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[Note]

Cultivation of *Laminaria japonica* (Laminariales, Phaeophyta) in Udo Coast, Jeju, Korea

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In order to produce *Laminaria japonica* in Jeju as feed for abalone, a transplant experiment was performed with the Baekryungdo and the Wando cultivar stocks at the Udo aquafarm from January to July 2003. Eight water conditions at the aquafarm and eleven traits of the two cultivar stocks were measured once a month. The water temperature ranged from 12.9°C to 23.5°C. The salinity was 31.3-36.8‰; the DO was 5.40-9.86 $mg \cdot l^{-1}$; the pH was 7.82-9.61. Concentrations of NO_2-N, NO_3-N, NH_4-N and PO_4-P were 0.02-0.15 μM, 2.27-3.49 μM, 0.16-0.56 μM and 0.07-0.99 μM, respectively. The whole frond length of the Baekryungdo and the Wando specimens were 173.84 and 153.67 cm. The blade width, stipe length, blade length, fascia length, blade thickness, total weight and substantiality of the Baekryungdo and the Wando specimens were 14.61 and 13.05 cm, 3.94 and 3.02 cm, 169.88 and 150.65 cm, 155.81 and 137.10 cm, 1.01 and 0.96 cm, 258.04 and 200.96 cm, and 101.56 and 94.62, respectively at the conclusion of the experiment in July. The measurements of the Baekryungdo specimens were slightly higher than those of Wando specimens. The fascia width, stipe thickness and fascia thickness of the Wando specimens were slightly higher than those of the Baekryungdo specimens. The relative growth rates of these traits of two cultivar stocks during the growth test were very similar. Generally, the performance of the Baekryungdo cultivar stock seems to be better than that of the Wando samples. Further study of the physiological ecology for cultivation and breeding is needed in the future.

Key Words: cultivation, Jeju, *Laminaria japonica*, transplant

INTRODUCTION

The brown algal genus *Laminaria*, with about 30 described species worldwide (Kain 1991), is native to cold-temperature waters of the northern hemisphere. However, some species are known in the warm temperate regions off the Philippines and Brazil (Joly and Oliveira Filho 1967; Petrov *et al.* 1973). *Laminaria japonica* f. *membranacea*, *L. ochotensis*, *L. cichorioides*, and *L. saccharina* f. *linearis* are naturally distributed in the northern east coast of Korea (Kang 1966), and *L. ochotensis*, *L. cichorioides* and *L. sacchrina* f. *linearis* are also reported as indigenous to the waters off Korea by Kawashima (1993). For cultivation, *L. religiosa* (Chang and Geon 1970; Chang and Chung 1971) and *L. japonica* (Baik and Pyen 1973; Chang *et al.* 1973) were transplanted from Hokkaido, Japan to Ilsan and Ilkwang Bay on the southeast coast and Jumunjin on the central east coast of Korea. Since then the aquarfarms have expanded to the south and west coast due to successful transplanting from the east coast.

Nowadays, natural wild populations of *Laminarias* that have been found in the east and south coast maybe due to the recruitment of spores from aquafarms (Nam *et al.* 1985; Sohn 1987, 1996), and the west coast due to the transplant.

Studies on cultivation (Chang and Geon 1970; Chang and Chung 1971; Chang *et al.* 1973; Baik and Park 1979), seed culture (Bae *et al.* 1977; Baik 1977), ecology (Nam *et al.* 1985; Sohn 1987), growth and morphological variation (Park 1975; Chang and Sohn 1993; Gong 1993),

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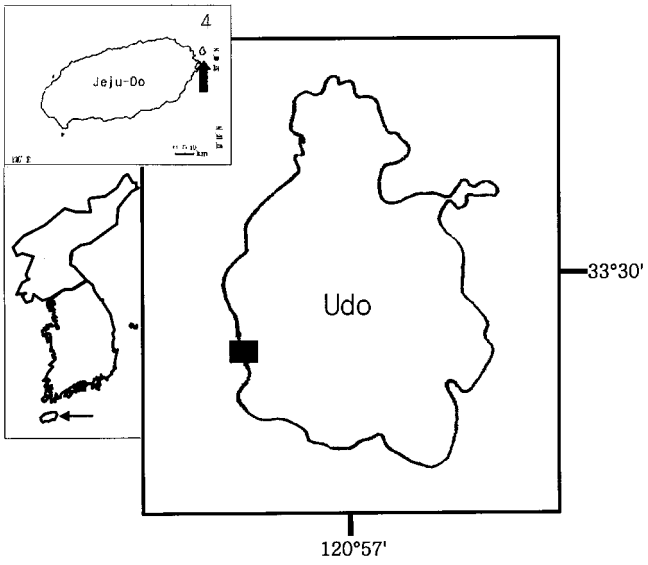

Fig. 1. The experimental site for the growth test.

