中国水产科学 2016 年 7 月, 23(4): 882–889
Journal of Fishery Sciences of China

研究论文

DOI: 10.3724/SP.J.1118.2016.15425

熊本牡蛎多嵴和无嵴品系 F_1 生长性状的群体选育

张跃环[1,2], 秦艳平[1,2], 张扬[1,2], 李军[1,2], 肖述[1,2], 向志明[1,2], 马海涛[1,2], 喻子牛[1,2]

1. 中国科学院 南海海洋研究所, 热带海洋生物资源与生态重点实验室, 广东省应用海洋生物学重点实验室, 广东 广州 501310;
2. 南海生物资源开发与利用协同创新中心, 广东 广州 501275

摘要: 为了改良熊本牡蛎(*Crassostrea sikamea*)生长性能, 以多嵴品系和无嵴品系熊本牡蛎为材料, 以壳高为指标, 按照 10%留种率, 采用截头法进行了两个品系的群体选育研究, 结果表明: 选择反应及现实遗传力随着个体增大而增加, 且多嵴品系选择反应略高于无嵴品系。对于多嵴品系而言, 幼虫期、稚贝期、养成的选择反应及现实遗传分别为 0.33±0.04、0.19±0.02, 0.46±0.03、0.26±0.02, 0.63±0.11、0.36±0.07; 无嵴品系的分别为 0.30±0.04、0.17±0.02, 0.43±0.03、0.25±0.02, 0.58±0.10、0.33±0.06。经过 1 周年的养成, 多嵴品系和无嵴品系的壳高遗传改进量分别为 8.41%、7.71%。由此可见, 两个品系的现实遗传力相对较高, 说明存在着一定程度的遗传变异。研究为熊本牡蛎遗传改良及新品系培育提供了理论与实践基础。

关键词: 熊本牡蛎; 群体选育; 选择反应; 现实遗传力; 遗传改进量
中图分类号: S91 文献标志码: A 文章编号: 1005−8737−(2016)04−0882−08

群体选育, 又称混合选择(mass selection), 是一种经典的选种方法, 实质是按改良目标, 进行表型选择, 即选择优良的表现型, 淘汰不良表现型。其特点是时间短、费用低、简单易行[1]。由于群体选育容易操作, 效果显著, 已经在海洋贝类上得到了广泛应用[2]。国内外学者以生长、存活等关键生产性状为指标, 采用群体选育的方法对海湾扇贝(*Argopecten irradians irradians*)[3–4]、长牡蛎(*Crassostrea gigas*) [5–7]、杂色鲍(*Haliotis diversicolor*)[8]、菲律宾蛤仔(*Ruditapes philippinarum*) [9–10]、马氏珠母贝(*Pinctada martensi*) [11–12]等经济贝类进行了遗传改良研究, 并且培育“中科红”海湾扇贝、“中科红 2 号”海湾扇贝、“蓬莱红”栉孔扇贝(*Chlamys farreri*)、“蓬莱红 2 号”栉孔扇贝、“海大金贝”虾夷扇贝(*Patinopecten yessoensis*)、“南澳 1 号”华贵栉孔扇贝(*C. nobilis*)、“海大 1 号”长牡蛎、“东优 1 号”杂色鲍、“斑马蛤”菲律宾蛤仔、“科浙 1 号”文蛤(*Meretrix meretrix*)、“南珠 1 号”马氏珠母贝等贝类养殖新品种[13]。

熊本牡蛎(*Crassostrea sikamea*), 又称蚝蛎、黄蚝、铁钉蚝等, 原产于东南亚, 包括中国(江苏以南)、韩国(顺天湾)及日本(有明海、濑户内海)等地[14–16], 是一种半咸水型偏好中高盐度的牡蛎类群, 且于 1943 年被引种至美国进行养殖[17]。国内外的研究中仅见熊本牡蛎人工繁育报道, 尚未发现对熊本牡蛎遗传改良研究[18–20]。熊本牡蛎味道鲜美, 但个体较小, 左壳较凹, 尤其是贝壳形态变化较大。为此, 根据左壳放射嵴有无及其数量将其划分为 3 类, 分别为多嵴品系(放射嵴≥6 个)、寡嵴品系(1 个≤放射嵴≤5 个)和无嵴品系(放

收稿日期: 2015-11-17; 修订日期: 2016-02-15.
基金项目: 广东省海洋与渔业局项目(A201501A07); 广东省科技计划项目(2016A020208011); 国家贝类产业体系建设项目(CARS-48).
作者简介: 张跃环(1981–), 男, 博士, 从事水产动物遗传育种学研究. E-mail: yhzhang@scsio.ac.cn
通信作者: 喻子牛. Tel: 020-89102507; E-mail: carlzyu@scsio.ac.cn

