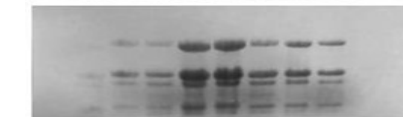
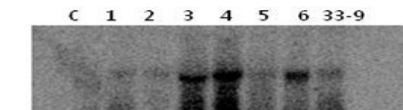
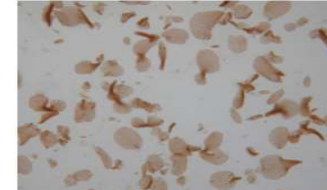
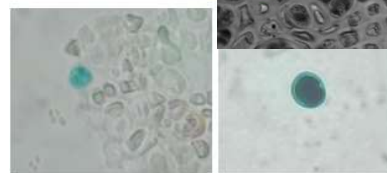
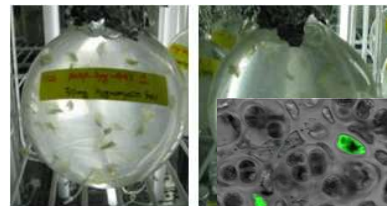
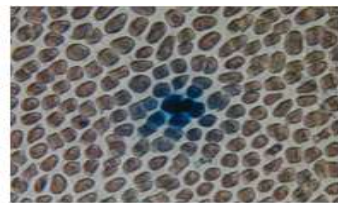
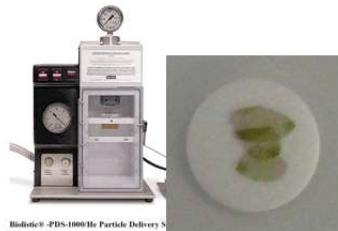
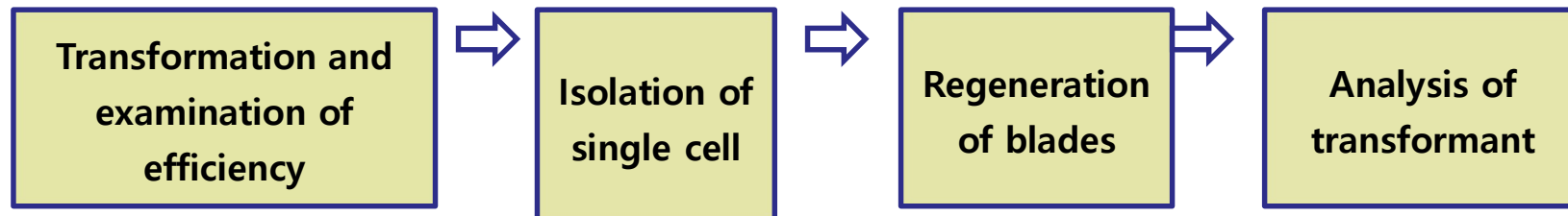


Genetic Transformation

*Living Modified Organism

◆ Technology of transformation in *Pyropia tenera* and *P. yezoensis*

→ patent registration (2012)



- * Transformation by gene gun method
- * Reporter gene: GUS and fluorescent protein (codon optimization GFP/CFP)
- * Transformation vector having antibiotic selection marker

New varieties of *Pyropia* developed by NIFS

- PVP rights application/ registration: 18 / 14 varieties
- 국내 품종보호권 출원(총 31건)의 58% 점유 → 품종다양화 주도 및 종자주권 확립

Pyropia cultivars of NIFS (APVP application 18/registration 12, APVC 2023)



Breeding method
 S Selection C Cross M Mutation

Blade shape
 W Wide M Middle N Narrow

Length measured after 8 weeks of cultivation

Pyropia yezoensis



Sugawon No.104 S M
 Length/Color: 17cm/Brown-purple
 Width/Shape: Middle/Linear, Obovoid
 Spore release: little
 Growth: fast (early~end)
 Fast sporangia formation & release
 APVP-8



Sugawon No.105 S M
 Length/Color: 28cm/Brown-green
 Width/Shape: Middle/Linear
 Spore release: little
 Growth: fast (early~end)
 APVP-11



Sugawon No.108 S W
 Length/Color: 21cm/Brown-purple
 Width/Shape: Wide/Obovoid
 Spore release: little
 Growth: fast (early~end)
 Slow sporangia formation & release
 APVP-15



Sugawon No.106 S W
 Length/Color: 17cm/Brown-purple
 Width/Shape: Wide/Obovoid
 Spore release: a lot
 Growth: fast (early~end)
 Fast sporangia formation & release
 APVP-17



Sugawon No.109 S M
 Length/Color: 22cm/Brown-green
 Width/Shape: Middle/Obovoid
 Spore release: a lot
 Growth: fast (early~end)
 Fast sporangia formation & release
 APVP-18



Sugawon No.110 S N
 Length/Color: 31cm/Brown-green
 Width/Shape: Narrow/Linear
 Spore release: little
 Growth: fast (early)
 Slow sporangia formation & release
 APVP-19



Jeonsu No.2 S W
 Length/Color: 22cm/Brown-green
 Width/Shape: Wide/Obovoid
 Spore release: a lot
 Growth: fast (early~end)
 Fast sporangia formation & release
 AQ-24