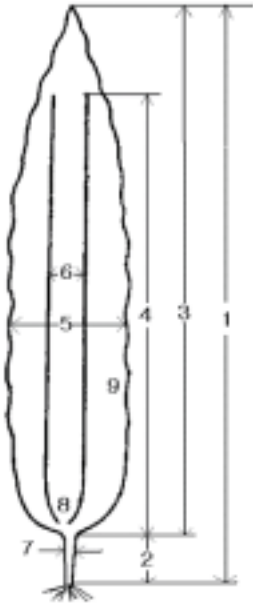

Fig. 2. External feature of the thallus of *Laminaria japonica*: 1, whole frond length; 2, stipe length; 3, blade length, 4, fascia length; 5, blade width; 6, fascia width, 7, stipe thickness; 8, fascia thickness; 9, blade thickness. Total weight and substantiality was not showed in this illustration.

gametogensis and early sporophyte development (Lee 1992), fine structure (Chung 1990), germination, growth and production (Kang 1999), and molecular phylogeny (Boo *et al.* 1999; Yoon 1999; Boo and Yoon 2000; Yoon and Boo 1999) of *Laminarias* in Korea have been reported.

Only a few species of *Laminaria* have been cultivated as a food source for human being as sea-vegetable or feed for abalones and other gastropods. This cultivation is one of the largest aquaculture industries in China, Japan and Korea. Its local names are “Haidai” in China, “Kombu” in Japan, and “Dasima” in Korea (Ohno and Largo 1998; Sohn 1998; Wu 1998).

In Jeju, although the abalone aquaculture has been increasing, feed for abalones, such as *Laminaria*, has been purchased from other places such as Jeollanamdo. Therefore, the cultivation experiment with two cultivars, the Baekryungdo and the Wando stocks, was performed at the Udo aquafarm in Jeju area from January to July 2003 to produce feed for abalones as a part of the ecological breeding studies of *Laminaria.*

MATERIALS AND METHODS

Seed collectors introduced from Baekryungdo and Wando aquafarms were cultivated in the Udo aquafarm, Jeju, where the sporelings were allowed to grow to about 2-3 cm long. The seeded strings were cut into 3-4 cm length and inserted at 30 cm intervals into intermediate slender ropes. The ropes were wound around the main cultivation ropes at depths of 1 m.

The provisional outplanting was started on October 6, 2002, when the water temperature was 21.5°C and the specific gravity, 1.0220. Regular full scale cultivation began on December 15, 2000, when the water temperature was 11.0°C and the specific gravity, 1.0240.

The experimental site for the growth test and the external feature of the thallus of *Laminaria* are shown in Figs 1 and 2, respectively. Eleven traits were measured monthly when plants were collected. The traits were whole frond length, stipe length, blade length, fascia length, blade width, fascia width, stipe thickness, fascia thickness, blade thickness, total weight, and substantiality. The transformed data of each traits using ratural log were used to estimate the relative growth rates (Erans 1972; Hunt 1982).

Water temperature and salinity were measured by a DO meter (YSI, Model 85 with 10 ft cable). Water was collected in 1.8 *l* portable midlayer water sampler with a thermometer (Wildlife Supply Co., Model 1920-H60-0896). These samples were used for determination of nitrite-nitrogen (NO_2-N) by the N-(1-Naphthyl)-ethylenedimine dihydrochloride method (Bendschneider and Robinson 1952), nitrate-nitrogen (NO_3-N) by cadmium-copper reduction method (Wood *et al.* 1967), ammonia-nitrogen (NH_4-N) by phenol-hypochlorite method (Solórzano 1969), and phosphate-phosphorus (PO_4-P) by ascorbic acid method (Murphy and Riley

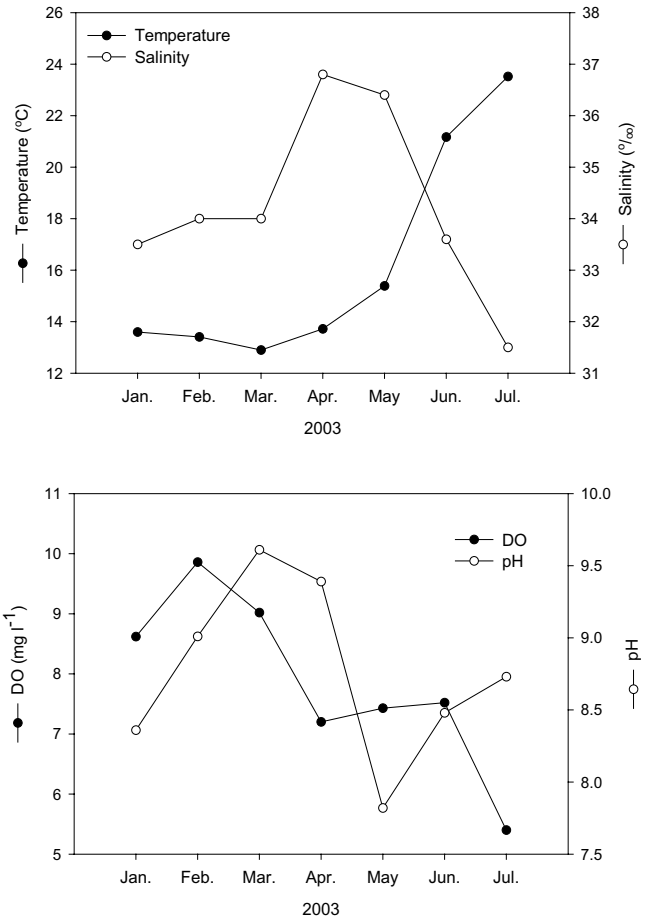

Fig. 3. Variation of water temperature, salinity, dissolved oxygen and pH at the Udo aquafarm.