射嵴=0 个)[21]。本研究以熊本牡蛎的多嵴和无嵴品系作为材料, 以壳高作为选育指标, 进行群体选育, 旨在为提高熊本牡蛎生长速度和生产熊本牡蛎新品系培育奠定实践和理论基础。

1　材料与方法

1.1　亲本来源

2013 年 5 月初, 以 2012 年生产的湛江群体熊本牡蛎子代作为基础群体(500 个个体混合产卵排精, 获得 60 多万个子代), 在竹林盐厂采用单体养殖模式养成。根据熊本牡蛎的左壳形态特点, 按照放射嵴多少, 将熊本牡蛎划分为 3 类, 分别为无嵴品系(放射嵴=0 个)、寡嵴品系(放射嵴≤5 个)、多嵴品系(放射嵴≥6 个)[21]。

1.2　实验处理

利用截头法分别对多嵴和无嵴品系进行群体选育, 留种率均为 10%, 选择强度均为 1.755[3–4]。从每种类型中随机抽取 800 个个体作为基础群体, 用游标卡尺进行测量(精确至 0.02 mm), 绘制个体壳高大小的频率分布图(图 1)。从每个群体中选择 10%的最大个体(80 个), 作为选择组(SG), 随机相应抽取 80 个个体作为对照组(CG)(图 1)。其中, 多嵴亲本截点为 58.07 mm, 雌雄比例为 60∶20; 无嵴亲本截点为 56.12 mm, 雌雄比例为 62∶18。

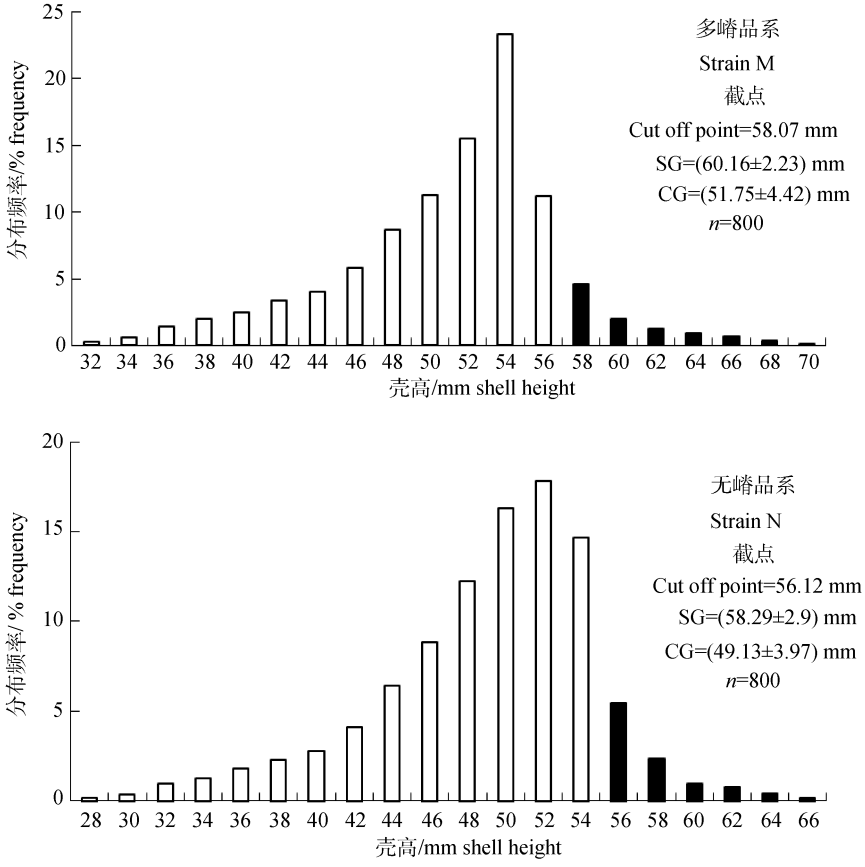

图 1　熊本牡蛎两个品系亲本的大小分布及选择部分

Strain M: 多嵴品系; Strain N: 无嵴品系; 黑色部分表示选择组. CG: 对照组; SG: 选择组.

Fig. 1　The size of shell height for two oyster strains of *Crassostrea sikamea*

Strains M and N indicate muti-ridge and non-ridge strains, respectively. The black histogram indicates selective parents. CG: control group; SG: selective group.