Sugawon No.111 S W
 Length/Color: 25cm/Green
 Width/Shape: Wide/Obovoid
 Spore release: a lot
 Growth: fast (early)
 Fast sporangia formation & release
 AQ-26



Sugawon No.112 S N
 Length/Color: 27cm/Brown-green
 Width/Shape: Narrow/Linear
 Spore release: little
 Growth: fast (early)
 Slow sporangia formation & release
 AQ-27



Sugawon No.114 S M
 Length/Color: 22cm/Brown-green
 Width/Shape: Wide/Obovoid
 Spore release: a lot
 Growth: fast (early)
 AQ-28



Sugawon No.115 M N
 Length/Color: 17cm/Brown-green
 Width/Shape: Narrow/Linear
 Spore release: little
 Growth: fast (early)
 APVP uner review



Sugawon No.116 S N
 Length/Color: 25cm/Brown-purple
 Width/Shape: Narrow/Linear
 Spore release: a lot
 Growth: fast (early)
 APVP under review



Sugawon No.117 S W
 Length/Color: 14cm/Brown-green
 Width/Shape: Wide/Obovoid
 Spore release: a lot
 Growth: fast (early)
 APVP under review



Sugawon No.118 S W
 Length/Color: 14cm/Brown-green
 Width/Shape: Wide/Obovoid
 Spore release: a lot
 Growth: fast (early~end)
 APVP under review



Jeonsu No.1 M W
 Length/Color: 10cm/Brown-green
 Width/Shape: Middle/Oval
 Contains antioxidants
 Low productivity
 APVP-13

Pyropia dentata



Sugawon No.401 S N
 Length/Color: 18cm/Brown-purple
 Width/Shape: Middle/Lanceolate
 Growth: fast (early)
 High quality
 AQ-25



Sugawon No.402 S N
 Length/Color: 18cm/Brown-purple
 Width/Shape: Narrow/Lanceolate
 Growth: fast (early)
 High quality
 APVP under review

Pyropia seriata



Sugawon No.501 S W
 Length/Color: 5cm/Yellow-green
 Width/Shape: Middle/Oval
 Growth: fast (early)
 APVP under review

Distribution of National Varieties

➤ Distribution of national varieties (2017~)

- Annual requirement of *Pyropia* seed (as free-living conchocelis filaments): about 30kg

2017	2023
2 varieties/ 21 cases/ 595g (about 2%)	9 varieties/ 152 cases/ 5,670g (about 19%)

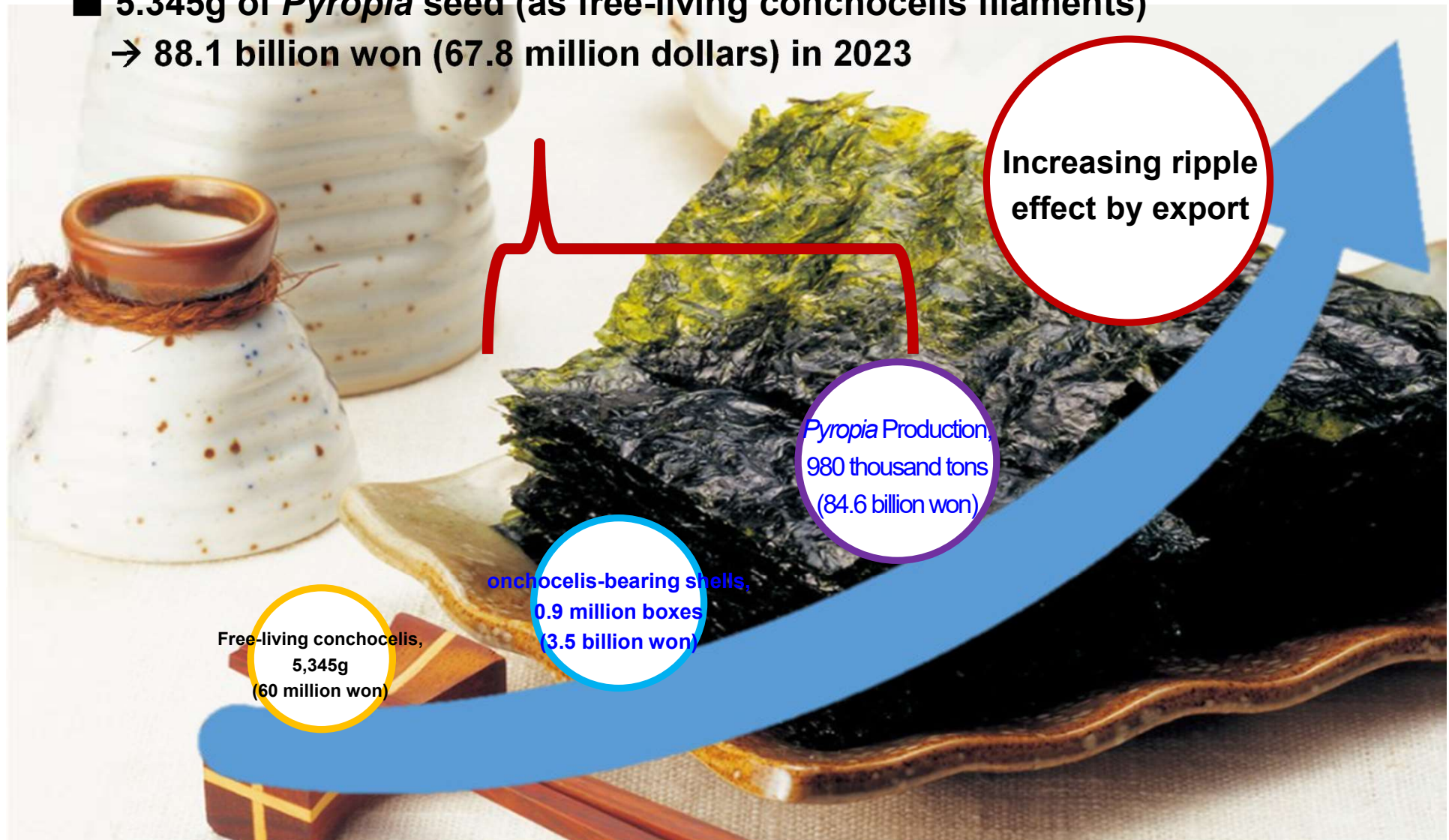
➤ Facility for seed production of national varieties

