

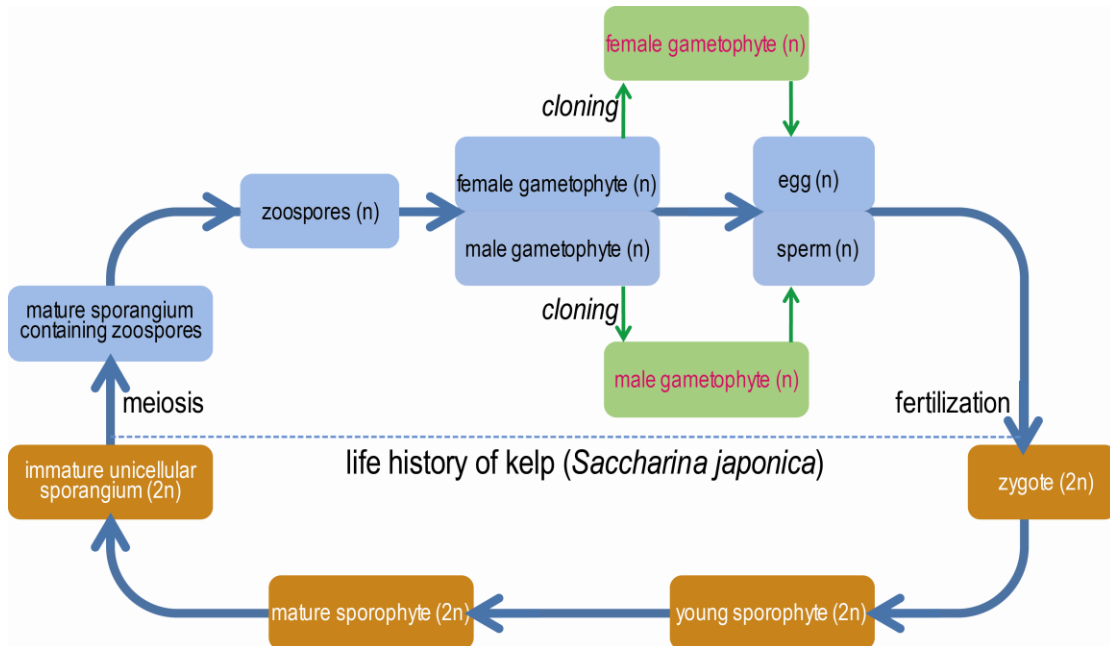
Improving seedless kelp (*Saccharina japonica*) during its domestication by hybridizing gametophytes and seedling-raising from sporophytes

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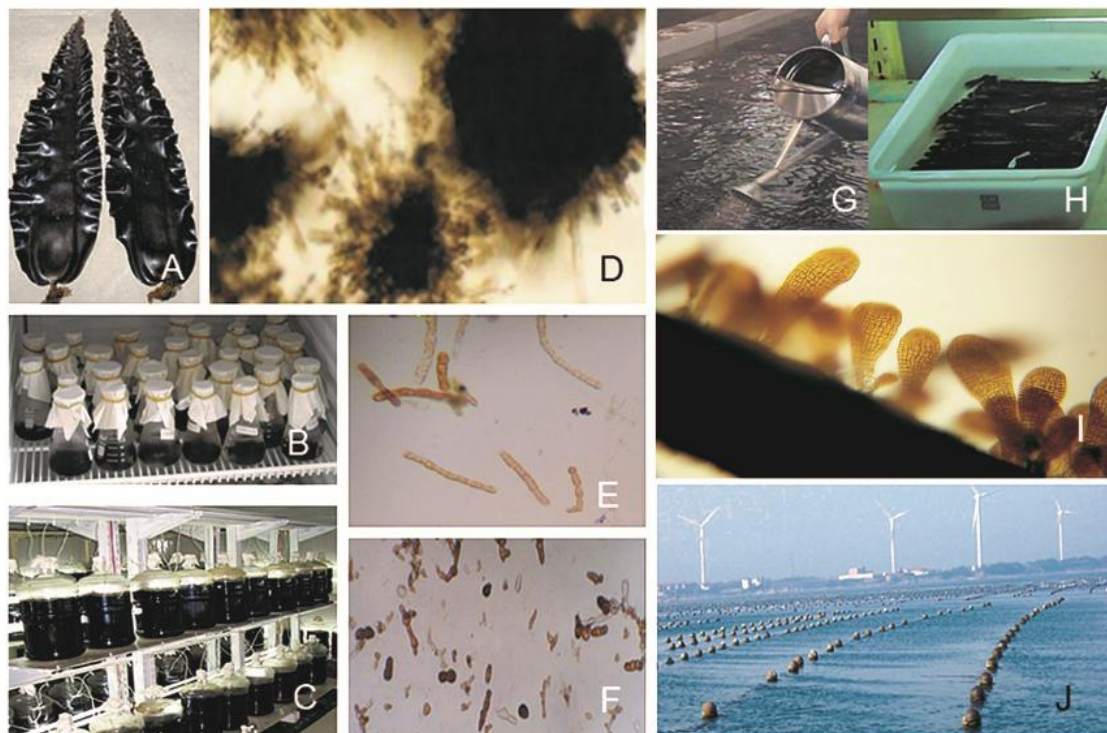
Supplementary Table 1 Microsatellites used to predicting heterosis