1.3　子代培育

采用解剖方式进行苗种生产, 为了保证所有雄性个体生产能力, 每个实验组均采用单个雄性个体与所有卵子配对的原则(1♂∶n♀); 待其发育至囊胚期后, 利用 500 目筛绢网洗卵 3~4 次去除多余精子, 之后各实验组间单独孵化, 防止发生

实验组间污染。

利用 300 目筛绢网进行幼虫选育，各实验组均保留 D 型幼虫 1.2 亿个，多余幼虫全部放掉；放置在 3 个 10 m^3 水泥池中培养，幼虫培养密度控制在 4 个/mL。幼虫培育期间，盐度控制在 20×10^{-12}~25×10^{-12}；幼虫变态以后，稚贝培养时的盐度控制在 15~20。室内培育期间，6 日龄以前，投喂云微藻 *Chlorella sp*，之后混合投喂云微藻和角毛藻(*Chaetoceros muelleri*) (体积比=1∶1)，投饵料视摄食情况而定。当幼虫出现鳃原基、眼点、足时，利用波纹板采苗。

当稚贝壳高在 10 mm 左右，轻轻剥离下来，装入 5 mm 网孔塑料袋中在竹林盐厂牡蛎养殖区进行中间育成，每袋密度控制在 240~300 个。随着稚贝生长，定期调整密度，最后更换至 10 mm 的扇贝笼中养成，密度控制在每层 50~60 个。

1.4 测定指标

壳高小于 400 μm 的幼虫在显微镜下用目微尺(10×)测量，壳长大于 3.0 mm 的子代和亲本用游标卡尺测量，精确至 0.02 mm。每个实验组设 3 个重复，每个重复随机测量 30 个个体。

1.5 参数计算

参照 Zheng 等[3−4]使用的方法，将两个品系熊本牡蛎的选择反应(SR)、现实遗传力(h_R^2)及遗传改进量(GG)用以下公式计算:

$$\mathrm{SR}=\frac{X_{\mathrm{SG}}-X_{\mathrm{CG}}}{S_{\mathrm{CG}}} \tag{1}$$

$$h_{\mathrm{R}}^2=\frac{X_{\mathrm{SG}}-X_{\mathrm{CG}}}{iS_{\mathrm{CG}}} \tag{2}$$

$$\mathrm{GG}=\frac{X_{\mathrm{SG}}-X_{\mathrm{CG}}}{X_{\mathrm{CG}}}\times100 \tag{3}$$

公式(1)、(2)和(3)中: X_{SG} 和 X_{CG} 分别是选择组(SG)和对照组(CG)个体的平均壳高, S_{CG} 是对照组(CG)的标准差, i 是选择强度。

1.6 数据处理

为了保证方差齐性，所有的壳高均转化对数 lg10。用 SPSS19.0 统计软件对数据进行分析处理，不同实验组间数据的比较采用单因素方差分析方法(One Way ANOVA, $\bar{x}$±SD)，用 Turkey 法进行组间多重比较，差异显著性设置为 P<0.05。

2 结果与分析

2.1 壳高大小

幼虫期间，3 日龄时，两个品系选择组与对照组幼虫尚未表现出壳高差异(P>0.05)；9 日龄时，两个品系幼虫选择组与对照组间仍无显著差异，但多嵴品系选择组显著大于无嵴品系对照组(P<0.05)；15 日龄时，多嵴品系选择组与对照组无显著差异，但显著无嵴品系的选择组合对照组(P<0.05)(表 1)。

稚贝期间，30 日龄时，多嵴品系的选择组合对照组均显著大于无嵴品系(P<0.05)，但是两个品系内的选择组与对照组彼此间无显著差异(P>0.05)；45~60 日龄期间，多嵴品系选择组显著大于无嵴品系对照组，与其他实验组间无显著差异(P>0.05)。中间育成期间，90 日龄时，多嵴品系选择组显著大于无嵴品系对照组；180~360 日龄期间，两个品系的选择组均显著大于对照组(P<0.05)，但是多嵴品系对照组与无嵴品系选择组无显著差异(P>0.05)(表 1)。

2.2 遗传参数

从各阶段生活史上看，随着个体增大，遗传参数逐渐增加(幼虫期<稚贝期<养成期)。多嵴品系幼虫期、稚贝期及养成期选择反应为 0.33±0.04、0.46±0.03、0.63±0.11；现实遗传力为 0.19±0.02、0.26±0.02、0.36±0.07；遗传改进量为(3.07±0.55)%、(5.03±0.55)%、(7.43±1.04)%。无嵴品系幼虫期、稚贝期及养成期选择反应为 0.30±0.04、0.43±0.03、0.58±0.10；现实遗传力为 0.17±0.02、0.25±0.02、0.33±0.06；遗传改进量为(2.82±0.60)%、(4.59±0.64)%、(6.75±1.36)%。经过一周年养成(360 日龄)，多嵴品系和无嵴品系的选择反应及现实遗传分别为 0.73、0.66, 0.42、0.38；其遗传改进量分别为 8.41、7.71(图 2，表 2)。

总体水平上而言，多嵴品系、无嵴品系的选择反应、现实遗传及遗传改进量分别为 0.47±0.14、0.27±0.08、(5.18±2.00)%; 0.44±0.13、0.25±0.08、(4.73±1.84)%，且多嵴品系遗传参数及遗传改进量略高于无嵴品系。