- more than 50% of annual requirement



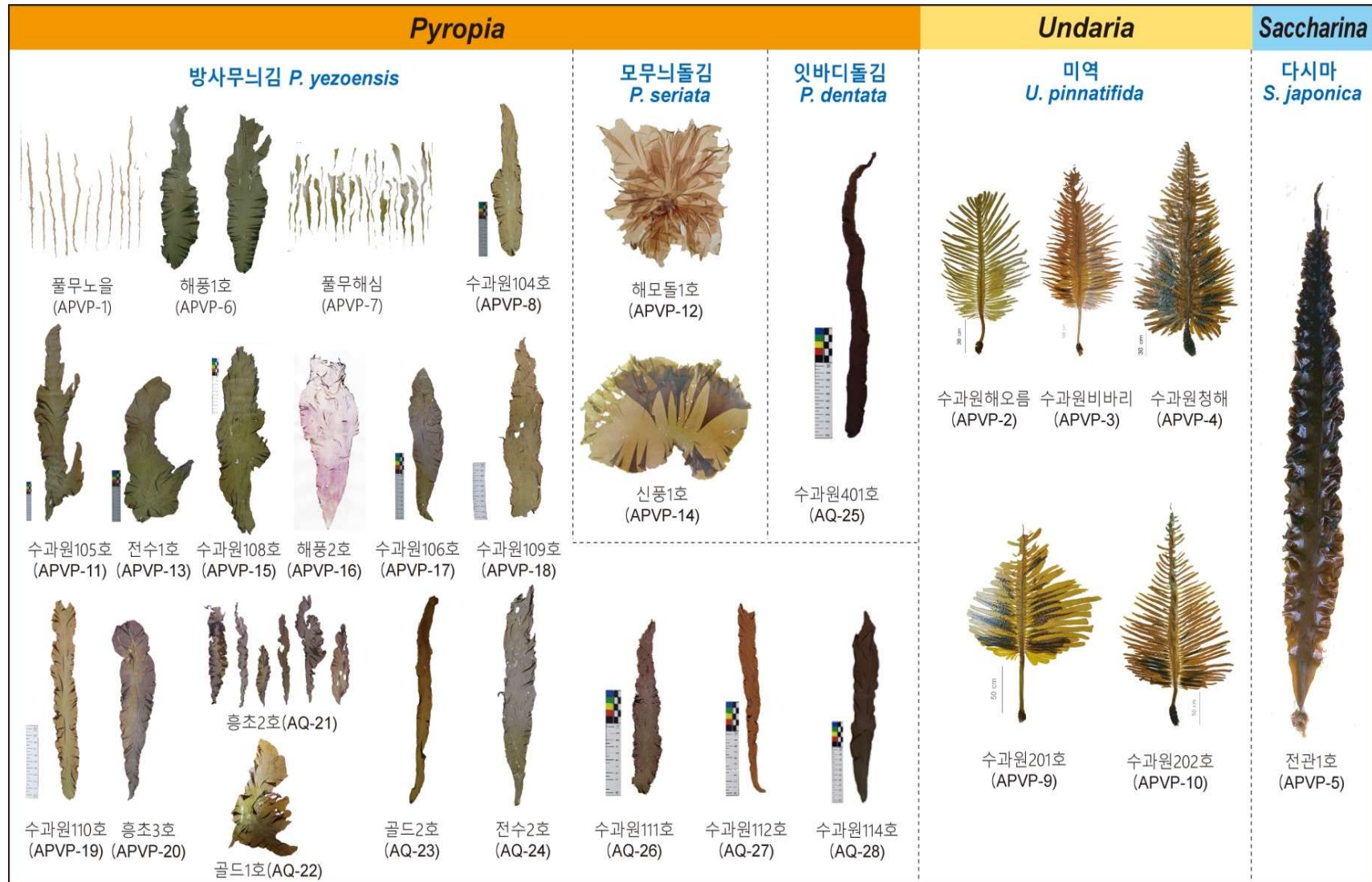
Economic ripple effect of the distribution of national varieties