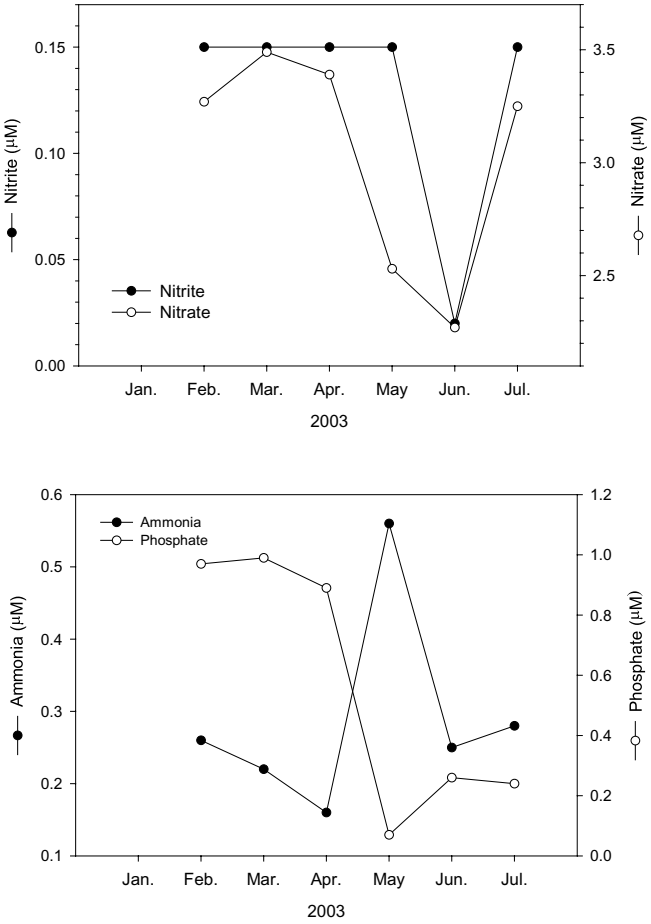

Fig. 4. Variation of nitrite-nitrogen (NO_2-N), nitrate-nitrogen (NO_3-N), ammonia-nitrogen (NH_4-N) and phosphate-phosphorus (PO_4-P) at the Udo aquafarm.

1962).

RESULTS AND DISCUSSION

Fig. 3 shows the variation of water temperature, water salinity, dissolved oxygen and pH at the Udo aquafarm from January to July, 2003. The water temperature ranged from 12.9°C to 23.5°C; the water temperature was the lowest in March and the highest in July. The salinity was fluctuated from 31.3‰ in July to 36.8‰ in April. DO changed from 5.40 mg·l^{-1} in July to 9.86 mg·l^{-1} in February. The pH ranged from 7.82 in May to 9.61 in March.

Fig. 4 shows the variation of NO_2-N, NO_3-N, NH_4-N and PO_4-P from February to July, 2003. NO_2-N was 0.15 μM from February to May and July, but was 0.02 μM in June; NO_3-N ranged from 2.27 μM in June to 3.49 μM in March; NH_4-N was fluctuated from 0.16 μM in April to 0.56 μM in May; NH_4-N has increased suddenly in May. The PO_4-P was varied from 0.07 μM in May to 0.99 μM in March and PO_4-P recorded lowest in May.

Fig. 5 shows a monthly comparison of the whole frond length of the Baekryungdo cultivar stock (BRD) and Wando cultivar stock (WD) samples of *Laminaria japonica.* The whole frond length of the BRD was longer than those of the WD. The relative frond growth rate of the BRD during the growth test was 0.013 (Table 1). The length of the two cultivars shortened in July; this seems to be because a typoon broke off the longer and larger individuals.

Fig. 6 shows a monthly comparison of the blade width of the two cultivars. The blade width of the BRD was wider than that of the WD. The relative blade width growth rates of the BRD and WD during the growth test were 0.010 and 0.009, respectively (Table 2).

Fig. 7 shows a monthly comparison of the stipe length of the two cultivars. The stipe length of the WD was shorter than that of the BRD after June. The stipe length of the two cultivars abruptly shortened in July; this seems to be due to a typhoon breaking off the large

Table 1. Mean whole frond length and its relative growth rate of the two cultivars of *Laminaria japonica* at the Udo aquafarm

Cultivars / date	Whole frond length (cm)						
	Jan 10 (0 d)	Feb 07 (28d)	Mar 11 (60d)	Apr 10 (90d)	May 12 (122d)	Jun 26 (167d)	Jul 27 (198d)
Baekryungdo	0.56	18.61	81.15	180.91	215.9	218.88	173.83
Wando	0.34	16.65	76.18	152.29	197.2	207.53	153.67
Cultivars / period	Relative growth rate						
	0-28	28-60	60-90	90-122	122-167	167-198	0-198
Baekryungdo	0.125	0.046	0.027	0.006	0.000	-0.007	0.013
Wando	0.139	0.048	0.023	0.008	0.001	-0.010	0.012