表 1　熊本牡蛎两个品系子代选择组和对照组壳高

Tab. 1　Shell height of control and selective groups at the different age of *Crassostrea sikamea*

n=800;　$\bar{x}$±SD

牡蛎日龄 oyster age	多嵴品系 muti-ridge		无嵴品系 non-ridge	
	CG	SG	CG	SG
幼虫期 larval stage/μm				
3	86.25±7.56 [a]	88.45±5.73 [a]	85.42±7.21 [a]	87.34±5.84 [a]
9	213.74±19.46 [a, b]	220.18±15.73 [a]	206.08±18.87 [b]	211.75±14.45 [a, b]
15	312.36±31.63 [a, b]	323.74±24.81 [a]	292.64±29.92 [c]	302.75±22.34 [b]
稚贝期 spat stage/mm				
30	1.82±0.18 [a]	1.90±0.12 [a]	1.50±0.15 [b]	1.56±0.09 [b]
45	4.56±0.53 [a, b]	4.80±0.31 [a]	4.23±0.44 [b]	4.42±0.30 [a, b]
60	10.87±1.20 [a, b]	11.46±0.75 [a]	10.25±1.17 [b]	10.79±0.72 [a, b]
养成期 grow-out stage/mm				
90	25.72±3.18 [a, b]	27.35±2.56 [a]	24.23±2.95 [b]	25.63±2.37 [a, b]
180	38.34±4.53 [b]	41.23±3.43 [a]	34.85±3.99 [c]	37.24±2.85 [b]
360	56.35±6.46 [b]	61.09±4.27 [a]	51.73±6.06 [c]	55.72±3.96 [b]

注: CG、SG 分别表示对照组和选择组. 每一行不同字母表示彼此间差异显著 (P<0.05).

Note: CG and SG indicate control group and selective group, respectively. Different letters of each line indicate significant difference (P<0.05) among experimental groups.

表 2　熊本牡蛎两个品系子代的选择反应、现实遗传力及遗传改进量

Tab. 2　Response to selection (SR), realized heritability (h_R^2) and genetic gain (GG) of two oyster strains of *Crassostrea sikamea*

牡蛎日龄 oyster age	SR		h_R^2		GG	
	MS	NS	MS	NS	MS	NS
幼虫期 larval stage/μm						
3	0.29	0.27	0.17	0.15	2.55	2.25
9	0.33	0.30	0.19	0.17	3.01	2.75
15	0.36	0.34	0.21	0.19	3.64	3.45
稚贝期 spat stage/mm						
30	0.44	0.40	0.25	0.23	4.40	4.00
45	0.45	0.43	0.26	0.25	5.26	4.49
60	0.49	0.46	0.28	0.26	5.43	5.27
养成期 grow-out stage/mm						
90	0.51	0.47	0.29	0.27	6.34	5.78
180	0.64	0.60	0.36	0.34	7.54	6.86
360	0.73	0.66	0.42	0.38	8.41	7.71

注: MS、NS 分别表示多嵴品系和无嵴品系.

Note: MS and NS indicate multi-ridge and non-ridge strain, respectively.

3　讨论

在群体选育中, 理想的选择群体是非常重要的, 群体存在较高的遗传变异水平, 是群体选育的关键前提, 对于纯系的选择通常是无效的[22]。本研究发现熊本牡蛎多嵴品系和无嵴品系亲本间存在着表型差异, 除了左壳放射嵴有无外, 还存在着明显的生长性状差异。Wang 等[14]通过对中国的熊本牡蛎分布发生研究中发现, 野生熊本牡蛎较高的遗传多样性, 这为本研究提供了可靠的保障。