- 5.345g of *Pyropia* seed (as free-living conchocelis filaments)
→ 88.1 billion won (67.8 million dollars) in 2023



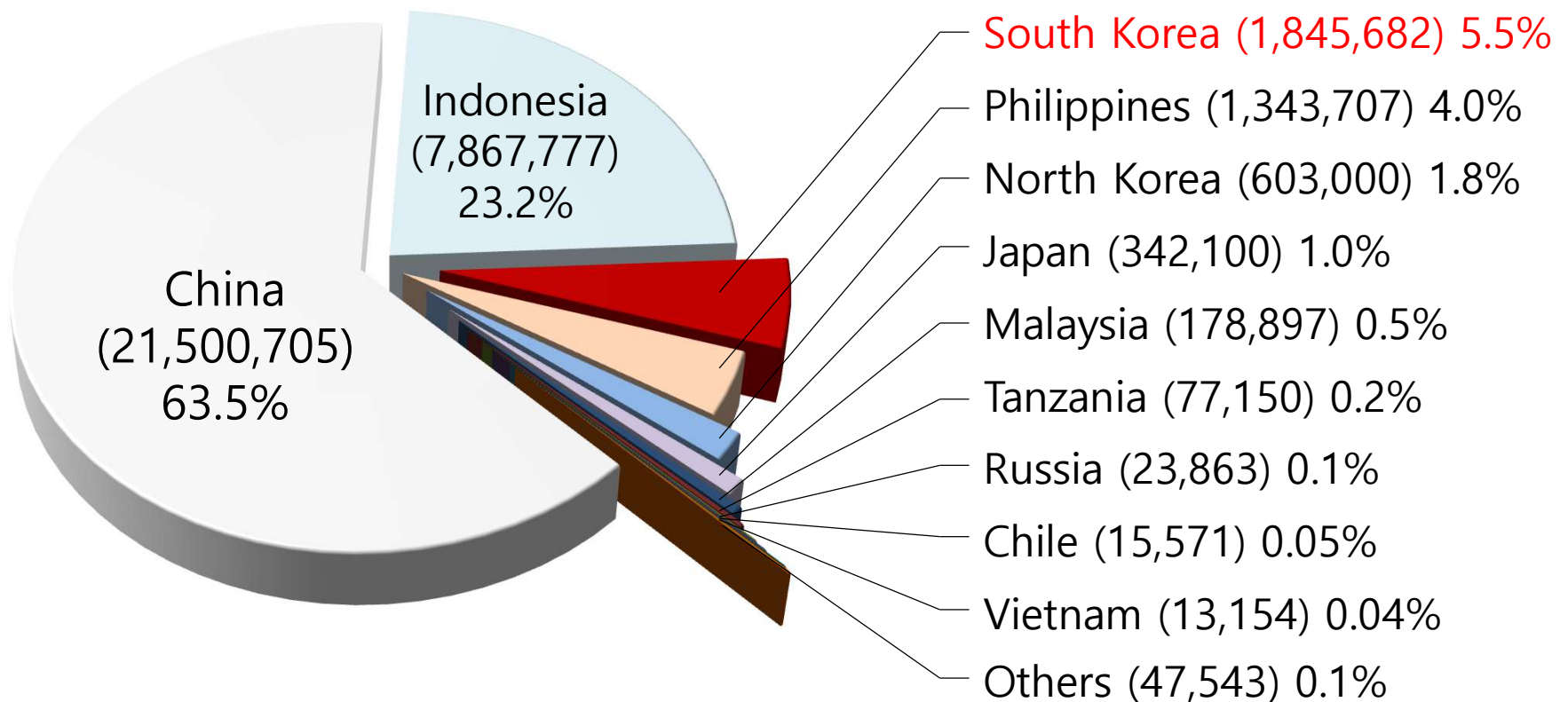
Application of PVP Rights of Seaweeds in Korea (2012~2023)

Total 37 varieties: 31 *Pyropia*, 5 *Undaria*, 1 *Saccharina*
 **Pyropia*: Korea 31, Japan 17, China 6



Aquaculture of *Pyropia* in Korea

Seaweed Aquaculture Production by Country



Worldwide production : 33,859,148 M/T (as of 2021, FAO 2024), wet weight

Overview of Seaweed Industry in Korea

- the 3rd producer of the world seaweed production
- Seaweed resources : 908 species
(Green 123, Brown 193, Red 592; NIMBRME 2013)
- Production and value of major seaweed species in 2022

Species	2022			
	Production (Ton)	Ratio (%)	Value (USD1,000)	Ratio (%)
<i>Undaria pinnatifida</i>	585,955	33.9	117,732	16.2
<i>Saccharina japonica</i>	560,848	32.4	110,893	15.3
<i>Pyropia</i> spp.	550,221	31.8	469,477	64.6
<i>Sargassum fusiforme</i>	13,443	0.8	6,951	1.0
<i>Ulva</i> spp.	6,283	0.4	5,157	0.7
<i>Capsosiphon fulvescens</i>	4,273	0.2	12,084	1.7
<i>Ecklonia stolonifera</i>	3,708	0.2	1,102	0.2
<i>Codium fragile</i>	2,462	0.1	1,617	0.2
<i>Gacilariopsis chorda</i>	2,356	0.1	948	0.1
<i>Sargassum fulvellum</i>	320	0.0	644	0.1
Other algae	2	0.0	-	0.0
Total	1,729,871	100	726,605	100

Data from the Ministry of Oceans & Fisheries, wet wt.