Table 2. Mean blade width and its relative growth rate of the two cultivars of *Laminaria japonica* at the Udo aquafarm

Cultivars / date	Mean blade width (cm)						
	Jan 10 (0 d)	Feb 07 (28d)	Mar 11 (60d)	Apr 10 (90d)	May 12 (122d)	Jun 26 (167d)	Jul 27 (198d)
Baekryungdo	0.1	2.68	6.85	12.23	13.40	12.84	14.61
Wando	0.1	2.35	4.95	12.16	12.57	12.53	13.05
Cultivars / period	Relative growth rate						
	0-28	28-60	60-90	90-122	122-167	167-198	0-198
Baekryungdo	0.117	0.029	0.019	0.003	-0.001	0.004	0.010
Wando	0.113	0.023	0.030	0.001	0.000	0.001	0.009

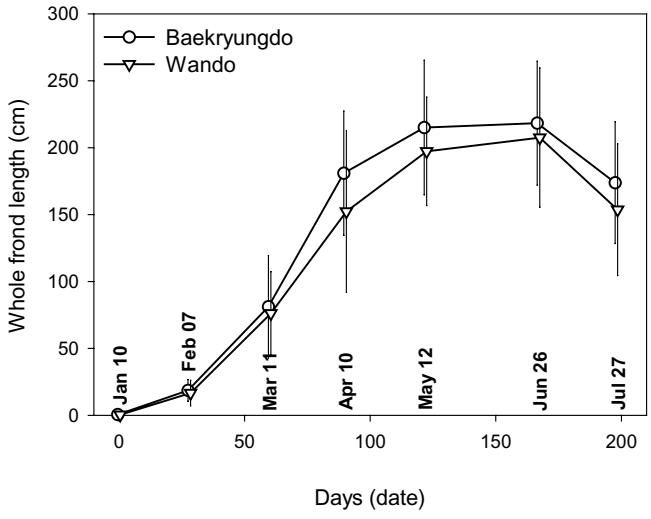

Fig. 5. Comparison of whole frond length of the two cultivars of *Laminaria japonica* at the Udo aquafarm.

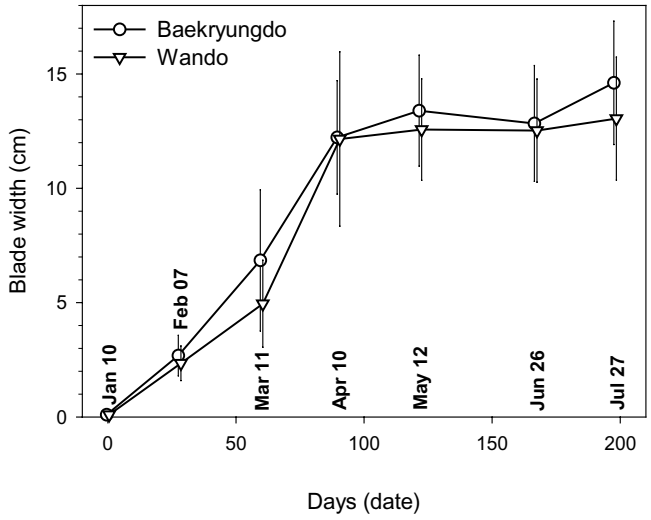

Fig. 6. Comparison of blade width of the two cultivars of *Laminaria japonica* at the Udo aquafarm.

individuals. The relative stipe growth rates of the BRD and WD during the growth test were 0.006 and 0.005, respectively (Table 3).

Fig. 8 shows a monthly comparison of the blade length of the two cultivars. The blade length of the BRD was longer than that of the WD. The length of the two cultivars decreased in July. The relative blade growth rates of the BRD and the WD during the growth test were 0.014 and 0.013, respectively (Table 4).

Fig. 9 shows a monthly comparison of the fascia length of the two cultivars. The fascia length of the BRD was longer than that of the WD. The length of the BRD

Table 3. Mean stipe length and its relative growth rate of the two cultivars of *Laminaria japonica* at the Udo aquafarm

Cultivars / date	Mean stipe length (cm)						
	Jan 10 (0 d)	Feb 07 (28d)	Mar 11 (60d)	Apr 10 (90d)	May 12 (122d)	Jun 26 (167d)	Jul 27 (198d)
Baekryungdo	0.1	1.38	3.08	4.07	5.23	7.37	3.94
Wando	0.1	1.36	3.61	4.79	5.00	6.54	3.02
Cultivars / period	Relative growth rate						
	0-28	28-60	60-90	90-122	122-167	167-198	0-198
Baekryungdo	0.094	0.025	0.009	0.008	0.008	-0.020	0.006
Wando	0.093	0.031	0.009	0.001	0.006	-0.025	0.005

Table 4. Mean blade length and its relative growth rate of the two cultivars of *Laminaria japonica* at the Udo aquafarm