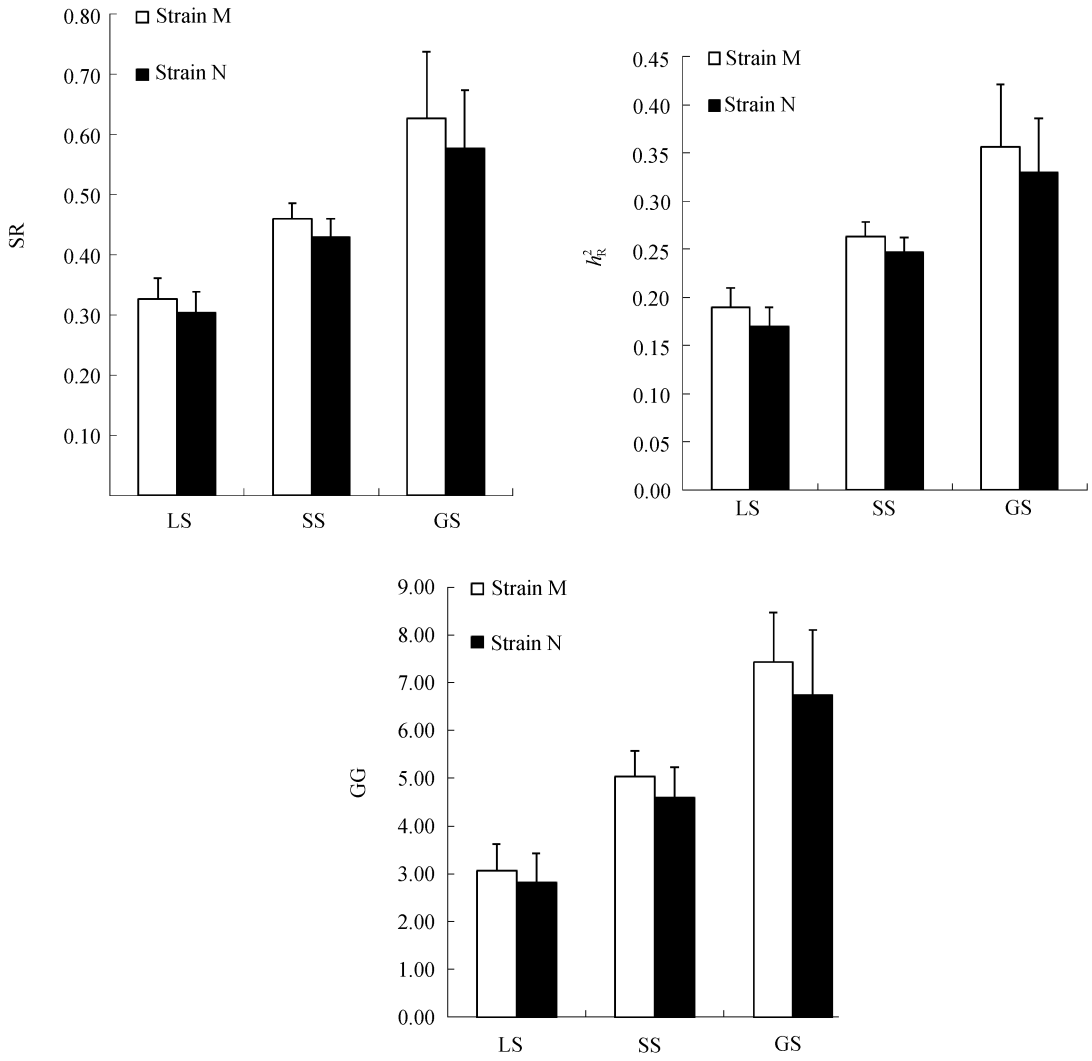

图 2 熊本牡蛎两个品系不同阶段平均的选择反应(SR)、现实遗传力(h_R^2)及遗传改进量(GG)

LS 表示幼虫期, SS 表示稚贝期, GS 表示养成期.

Fig. 2 Response to selection (SR), realized heritability (h_R^2) and genetic gain (GG) of two oyster strain during the different stage of *Crassostrea sikamea*

LS, SS, GS indicate larval stage, spat stage and grow out stage, respectively.

通过群体选育，两个品系熊本牡蛎生长性状均得到了明显提高。在 90 日龄以前，两个品系熊本牡蛎选择组与对照组无显著差异，但仍获了一定程度的遗传改进量。这与 Zheng 等[3–4]对海湾扇贝群体选育研究结果相似，说明亲本对子代早期影响并不大。180~360 日龄期间，选择组与对照组出现了显著的生长差异，且多嵴品系壳高显著大于无嵴品系。这与大多数贝类群体选育相似，在相同的养殖环境下，选择组和对照组的生长差异是由于遗传差异引发的[9–12]。产生遗传差异的主要原因是人工选择导致选择组在某些位点的基因频率发生了变化，而这些位点与某些性状相关，从而表现为选择组和对照组的表型差异[23–24]。相对于其他的牡蛎群体选育而言，多嵴品系和无嵴品系熊本牡蛎选择组壳高在 360 日龄的遗传改进量 8.41%、7.71%，这一选择结果略显偏低。Newkirk 等[25]对欧洲牡蛎(*Ostrea edulis*)进行了生长性状选择，获得了 10%~20%改良效果; Nell 等[26]对悉尼岩牡蛎(*Saccostrea commercialis*)进行鲜重性状选择时，第一代、第二代分别获得了 4%、18%的遗传改良效果; Langdon 等[27]认为，长牡蛎在不同环境下的家系选育每代的产量可提高 10%~