<i>Locus</i>	Acc. no.	Sequence (5'-3')	<i>Ta</i> (°C)	Source
<i>D3</i>	CX943083	F: GCGTGGGAGGCTTTCTTC R: CGTGGGATTGCTGATACTG	56	29
<i>D5</i>	CX943061	F: CGGCTTCATCTCCCACAG R: TGACGGAATAGACCCAAA	53	29
<i>D9</i>	CX942859	F: CAATAATCGCAGAAAGGG R: CCGTCCGAACAACCAACT	54	29
<i>H1</i>	DQ978338	F: CAACTCAACTACTGCCACCTA R: GTCCTCATCCGTTTCGTC	59	30
<i>H10</i>	DQ978340	F: TATCCCGTTCGTTCCACTC R: CGACCCTAATAAGCTCTACCT	57	30
<i>H49</i>	DQ978343	F: TGGGTATGATGGATGTTCG R: CAATAATAGCATGGCCGTAA	59	30
<i>H123</i>	DQ978346	F: AAAGGTCGATAAGCTCGCAGTT R: GCGTTGTTTCGCAAAGTGATT	59	30
<i>Zspj5</i>	AB859681	F: CTGTGTATGTGGAGACTGCG R: CTTCTGTGCTGCTGTACGTG	62	31
<i>Zspj6</i>	AB859682	F: CACACCAAAATGCTGCCCTG R: TAGTGGGGAGGAGGGAAAAG	62	31
<i>Zspj8</i>	AB859683	F: GATGGTGATATCATGGTGCG R: CGGCATGAACGTATGTATGG	55	31
<i>Zspj9</i>	AB859684	F: GCGGCTTACCCAATGTTTC R: ACAAACGGGGCTTCCATC	55	31
<i>Zspj14</i>	AB859685	F: CTCGCTGCCACCATAACATTG R: CGCTGTTCTACCACACGAAC	55	31
<i>Zspj19</i>	AB859687	F: GCCCACCAGACAACCTAATC R: CTGTAGTAGAGCCCATAACCCC	62	31
<i>Zspj21</i>	AB859689	F: CAAGTAGCAGACAACACCCC R: CCGAAACCTGCCGAAACT	62	31
<i>Zspj22</i>	AB859690	F: TAGGACGGTATGTGTGCC R: GTACAGAGTAGAAGGGTGGG	62	31
<i>Zspj23</i>	AB859691	F: CGAGAGACCAACACACCAAG R: CGAAGCTCTCCGATCATCAG	55	31
<i>Zspj26</i>	AB859693	F: CGTTTGTCATCTCCCAGTTCC R: CCAATTACCGAGCCAAAGGAG	62	31
<i>Zspj28</i>	AB859694	F: TGCTCCTACAGACGAAAGC R: CCCACATCTTCATCGTTGTCC	62	31
<i>Zspj39</i>	AB859701	F: CTCGGTTCAAAGTTCCGCAAG R: CATCCGCAATTTCTTCCACGG	55	31
<i>Zspj40</i>	AB859702	F: CTACCAGGCATCACACACGA R: GATGCGAGGGTCTATGGTCA	62	31
<i>Zspj43</i>	AB859703	F: CTCGCTAGTATTCCAGAGCAG R: CTGTCCTTACCCAACACGAAG	62	31
<i>Zspj82</i>	AB921195	F: GAGACACACTTTCAGAGGAG R: CTTTGTCTTCCCTTGATCCC	58	31
<i>Zspj89</i>	AB921199	F: GGACAGCAATCGGTACATG R: GGTGAGTGAGCAACAACAG	58	31

Acc. no., accession number; *Ta*, annealing temperature.