Cultivars / date	Mean blade length (cm)						
	Jan 10 (0 d)	Feb 07 (28d)	Mar 11 (60d)	Apr 10 (90d)	May 12 (122d)	Jun 26 (167d)	Jul 27 (198d)
Baekryungdo	0.5	16.96	78.06	176.84	209.83	210.97	169.88
Wando	0.3	15.01	71.82	147.50	192.23	200.99	150.65
Cultivars / period	Relative growth rate						
	0-28	28-60	60-90	90-122	122-167	167-198	0-198
Baekryungdo	0.122	0.048	0.027	0.005	0.000	-0.007	0.014
Wando	0.135	0.049	0.024	0.008	0.001	-0.009	0.013

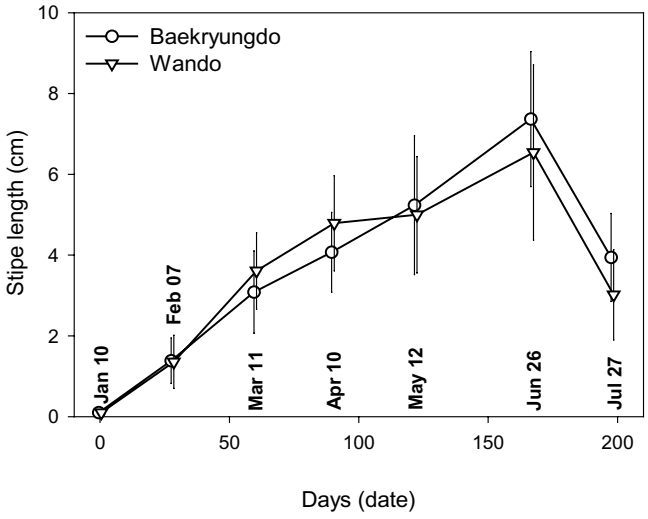

Fig. 7. Comparison of stipe length of the two cultivars of *Laminaria japonica* at the Udo aquafarm.

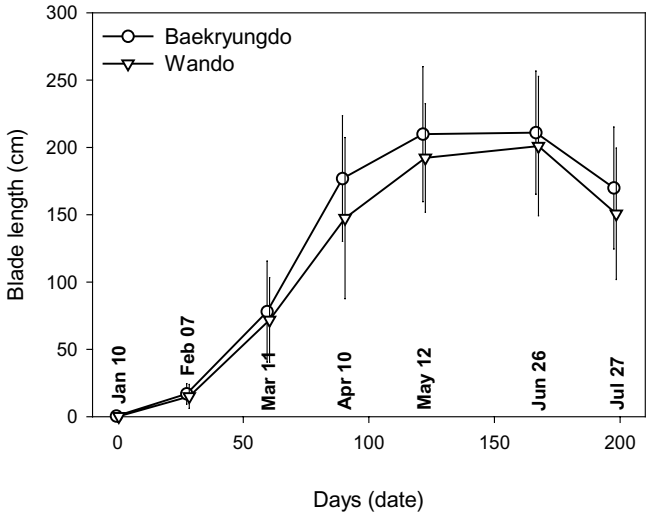

Fig. 8. Comparison of blade length of the two cultivars of *Laminaria japonica* at the Udo aquafarm.

decreased after May, and that of the WD samples decreased after June. The relative linear fascia growth rates of the BRD and the WD during the growth test were 0.016 and 0.015, respectively (Table 5).

Fig. 10 shows a monthly comparison of the fascia width of the two cultivars. Generally, the fascia width of the two cultivars increased during the growth test, and that of the WD was wider than that of the BRD after May. The relative fascia growth rates of the BRD and the WD in terms of width were 0.010 and 0.011, respectively (Table 6).

Fig. 11 shows a monthly comparison of the stipe

Table 5. Mean fascia length and its relative growth rate of the two cultivars of *Laminaria japonica* at the Udo aquafarm

Cultivars / date	Mean fascia length (cm)						
	Jan 10 (0 d)	Feb 07 (28d)	Mar 11 (60d)	Apr 10 (90d)	May 12 (122d)	Jun 26 (167d)	Jul 27 (198d)
Baekryungdo	0.2	9.98	31.17	142.53	180.63	166.00	155.81
Wando	0.1	7.70	22.13	125.92	152.53	154.55	137.1
Cultivars / period	Relative growth rate						
	0-28	28-60	60-90	90-122	122-167	167-198	0-198
Baekryungdo	0.103	0.036	0.051	0.007	-0.002	-0.002	0.016
Wando	0.111	0.033	0.058	0.006	0.000	-0.004	0.015

Table 6. Mean fascia width and its relative increase rate of the two cultivars of *Laminaria japonica* at the Udo aquafarm

Cultivars / date	Mean fascia width (cm)						
	Jan 10 (0 d)	Feb 07 (28d)	Mar 11 (60d)	Apr 10 (90d)	May 12 (122d)	Jun 26 (167d)	Jul 27 (198d)
Baekryungdo	0.05	1.10	1.87	4.08	4.68	4.61	6.49
Wando	0.03	0.89	0.87	3.76	4.43	4.96	6.62
Cultivars / period	Relative growth rate						
	0-28	28-60	60-90	90-122	122-167	167-198	0-198
Baekryungdo	0.024	0.017	0.026	0.004	0.000	0.011	0.010
Wando	0.034	-0.001	0.049	0.005	0.003	0.009	0.011