20%。此外, 本研究中的遗传改进量可能还与熊本牡蛎生长缓慢, 个体较小有关。

现实遗传力是选择反应的一个基本描述, 某一性状的遗传力越大, 其加性遗传效应就越明显, 选择越有效[2]。Toro 等[28]估计了智利牡蛎(*O. chilensis*)壳高的现实遗传力为 0.34±0.12; 欧洲牡蛎(*O. edulis*) 6 月龄和 18 月龄壳高的现实遗传力分别为 0.11±0.04 和 0.19±0.07[29]。Jarayabhand 等[30]计算了僧帽牡蛎(*S. cuculata*)鲜重的现实遗传力为 0.28±0.01; Langdon 等[27]计算了长牡蛎(*C. gigas*)12 月龄壳高的现实遗传力为 0.15~0.40; Li 等[23]估计了长牡蛎壳高的现实遗传力为 0.14~0.40; Wang 等[24]估计子二代长牡蛎壳高的现实遗传力为 0.33~0.46。在本研究中, 12 月龄时多嵴和无嵴品系壳高的现实遗传力分别为 0.42、0.38, 选择反应随着个体增大而增加。这与大多数贝类现实遗传力相比, 本研究中的遗传力(>0.2)处于中高等遗传水平[31–32]。尽管两个品系熊本牡蛎养殖环境相同, 且选择压力相同, 但是两个品系间的选择反应略有所差异, 多嵴品系较无嵴品系选择反应略高一些。这种现象与其他贝类相似, 可能是由选择差异、基因主效应等多种因素引发的[3–4, 9, 23–24]。

由此可见, 熊本牡蛎具有较好的遗传改良潜力, 在今后的群体选育中, 我们应根据选育群体的目的性状、遗传参数, 制定合理的育种方案, 可能会培育出具有明显生长优势的熊本牡蛎新品系。

参考文献:

[1] Lou Y D. Fish Breeding[M]. Beijing: China Agriculture Press, 1999: 10–19. [楼允东. 鱼类育种学[M]. 北京: 中国农业出版社, 1999: 10–19.]

[2] Zhang G F, Zheng H P. Aquaculture Genetics in Bay Scallop[M]. Beijing: Science Press, 2009: 52–73. [张国范, 郑怀平. 海湾扇贝养殖遗传学[M]. 北京: 科学出版社, 2009: 52–73.]

[3] Zheng H P, Zhang G F, Liu X, et al. Different responses to selection in two stocks of the bay scallop, *Argopecten irradians irradians* Lamarck (1819)[J]. J Exp Mar Biol Ecol, 2004, 313(2): 213–223.

[4] Zheng H P, Zhang G F, Liu X, et al. Sustained response to selection in an introduced population of the hermaphroditic bay scallop *Argopecten irradians irradians* Lamarck (1819)[J]. Aquaculture, 2006, 255(1–4): 579–585.

[5] Wang Q Z, Li Q, Liu S K, et al. Comparison of quantitative traits among the breeding lines of different geographic populations of *Crassostrea gigas*[J]. Periodical of Ocean University of China, 2011, 41(7): 36–41. [王庆志, 李琪, 刘士凯, 等. 长牡蛎不同地理群体选育系数量性状的比较[J]. 中国海洋大学学报: 自然科学版, 2011, 41(7): 36–41.]

[6] Wang Q Z, Li Q, Liu S K, et al. Estimates of heritabilities and genetic correlations for growth in *Crassostrea gigas* larvae[J]. Journal of Fishery Sciences of China, 2009, 16(5): 736–743. [王庆志, 李琪, 刘士凯, 等. 长牡蛎幼体生长性状的遗传力及其相关性分析[J]. 中国水产科学, 2009, 16(5): 736–743.]

[7] Wang Q Z, Li Q, Liu S K, et al. Estimates of genetic parameters for growth-related traits in adult *Crassostrea gigas*[J]. Journal of Fishery Sciences of China, 2012, 19(4): 700–706. [王庆志, 李琪, 刘世凯, 等. 长牡蛎成体生长性状的遗传参数估计[J]. 中国水产科学, 2012, 19(4): 700–706.]

[8] You W W, Ke C H, Luo X, et al. Divergent selection for shell length in two stocks of small abalone *Haliotis diversicolor*[J]. Aquac Res, 2010, 41(6): 921–929.

[9] Yan X W, Zhang Y H, Huo Z M, et al. Responses to selection and realized heritability in three geographical populations of Manila clam (*Ruditapes philippinarum*)[J]. Journal of Fisheries of China, 2010, 34(5): 704–710. [闫喜武, 张跃环, 霍忠明, 等. 不同地理群体菲律宾蛤仔的选择反应及现实遗传力[J]. 水产学报, 2010, 34(5): 704–710.]

[10] Zhang G F, Yan X W. Clam Aquaculture[M]. Beijing: Science Press, 2010: 287–291. [张国范, 闫喜武. 蛤仔养殖学[M]. 北京, 科学出版社, 2010: 287–291.]

[11] Deng Y W, Fu S, Du X D. Response to selection and realized heritability for early growth in the second-generation selected line of pearl oyster *Pinctada martensii*[J]. Journal of Guangdong Ocean University, 2008, 28(4): 26–29. [邓岳文, 符韶, 杜晓东. 马氏珠母贝选系 F_2 早期选择反应和现实遗传力估计[J]. 广东海洋大学学报, 2008, 28(4): 26–29.]

