Acta Ecologica Sinica 37 (2017) 75–78

Contents lists available at ScienceDirect

Acta Ecologica Sinica

journal homepage: www.elsevier.com/locate/chnaes

Effects of shell morphological traits on the weight trait of the orange strain of the Manila clam

Huo Zhong-ming [a], Wu Yu-an [a], Gao Zhi-ying [b], Chu Guan-nan [c], Yan Xi-wu [a,*], Yang Feng [a], Zhang Guo-fan [d]

[a] Engineering Research Center of Shellfish Culture and Breeding in Liaoning Province, College of Fisheries and Life Science, Dalian Ocean University, Dalian 116023, PR China
[b] Dalian Fisheries Research Institute, Dalian 116023, PR China
[c] Zhangzidao Group Co., LTD, Dalian 116023, PR China
[d] Key Laboratory of Experimental Marine Biology, Institute of Oceanography, Chinese Academy of Science, Qingdao 266071, PR China

ARTICLE INFO

Article history:
Received 29 March 2013
Received in revised form 27 November 2016
Accepted 6 December 2016

Keywords:
Morphology
Weight
Orange strain
Manila clam
Correlation coefficients

ABSTRACT

A new strain of Manila clam with orange shell color was produced after selection within a full-sib family for two generations. In the present study, the shell length, height, and width, and the live body weight of the orange strain were measured, and their correlation coefficients were calculated. The shell morphological traits were used as independent variables, and the live body weight was used as the dependent variable for calculating the path coefficients, correlation index, and determination coefficients. The results showed that the correlation coefficients between each shell morphological trait and the live body weight were all highly significant ($P < 0.01$). The correlation indices (R^2) of morphological traits against the live body weight of clams were larger than 0.85, indicating that the morphology traits were the main factors affecting the body weight. Multiple regression equations were obtained to estimate shell length X_1 (cm), shell height X_2 (cm), and shell width X_3 (cm) against live body weight Y (g): $Y = -2.62 + 0.34\,X_1 + 0.145\,X_2$, ($X_1 < 0.05$, $X_2 < 0.05$). The results suggest that the shell length could be used as the main trait for selective breeding and could indirectly make a large improvement in the weight trait.

1. Introduction

In quantitative genetic studies of the selective breeding of marine bivalves, analysis of the effects of morphological traits on weight traits using path analysis and multiple regression is basic. The results are used to optimize the breeding strategy, which can effectively improve the economic value of shellfish [1,2]. The path analysis proposed by Wright (1921) [3] has become a powerful tool for analyzing the creature traits. This approach has three merits: firstly, there is variable standardization, which allows for comparison between independent variables and the dependent variables; secondly, the correlation coefficients among the different traits can be decomposed into direct and indirect effects; and lastly, the path diagram can be implemented, so that the relationships among the traits can be directly understood

The Manila clam, *Ruditapes philippinarum*, which is naturally distributed along the coast of China, is the most popular bivalve cultured in China because of its high nutritional value, delicate flavor and rapid growth. China is the most important Manila-clam-producing country in the world. In 2011, the annual production of Manila clams in China had increased to over 3,200,000 tons, accounting for an estimated 90% of the world production [4,5]. For these reasons, studies on the breeding technology, healthy culture, and selective breeding, in terms of shell color and shell shape, of the Manila clam have been reported in recent years [6].

The Manila clam presents a large polymorphism for shell colors and patterns. The attractive and exclusive shell color of this species can give consumers an aesthetic appreciation that leads to higher prices in the international market. We have found that the orange shell color of the Manila clam occurs in only 0.4% of wild populations [7]. This makes it ideal for mass commercial production. As a result, the full-sib family with orange shell color has been produced since 2008, and 100,000 individuals of the orange strain have been cultured after a two-generation oriented selection from this full-sib family.

The objective of the present study was to evaluate the effects of morphological traits on the weight trait of the orange strain of Manila clam. The data obtained can provide valuable information for determining the main morphological traits affecting the weight trait and thereby help in the design of a reasonable breeding strategy for predicting the candidate traits.