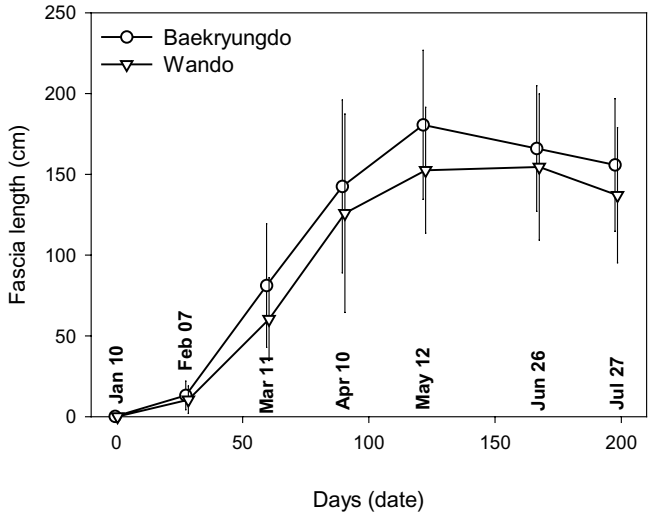

Fig. 9. Comparison of fascia length of the two cultivars of *Laminaria japonica* at the Udo aquafarm.

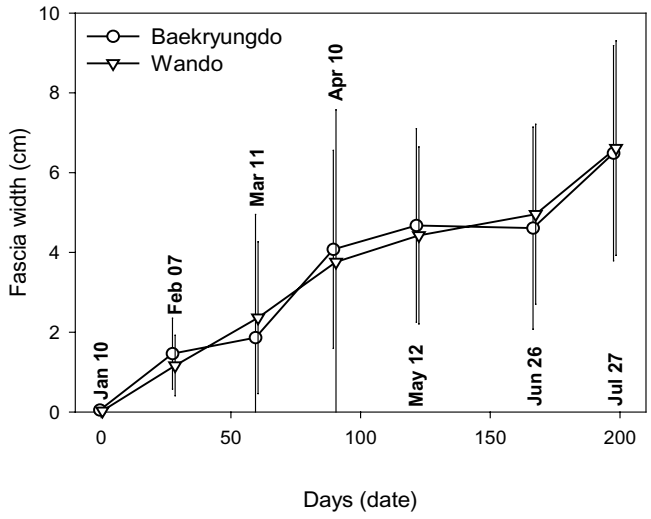

Fig. 10. Comparison of fascia width of the two cultivars of *Laminaria japonica* at the Udo aquafarm.

thickness of the two cultivars. The stipe thickness of the WD was thicker than that of the BRD after June. Stipe thickness of both cultivar samples decreased in July. The relative stipe thickness growth rate of the BRD and the WD during the growth test were 0.006 and 0.007, respectively (Table 7).

Fig. 12 shows the monthly comparison of the fascia thickness of the two cultivars. The fascia thickness of the WD was slightly thicker than that of the BRD in February, June and July. Fascia thickness of both stocks decreased after June. The relative fascia thickness growth rates of the BRD and the WD in terms of thickness

Table 7. Mean stipe thickness and its relative growth rate of the two cultivars of *Laminaria japonica* at the Udo aquafarm

Cultivars / date	Mean stipe thickness (mm)						
	Jan 10 (0 d)	Feb 07 (28d)	Mar 11 (60d)	Apr 10 (90d)	May 12 (122d)	Jun 26 (167d)	Jul 27 (198d)
Baekryungdo	0.1	1.14	3.24	4.42	5.27	5.30	3.43
Wando	0.1	0.90	2.95	4.46	4.70	5.52	3.92
Cultivars / period	Relative growth rate						
	0-28	28-60	60-90	90-122	122-167	167-198	0-198
Baekryungdo	0.251	0.033	0.010	0.005	0.000	-0.014	0.006
Wando	0.243	0.037	0.014	0.002	0.004	-0.011	0.007

Table 8. Mean fascia thickness and its relative increase rate of the two cultivars of *Laminaria japonica* at the Udo aquafarm

Cultivars / date	Mean fascia thickness (mm)						
	Jan 10 (0 d)	Feb 07 (28d)	Mar 11 (60d)	Apr 10 (90d)	May 12 (122d)	Jun 26 (167d)	Jul 27 (198d)
Baekryungdo	0.01	0.11	0.84	1.52	1.98	2.32	1.81
Wando	0.01	0.16	0.75	1.18	1.86	2.39	1.84
Cultivars / period	Relative growth rate						
	0-28	28-60	60-90	90-122	122-167	167-198	0-198
Baekryungdo	0.068	0.064	0.020	0.008	0.004	-0.008	0.016
Wando	0.081	0.048	0.015	0.014	0.006	-0.008	0.017