Pyropia



Undaria



Saccharina



Hizikia



Sargassum



Ecklonia



Ulva



Capsosiphon

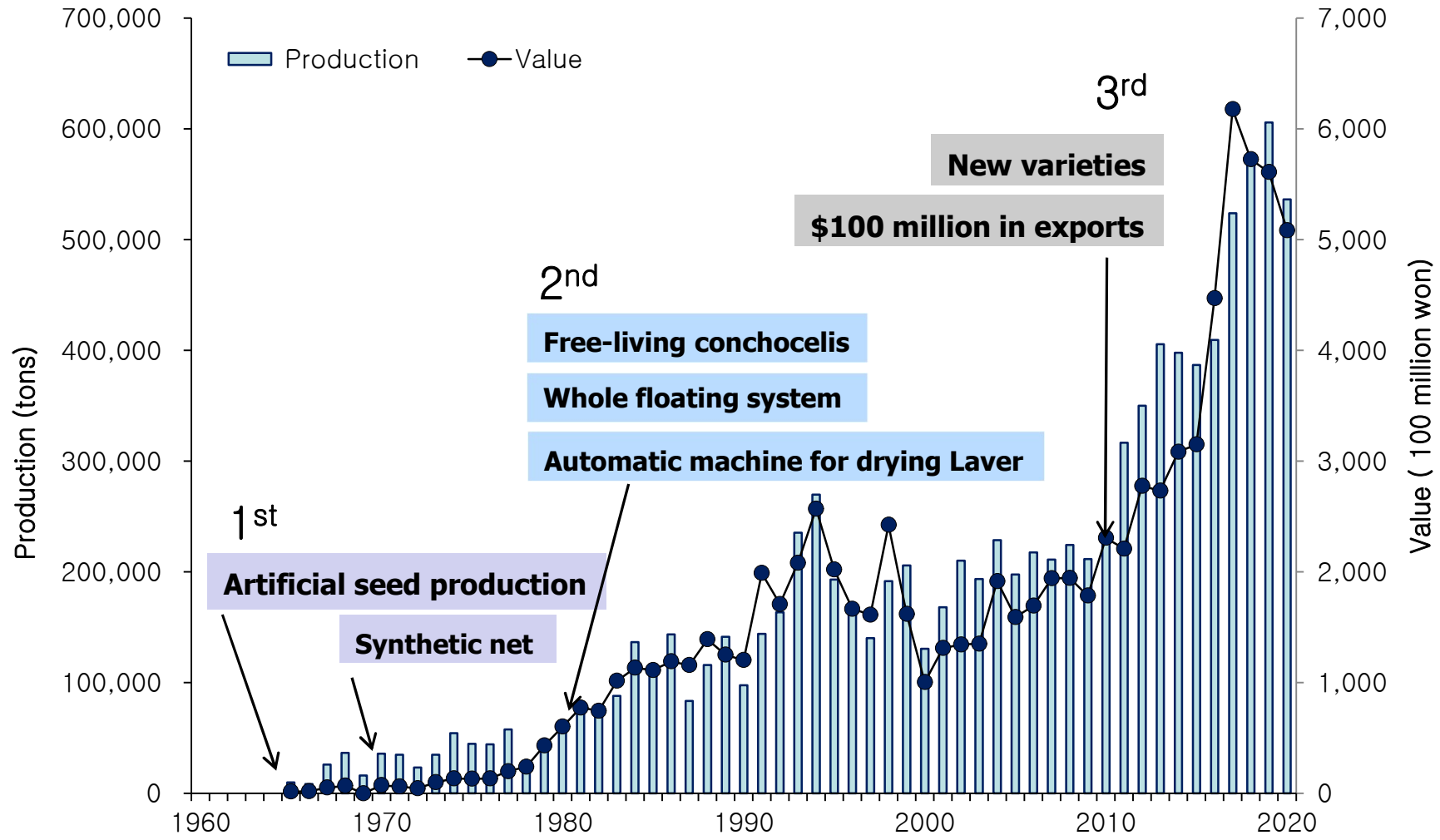


Codium



Gracilariopsis

Pyropia Production in Korea



Comparison of Production in 3 Countries

A: average annual growth rate

year country	Production (1,000 M/T)				Value (1,000\$)			
	2000	2010	2020	A	2000	2010	2020	A
Korea	130.5	235.5	547.6	7.4%	100,276	230,588	474,956	8.1%
China	424.9	1,040.7	2,219.8	8.6%	195,460	596,308	1,354,310	10.2%
Japan	391.7	328.7	288.7	-1.5%	981,673	971,966	1,036,545	0.3%