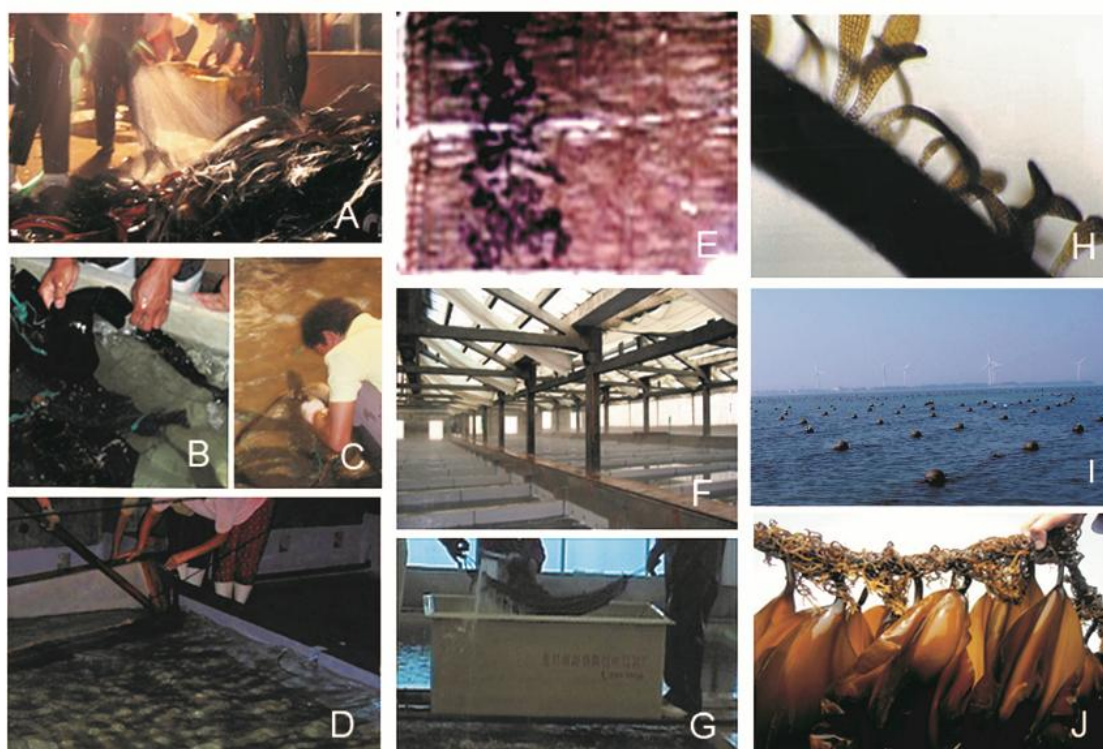


Supplementary Figure 1 Life history of kelp (*Saccharina japonica*)