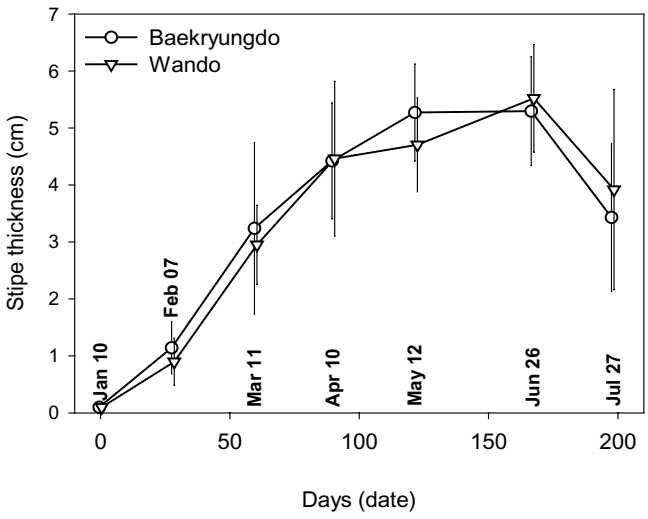

Fig. 11. Comparison of stipe thickness of the two cultivars of *Laminaria japonica* at the Udo aquafarm.

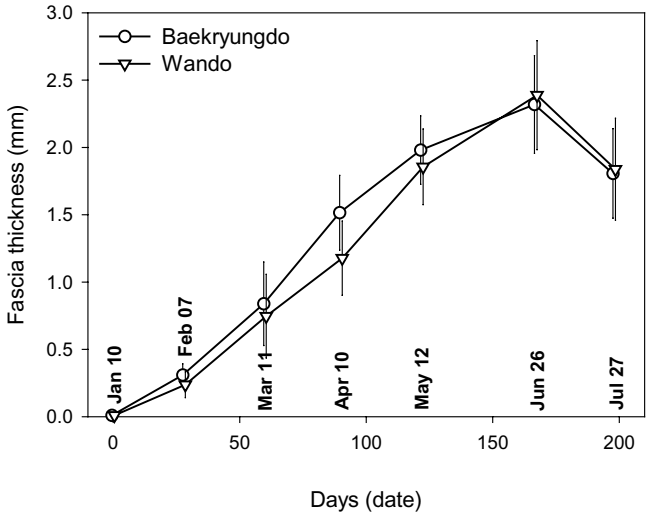

Fig. 12. Comparison of fascia thickness of the two cultivars of *Laminaria japonica* at the Udo aquafarm.

during the growth test were 0.016 and 0.017, respectively (Table 8).

Fig. 13 shows a monthly comparison of the blade thickness of the two cultivars. The blade thickness of the BRD was thicker than of the WD. Blade thickness of the two cultivars decreased in July. The relative weight growth rate of the BRD and the WD during the growth test were 0.014 and 0.013, respectively (Table 9).

Fig. 14 shows a monthly comparison of the total weight of the two cultivars. Generally, the total weight of the BRD was heavier than that of the WD, and that of both cultivars decreased in July. The relative total weight

Table 9. Mean blade thickness and its relative growth rate of the two cultivars of *Laminaria japonica* at the Udo aquafarm

Cultivars / date	Mean blade thickness (mm)						
	Jan 10 (0 d)	Feb 07 (28d)	Mar 11 (60d)	Apr 10 (90d)	May 12 (122d)	Jun 26 (167d)	Jul 27 (198d)
Baekryungdo	0.01	0.1	0.35	0.61	0.81	1.16	1.01
Wando	0.01	0.1	0.32	0.41	0.79	1.04	0.96
Cultivars / period	Relative growth rate						
	0-28	28-60	60-90	90-122	122-167	167-198	0-198
Baekryungdo	0.064	0.039	0.019	0.009	0.008	-0.004	0.014
Wando	0.064	0.036	0.008	0.020	0.006	-0.003	0.013

Table 10. Mean total weight and relative growth rate of the two cultivars of *Laminaria japonica* at the Udo aquafarm

Cultivars / date	Mean total weight (g)						
	Jan 10 (0 d)	Feb 07 (28d)	Mar 11 (60d)	Apr 10 (90d)	May 12 (122d)	Jun 26 (167d)	Jul 27 (198d)
Baekryungdo	0.01	0.82	20.15	121.7	212.7	289.5	258.04
Wando	0.01	0.45	10.40	87.73	186.47	290.87	200.96
Cultivars / period	Relative growth rate						
	0-28	28-60	60-90	90-122	122-167	167-198	0-198
Baekryungdo	0.157	0.100	0.060	0.017	0.007	-0.004	0.034
Wando	0.136	0.098	0.071	0.024	0.010	-0.012	0.032

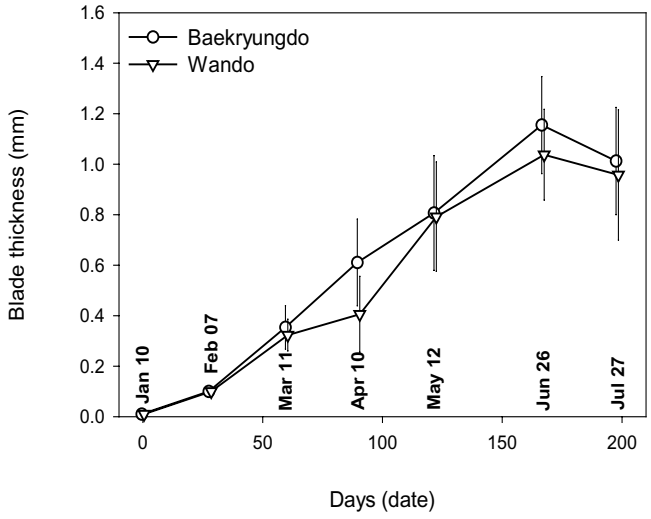

Fig. 13. Comparison of blade thickness of the two cultivars of *Laminaria japonica* at the Udo aquafarm.