◆ *Pyropia* species for aquaculture

Korea: *P. yezoensis*, *P. dentate*, *P. seriata*

China: *P. yezoensis*, *P. haitanensis*

Japan: *P. yezoensis*



Procedure of *Pyropia* cultivation

1. Conchocelis culture → 2. Conchocelis-bearing shells → 3. Seeding



4. Cultivation



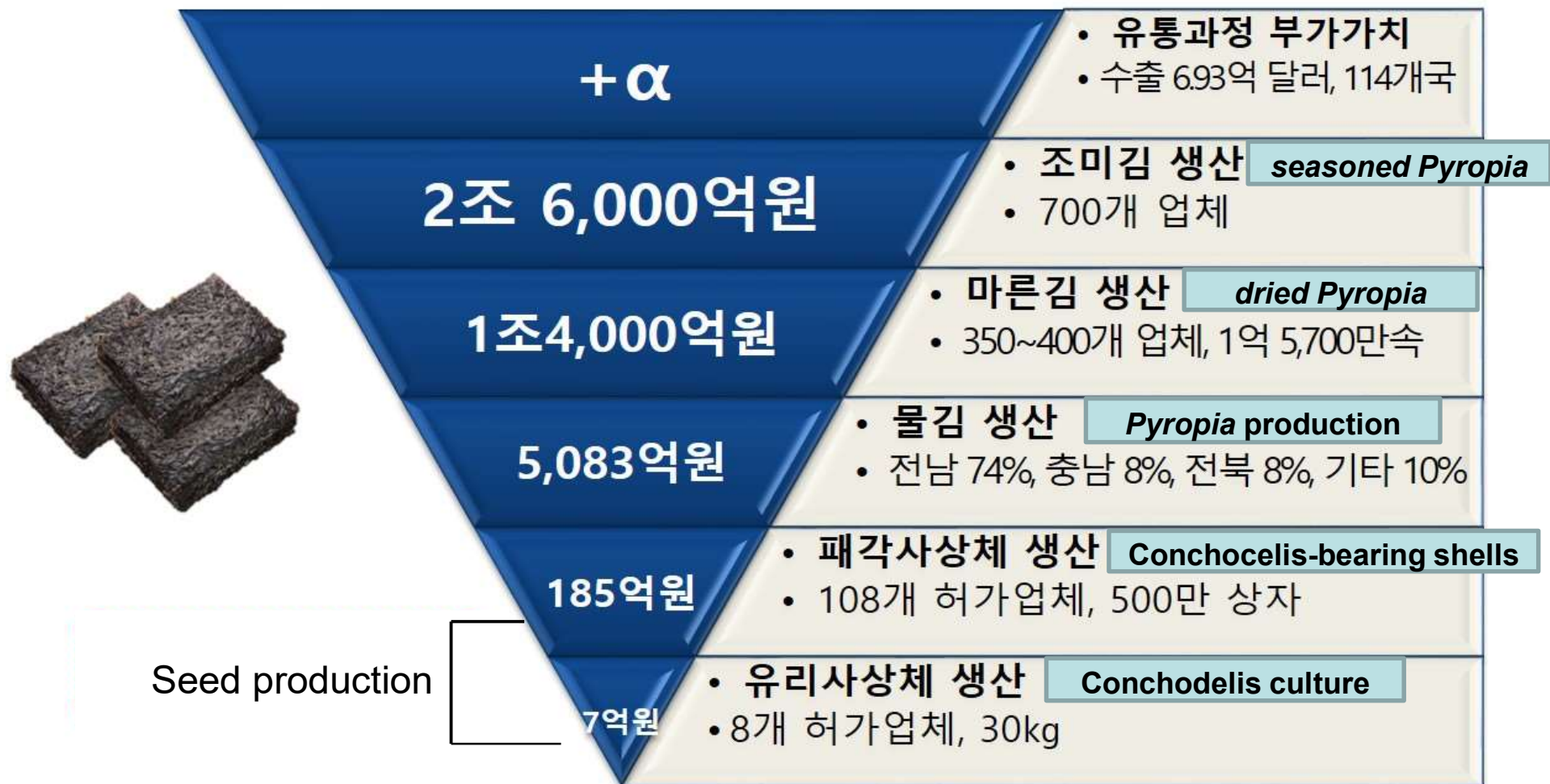
5. Harvest



6. Process of drying *Pyropia*

Structure and Size of *Pyropia* Industry in Korea

» about 5 trillion won (\$3.8 billion) in 2023



Export of *Pyropia*

➤ *Pyropia* (Gim) industry: Growing into an export-driven food industry

- Export reaching record high of \$790 million in 2023
- No. 1 in agricultural and fisheries exports

Export to 122 countries (2023)