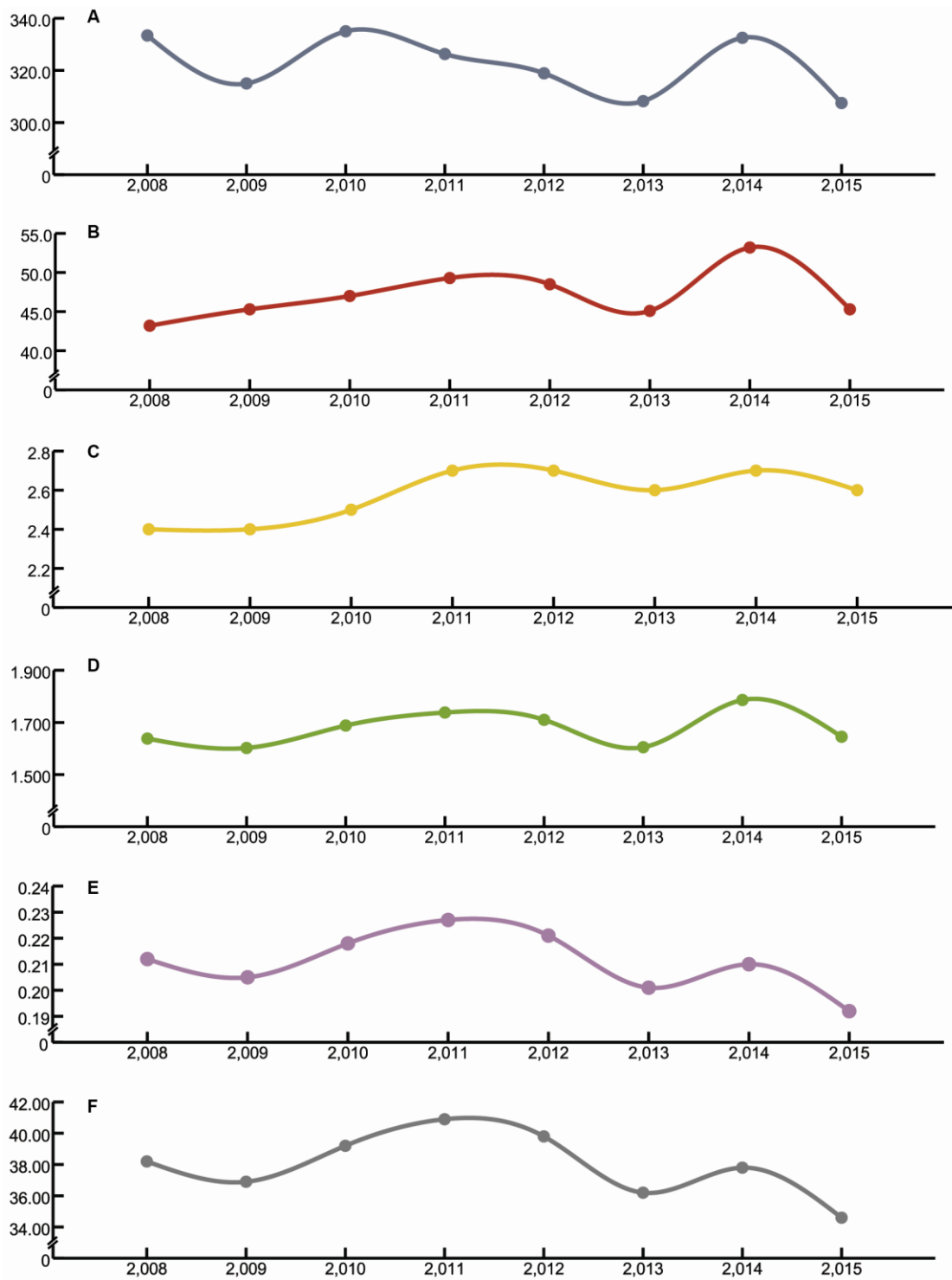


Supplementary Figure 2 Gametophyte clone hybridization and hybrid seedling-raising. From mature sporophytes (A), gametophytes are isolated, cloned and stored at low temperature and under weak light (B). Gametophyte clones are biomass amplified indoor (C), during which the gametophytes are fragmented (E) when they grow into balls (D). Such amplification may be