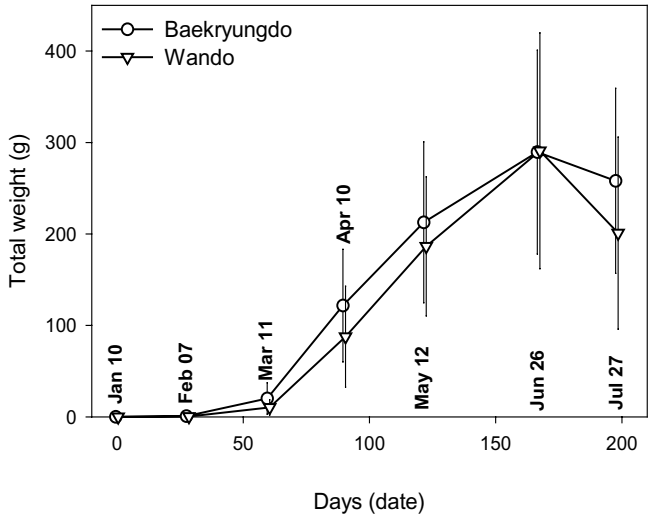

Fig. 14. Comparison of total weight of the two cultivars of *Laminaria japonica* at the Udo aquafarm.

growth rates of the BRD and the WD during the growth test were 0.034 and 0.032, respectively (Table 10).

Fig. 15 shows a monthly comparison of the substantiality of the two cultivars. Generally, the substantiality of the BRD was higher than that of the WD except that in May and Jun. Values of both samples decreased after June. The relative substantiality of both samples was the same, 0.010 (Table 11).

One year growth test can not determine which cultivar stock is superior, thus a variety of performance test over a period of years need to be made so that cultivability and marketability may be improved, including

Table 11. Mean substantialiy and relative growth rate of the two cultivars of *Laminaria japonica* at the Udo aquafarm

Cultivars / date	Mean substantiality						
	Jan 10 (0 d)	Feb 07 (28d)	Mar 11 (60d)	Apr 10 (90d)	May 12 (122d)	Jun 26 (167d)	Jul 27 (198d)
Baekryungdo	0.1	18.04	27.15	52.14	73.10	103.54	101.56
Wando	0.4	8.61	27.09	42.31	73.90	110.83	94.62
Cultivars / period	Relative growth rate						
	0-28	28-60	60-90	90-122	122-167	167-198	0-198
Baekryungdo	0.186	0.013	0.022	0.011	0.008	-0.001	0.010
Wando	0.110	0.036	0.015	0.017	0.009	-0.005	0.010

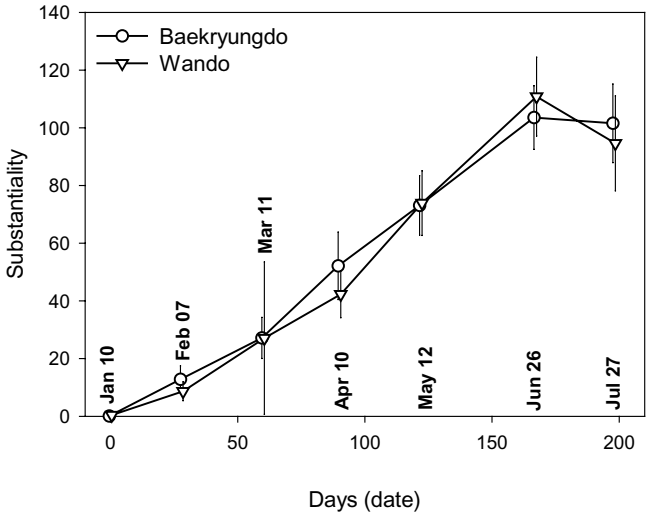

Fig. 15. Comparison of substantiality of the two cultivars of *Laminaria japonica.* at the Udo aquafarm.

increasing yield, improving quality, increasing stability, improving adaptability, and broadening resistance. These are traits that are asked by consumers, traders and farmers.

Also, for the ecological breeding of *Laminarias*, studies on ecomorphology, adaptability, and quantitative-genetical analysis of this marine crop are needed because they are closely related one another. Breeding is artficial evolution, and the taxon has broad morpological variation.

For the first time *Laminaria* cultivation proved successful in Jeju, therefore, laminarian plants may be cuiltivated in Jeju to produce feed for abalones.

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