Annual Export Amount

\$100 million in 2010



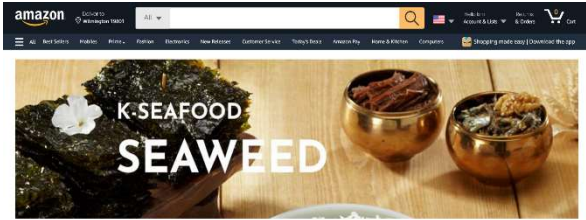
\$790 million in 2023

17% growth annually

2010년

2023년

Pyropia Products



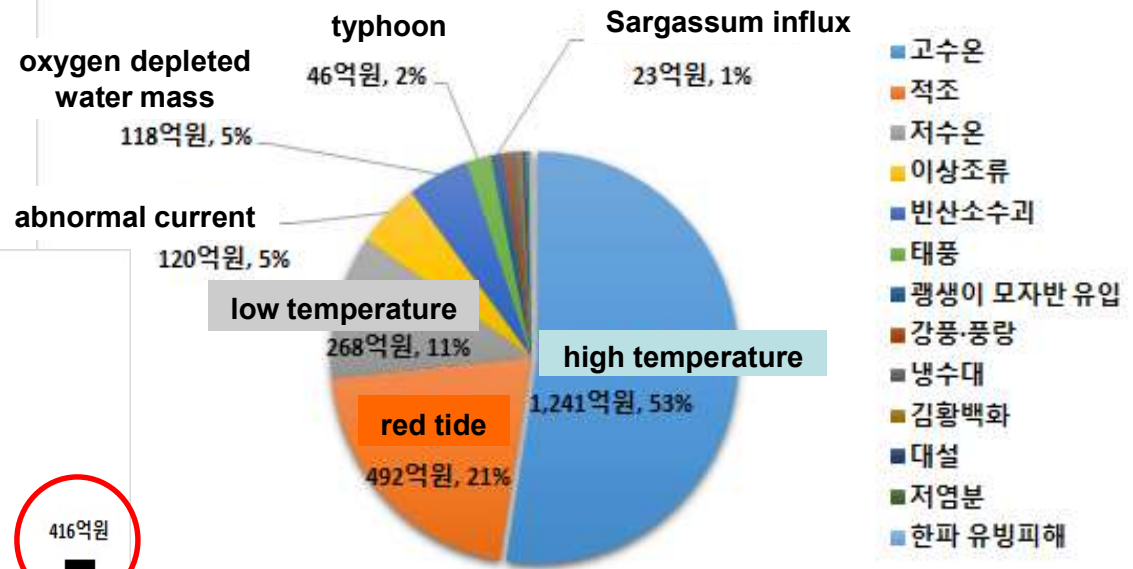
Frozen Gimbap



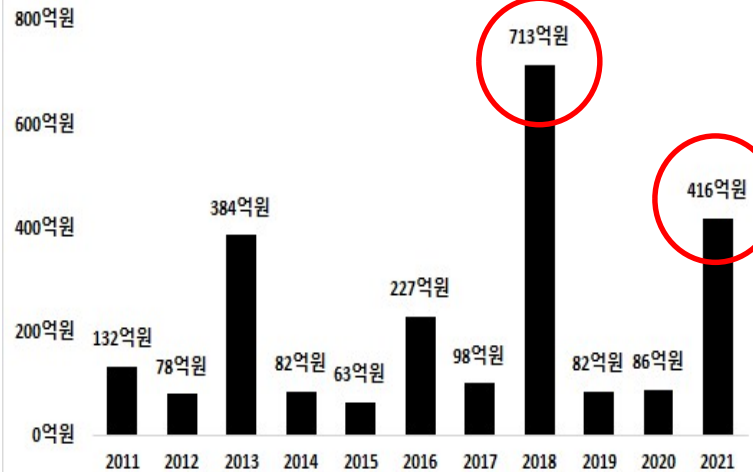
Hot Issue in *Pyropia* Cultivation

Damage of Natural Disaster in the Fisheries

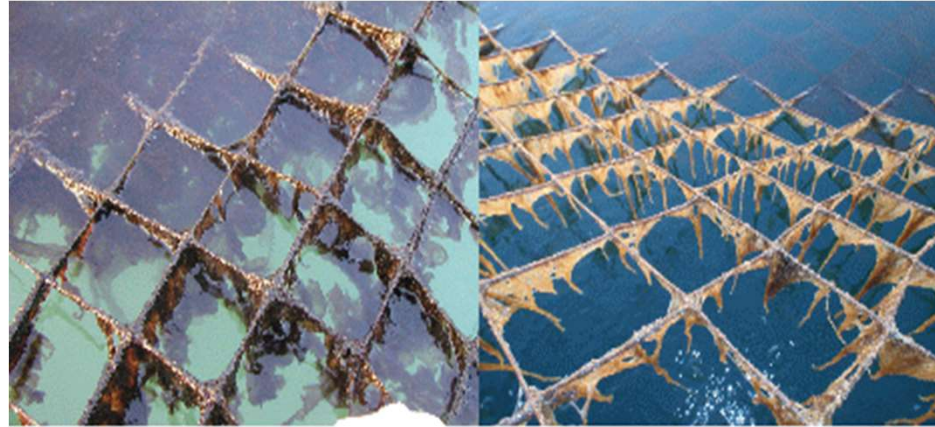
Damage by natural disaster (2011-2021)