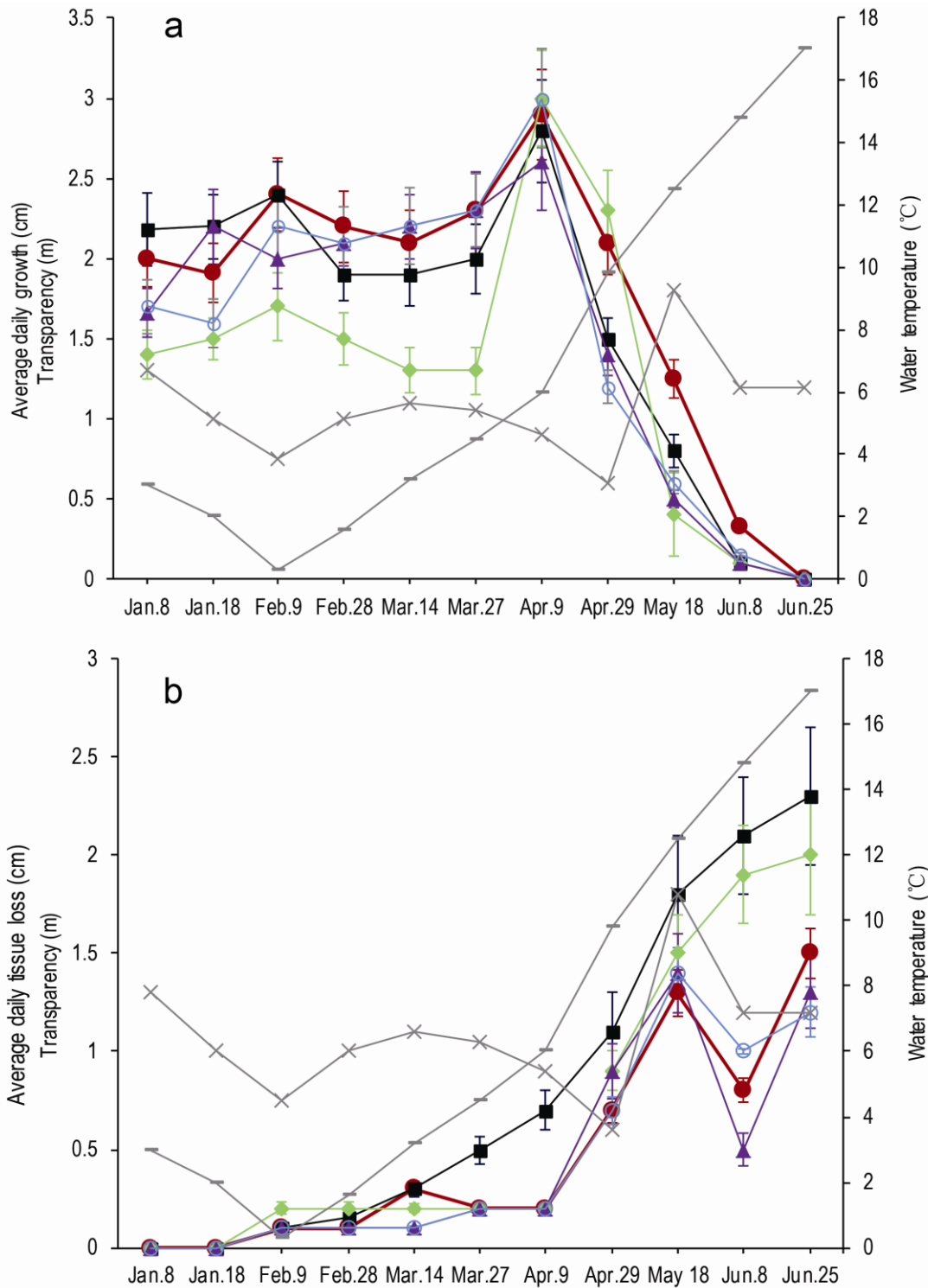
cycled depending on the biomass amount needed. Female and male clones are mixed, cultured and fragmented once egg releasing is observable (F). The fragmented are sprayed onto coir rope curtains in either cement pools (G) or trays (H) depending on the number of seedlings needed, on which young sporophytes developed (I). When seawater temperature is $<20^{\circ}\text{C}$, the curtain rope is stretched out and cultured in open sea temporarily till young sporophytes are about 20cm in length. The seedlings are insertion fixed on floating ropes, cultured and harvested finally (J).