* Corresponding author.
E-mail addresses: hzm1983@163.com (Z. Huo), yanxiwu@dlou.edu.cn (X. Yan).

http://dx.doi.org/10.1016/j.chnaes.2016.12.007
1872-2032/

The results of this study provide a method to predict the live body weight of the Manila clam through measuring its shell morphological traits, which is laborsaving and cost effective.

2. Materials and methods

2.1. Experimental material

The clams with an orange shell color were sampled from an orange strain of Manila clam that had been selected for two generations (Fig. 1).

2.2. Data and analysis

The shell length (SL), shell height (SH), and shell width (SW) of 100 randomly sampled adult individuals (1 year of age) were individually measured using a vernier caliper (0.02 mm). Live body weight (LW) was measured individually using an electronic balance (accuracy, 0.0001 g).

The mean values of the morphological and weight traits, the standard deviation, and the coefficient of variation (CV) were calculated using Excel software. The correlation coefficient and multiple regression analysis between the traits were evaluated using the SPSS13.0 software, and the multiple regression equations were established. The path coefficients, correlation index, single-trait determination coefficients, and common-trait determination coefficients were derived using path analysis (Wright 1921) [3]. The formulas are as follows:

Fig. 1. The orange strain of Manila clam.

Table 1
Statistical analyses of various traits of the orange strain of *Ruditapes philippinarum*.

Traits	(SL) X_1 (mm)	(SH) X_2 (mm)	(SW) X_3 (mm)	(LW) Y (g)
Mean	9.624	7.092	3.804	0.158
SD	1.897	1.361	0.788	0.087
(CV%)	19.711	19.275	20.715	55.063

If the correlation variables y, x_1, x_2, x_3 exist in a linear equation, the regression equation is:

$$y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + e \quad (1)$$

where y is a dependent variable; x_1, x_2, and x_3 are independent variables; b_0 is the absolute term; b_1, b_2, and b_3 are the bias regression coefficients of y on x_1, x_2, and x_3; and e is the remaining item. The matrix notation of the k independent variable of the path analysis was obtained using a least-squares method and an identically equal distortion:

$$\begin{pmatrix} 1 & r_{12} & r_{13} & \ldots r_{1k} \\ r_{21} & 1 & r_{23} & \ldots r_{2k} \\ r_{31} & r_{32} & 1 & \ldots r_{3k} \\ \vdots & \vdots & \vdots & \ldots \vdots \\ r_{k1} & r_{k2} & r_{k3} & \ldots 1 \end{pmatrix} \begin{pmatrix} P_{01} \\ P_{02} \\ P_{03} \\ \vdots \\ P_{04} \end{pmatrix} \begin{pmatrix} r_{01} \\ r_{02} \\ r_{03} \\ \vdots \\ r_{04} \end{pmatrix}$$

$$R^2 = \sum r_{x_i y} \times P_i \quad (2)$$

$$d_i = P_i^2 \quad (3)$$

$$d_{ij} = 2r_{ij} \times P_i \times P_j \quad (4)$$

3. Results

3.1. Statistical phenotypic traits

The statistical phenotypic traits of shell length (SL), shell height (SH), shell width (SW), live body weight (LW), and the coefficient of variation are shown in Table 1. The results show that the coefficient of variation of the weight trait was greater than those of the morphological traits.

3.2. Phenotypic correlation coefficients among the traits

The phenotypic correlation coefficients of the traits are listed in Table 2. The correlation coefficients of the various traits showed significant differences ($P < 0.01$).

3.3. Path coefficients and correlation indices of the morphological traits against the weight trait

The path coefficients and correlation indices are shown in Table 3. Path analysis was conducted by using the shell length, shell height, and shell width as independent variables and the live body weight as the dependent variable. The results show that the direct effect of the

Table 2
Phenotype correlation coefficients between the traits of the orange strain of *Ruditapes philippinarum.*

Traits	LW	SL	SH	SW
LW	1	0.957**	0.935**	0.932**
SL	–	1	0.958**	0.955**
SH	–	–	1	0.946**
SW	–	–	–	1

** Highly significant correlation ($P < 0.01$).