Annual damage



Discoloration (Chlorosis) of *Pyropia*



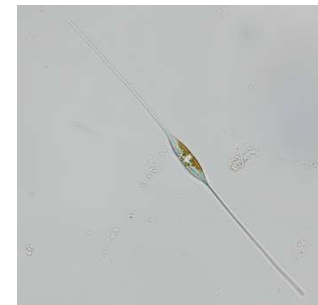
normal

discolorated

- Remarkably reduced photosynthetic pigments and enlarged vacuoles in the cell, due to lack of nutrients in seawater

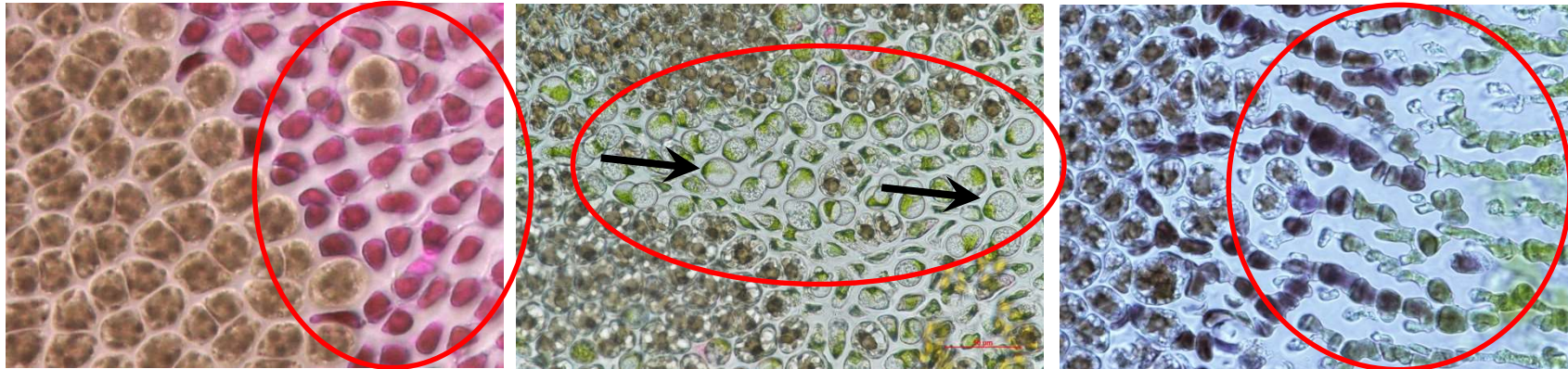


Large-scale discoloration in Haenam aquafarm (2022)



Cylindrotheca closterium

Diseases by *Pythium*, *Olpidiopsis*, etc.



Pythium

Olpidiopsis

virus

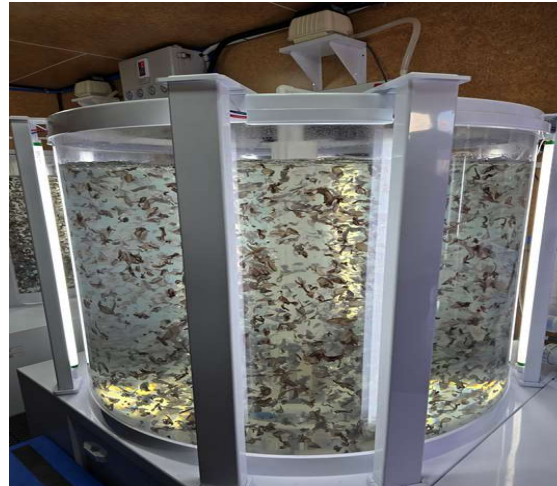
Seedlings melting away due to high temperature



* Large scale damage in 6 counties of Jeonnam (2021)

Solution on Climatic changes

- 1) Development of high-temperature tolerant and disease resistant varieties
- 2) Research on pathogens (fungi, bacteria, virus, etc.)
- 3) Research on environmental carrying capacity of *Pyropia* aquafarms
- 4) Development of land-based aquaculture technology
- 5) Relocation of aquafarms



International Cooperation for Seaweed Industry



Go to www.menti.com and use the code 5227 7107

Welcome to the FAO Seaweed Aquaculture Policy Dialogue

The Policy Dialogue will start at 9:00 Rome time.
Please mute your mics.

After the presentations we will have a short mentimeter session. In preparation, please feel free to go to menti.com on your mobile phone or computer and enter in the code at the top of the screen. Once we start the mentimeter session you will be able to submit your responses and see the live results.

INTERNATIONAL YEAR OF
ARTISANAL FISHERIES
AND AQUACULTURE
2022

Seaweed Insights FARM INSIGHTS GLOBAL PRODUCTION MARKET REPORT ABOUT

<https://seaweedinsights.com>

by HATCH
Innovation Services

sponsored by the Nest

FARM INSIGHTS GLOBAL PRODUCTION

In 2022 we conducted an in-field survey with seaweed farmers across the major seaweed producing regions globally. This report provides our insights from the field reality of the top 5 commercially produced seaweed species today.

* Hot interest in the seaweed industry by FAO, WB, WWF

Green Harvest in South Korean Waters



Jindo

Haenam

Wando

Nohwado

Bogildo

Soando



Thank you!