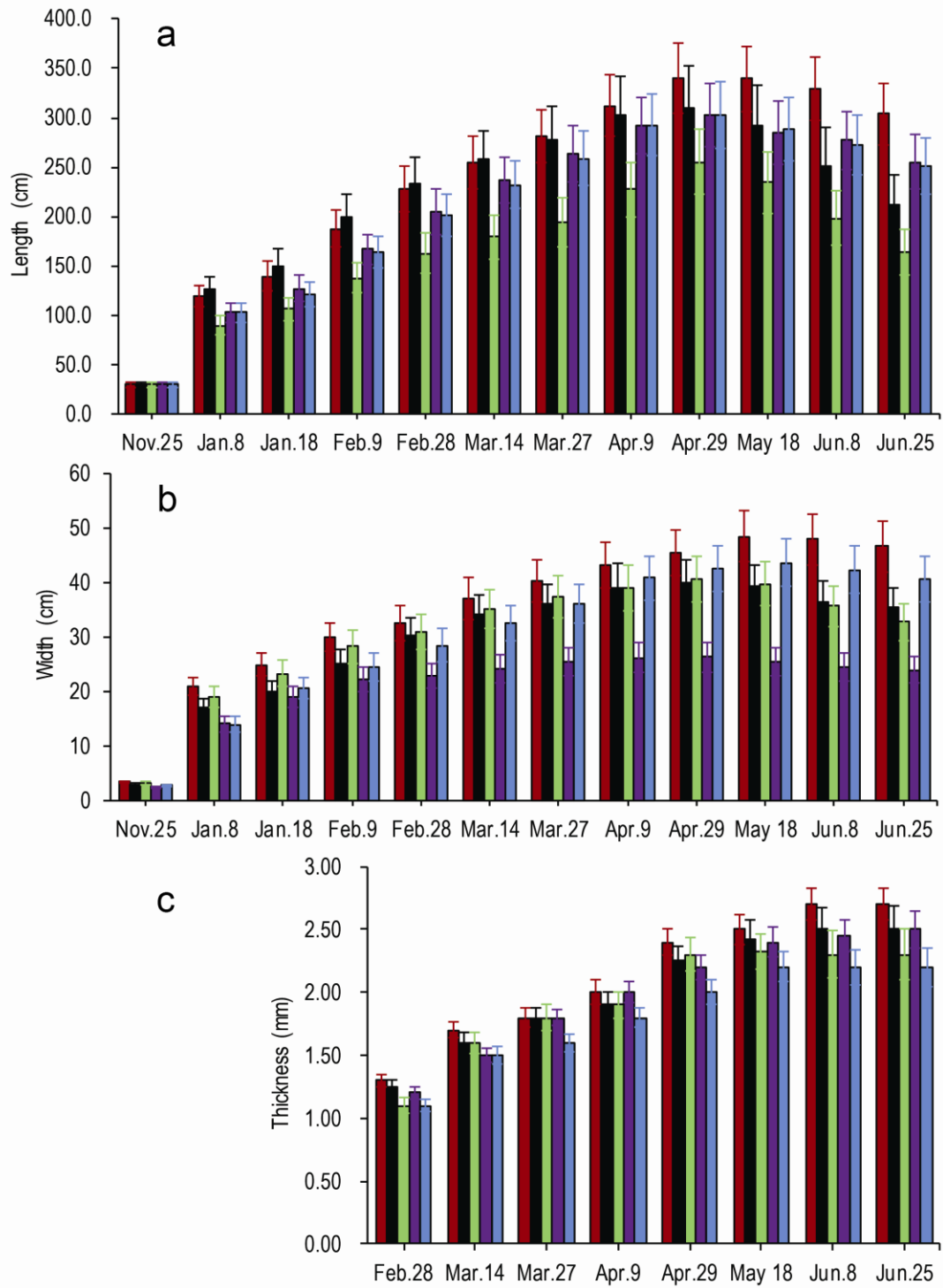
Supplementary Figure 3 Seedling-raising from bulked sporophytes. As a traditional seedling-raising method, a collection of mature sporophytes are intensively washed with high pressure seawater (A), seawater (B) and flowing seawater (C) successfully. These sporophytes are briefly air dried and then sunk in seawater, letting zoospores release (D). After cleaning, the coir rope curtains (E) are sunk into zoospore-containing seawater, letting zoospores adhere to the curtains. These curtains are arrayed at the bottom of cement pool arrays where young sporophytes develop (F). In order to delete weak sporophytes and unwanted organisms (*e.g.* some microalgae), the curtains are washed with high pressure seawater frequently (G). The seedlings grow indoor in sand filtrated, UV sterilized and temperature constant (8°C) seawater across the whole summer when seawater is $\geq 20^{\circ}\text{C}$, lasting about 3 months (H). The seedlings are temporarily cultured in open sea, transplanted when they are about 20 cm in length (I), cultured and harvested as are done for hybrids (J).