[12] He M X. "Nanke Pearl Red" breeding line of pearl oyster *Pinctada martensii*[J]. Journal of Tropical Oceanography, 2006, 25(2): 58. [何毛贤. 马氏珠母贝红壳品系"南科珍珠红"的培育[J]. 热带海洋学报, 2006, 25(2): 58.]

[13] National Commission on Aquatic New Species. Name List of Aquatic New Species[EB/OL]. 2015. http://nccav. moa. gov.cn/news-show.asp?anclassid=131&nclassid=6&xclassid=0&id=2172. [全国水产新品种良种委员会. 水产新品种名单

[EB/OL]. 2015. http://nccav.moa.gov.cn/news-show.asp?anclassid=131&nclassid=6&xclassid=0&id=2172.]

[14] Wang H Y, Qian L M, Wang A M. et al. Occurrence and distribution of *Crassostrea sikamea* (Amemiya 1928) in China[J]. J Shellfish Res, 2013, 32: 439–446.

[15] Hong J S, Sekino M, Sato S. Molecular species diagnosis confirmed the occurrence of Kumamoto oyster *Crassostrea sikamea* in Korean waters[J]. Fish Sci, 2012, 78(2): 259–267.

[16] Sekino M. In search of the Kumamoto oyster *Crassostrea sikamea* (Amemiya, 1928) based on molecular markers: is the natural resource at stake?[J]. Fish Sci, 2013, 75(4): 819–831.

[17] Lv X Y. Studies on single-seed oyster spat production and culture techniques of *Crassostrea sikamea*[D]. Qingdao: Ocean University of China, 2013: 12–15. [吕晓燕. 熊本牡蛎人工繁育和长牡蛎单体培育技术研究[D]. 青岛: 中国海洋大学, 2013: 12–15.]

[18] Zhang Y H, Wang Z P, Yu Z N, et al. A recent review of interspecific hybridization among cultivated oysters[J]. Journal of Fisheries of China, 2014, 38(4): 613–623. [张跃环, 王昭萍, 喻子牛, 等. 养殖牡蛎种间杂交的研究概况与最新进展[J]. 水产学报, 2014, 38(4): 613–623.]

[19] Li Q, Wang W J, Cong R H, et al. A method of the artificial breeding for *Crassostrea sikamea*: China, 201210296474.6[P]. 2013-08-19.[李琪, 王卫军, 丛日浩, 等. 一种熊本牡蛎人工繁育方法: 中国, 201210296474.6[P]. 2013-08-19.]

[20] Zhang Y H, Xiao S, Zhang Y, et al. A new salinity-dependent method of artificial breeding for the Kumamoto oyster *Crassostrea sikamea*: China, 201410037056.4[P]. 2015-08-01. [张跃环, 肖述, 张扬, 等. 一种适用于华南沿海盐度渐变式熊本牡蛎室内大规模人工繁育新方法: 中国, 201410037056.4[P]. 2015-08-01.]

[21] Zhang Y H, Xiao S, Xiang Z M, et al. A new breeding method for the Kumamoto oyster *Cassostrea sikamea* by the number of ribs on the left shell: China, 201410153760.6[P]. 2015-08-01.[张跃环, 肖述, 向志明, 等. 一种以左壳放射嵴数目为标记的熊本牡蛎制种方法: 中国, 201410153760.6[P]. 2015-08-01.]

[22] Kong J, Luan S, Zhang T S, et al. BLUP genetic assessment and simulation of three breeding modes in *Fenneropenaeus chinensis*[J]. Marine Fisheries Research, 2008, 29(3): 27–34. [孔杰, 栾生, 张天时, 等. 中国对虾 3 种育种模式的 BLUP 遗传评定分析[J]. 海洋水产研究, 2008, 29(3): 27–34.]

[23] Li Q, Wang Q Z, Liu S K, et al. Selection response and realized heritability for growth in three stocks of the Pacific oyster *Crassostrea gigas*[J]. Fish Sci, 2011, 77(4): 643–648.

[24] Wang Q Z, Li Q F, Kong L F, et al. Response to selection for fast growth in the second generation of Pacific Oyster (*Crassostrea gigas*)[J]. J Ocean U China, 2012, 11(3): 413–418.

[25] Newkirk G F, Haley L E. Phenotypic analysis of the European oyster *Ostrea edulis* L.: relationship between larval period and postsetting growth rate[J]. J Exp Mar Biol Ecol, 1982, 59(2): 177–184.

[26] Nell J A, Smith I R, Sheridan A K. Third generation evaluation of Sydney rock oyster *Saccostrea commercialis* (Iredale and Roughley) breeding lines[J]. Aquaculture, 1999, 170(3–4): 195–203.

[27] Langdon C, Evans F, Jacobson D, et al. Yields of cultured Pacific oysters *Crassostrea gigas* Thunberg improved after one generation of selection[J]. Aquaculture, 2003, 220(1–4): 227–244.

[28] Toro J E, Newkirk G F. Response to artificial selection and realized heritability estimate for shell height in the Chilean oyster *Ostrea chilensis*[J]. Aquat Living Resour, 1991, 4(2): 101–108.

[29] Toro J E, Newkirk G F. Divergent selection for growth rate in the European oyster *Ostrea edulis*: response to selection and estimation of genetic parameters[J]. Mar Ecol Prog Ser, 1990, 62(3): 219–227.

[30] Jarayabhand P, Thavornyutikarn M. Realized heritability estimation on growth rate of oyster, *Saccostrea cucullata* Born, 1778[J]. Aquaculture, 1995, 138: 111–118

[31] Appleyard S A, Ward R D. Genetic diversity and effective population size in mass selection lines of Pacific oyster (*Crassostrea gigas*)[J]. Aquaculture, 2006, 254(1–4): 148–159.

[32] Dégremont L, Bédier E, Boudry P. Summer mortality of hatchery-produced Pacific oyster spat (*Crassostrea gigas*). II. Response to selection for survival and its influence on growth and yield[J]. Aquaculture, 2010, 299(1–4): 21–29.

Population selection for growth in two strains of the Kumamoto oyster *Crassostrea sikamea*

ZHANG Yuehuan[1, 2], QIN Yanping[1, 2], ZHANG Yang[1, 2], LI Jun[1, 2], XIAO Shu[1, 2], XIANG Zhiming[1, 2], MA Haitao[1, 2], YU Ziniu[1, 2]

1. Key Laboratory of Tropical Marine Bio-resources and Ecology, South China Sea Institute of Oceanology, Chinese Academy of Sciences, Guangzhou 501310, China;
2. South China Sea Bio-Resource Exploitation and Utilization Collaborative Innovation Center, Guangzhou 501275, China

Abstract: The Kumamoto oyster (*Crassostrea sikamea*) is an important wild oyster resource in Southeast Asia, including China, Japan and Korean. They are not only distributed naturally in China, but also live in abundance over a wide geographical distribution, ranging from Jiangsu to Guangxi, and Hainan Island. Traditionally, this species is a wild fishery resource; farmers capture these oysters from the reef or stone on the inter-tidal zone. Although the artificial breeding of this oyster was successfully conducted, but no relative information for genetic improvement was found. Selective breeding is the genetic manipulation of a cultured species for the purpose of improving specific traits of interest to humans. A variety of approaches have been taken in the study of the genetic breeding of mollusks, including Mendelian genetics, quantitative genetics, and cytogenetic and molecular genetic studies. However, not all of these approaches have contributed equally to the immediate development of genetically improved strains. Classically, population selection indicates the method of selection for the offspring bred by free mating among individuals with superior phenotypic traits in the majority from populations of original species according to the selective breeding objective via a comparison and appraisal between the original species and local species. Due to its simple operation and easy promotion, it has been widely used in the improvement of plant and animal species. Through continuous population selection, better cultivated species with rapid growth, strong stress resistance, high meat rate and high yield can be obtained. To improve the growth trait, response to selection and realized heritability for shell height was evaluated using the many radial rib line (Stock M: a number of ribs of left shell$\geqslant$6) and the non-radial rib line (Stock N: a number of ribs of left shell=0) of the cultchless Kumamoto oyster in southern China. The shell height of Kumamoto oyster was considered to be a growth characteristic due to the positive association between shell height and yield. Truncation selection was conducted by selecting the largest 10% oyster from two stocks as parents for selected groups, while the equal number parents were randomly chosen as control groups before the removal of parents for truncation selection. Progeny from four groups were cultured the identical environmental conditions at larvae, spat and grow-out stage. Genetic index increased with oyster growth, strain M showed slightly higher response to selection and realized heritability than strain N during the whole history life. For strain M, response to selection and realized heritability were 0.33±0.04, 0.19±0.02 for larvae, 0.46±0.03, 0.26±0.02 for spat, and 0.63±0.11, 0.36±0.07 for grow out stage, respectively. The response to selection and realized heritability of Strain N were 0.30±0.04, 0.17±0.02 for larvae, 0.43±0.03, 0.25±0.02 for spat, and 0.58±0.10, 0.33±0.06 for growing out stage, respectively. At the end of 360 day, current genetic gain was 8.41% for Strain M, 7.71% for Strain N, respectively. The relatively high realized heritability has been obtained from the two strains, suggesting that there existed a degree of genetic variation between selective and control lines of this species. Our results clearly demonstrate that population selection can effectively improve growth trait and it is a promising way to Kumamoto oyster aquaculture.

Key words: *Crassostrea sikamea*; mass selection; response to selection; realized heritability; genetic gain
Corresponding author: YU Ziniu. E-mail: carlzyu@scsio.ac.cn