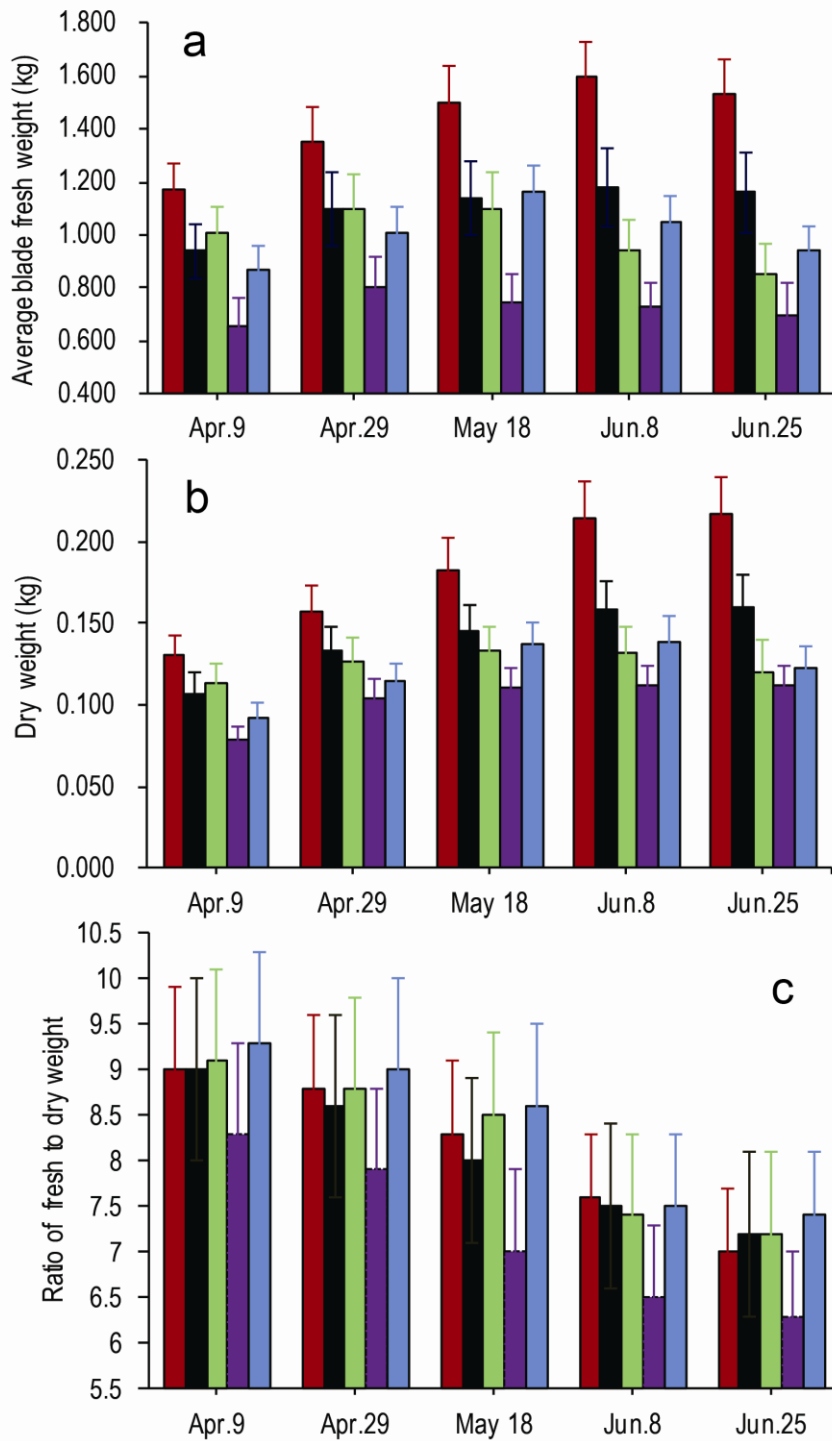
Supplementary Figure 4 The performance of Dongfang no.7 traits including blade length (A), width (B), thickness (C), fresh weight (D) and air dry weight (E) and yield (F) derived from air dry weight by multiplying the dry weight with 180,000.



Supplementary Figure 5 Average daily growth of blade (centimeters) (a) and average daily tissue loss (centimeters) (b), seawater transparency (meters) and temperature (°C). Red line dotted with solid red circle, Dongfang no. 7; black line interrupted by black squares, Control 1; green line interrupted by green rhombuses, Control 2; purple line interrupted by triangles, Korean kelp; blue line interrupted by empty circles, Kuanbao haidai; grey line interrupted by crosses, Transparency; grey line interrupted by dashes, Seawater temperature. Average daily growth of blade (a), average tissue loss (b) shares the left vertical axis with seawater transparency.



Supplementary Figure 6 The change in blade length (a), width (b) and thickness (c). Red bar, Dongfang no.7; black bar, Control 1; green bar, Control 2; purple bar, Korean kelp; blue bar, Kuanbao haidai.



Supplementary Figure 7 Average blade fresh weight (a), average blade dry weight (b) and ratio of fresh to dry weight (c). Red bar, Dongfang no.7; black bar, Control 1; green bar, Control 2; purple bar, Korean kelp; blue bar, Kuanbao haidai.