Breeding for Resistance to Taura sydrome virus (TSV):

A Brief Summary of USMSFP Efforts

Oceanic Institute Shrimp Program

Taura syndrome, caused by Taura syndrome virus (TSV), is an economically important disease of the Pacific white shrimp, *Penaeus* (*Litopenaeus*) *vannamei*. TSV was first identified in Ecuador in 1992 and has since spread to the major shrimp farming regions of the Americas and Asia. Initial outbreaks of TSV in the US occurred in Hawaii and Florida in 1994, followed by an outbreak in Texas in 1995. Pond mortality during early TSV outbreaks ranged from 40-95% in unselected populations of *P. vannamei*. The value of TSV-associated crops losses in the Americas between 1992 and 1995 was estimated at >$1 billion USD. While no published estimates of TSV-associated crop losses from 1996 to present are available, frequent outbreaks throughout the Americas since 1995 and the spread of TSV to Asia have undoubtedly had an enormous economic impact on the shrimp farming industry.

Selection for TSV Resistance

In response to TSV outbreaks in the US, the US Marine Shrimp Farming Program (USMSFP), with funding from the US Department of Agriculture, initiated a selective breeding program to improve TSV resistance in *P. vannamei*. The USMSFP breeding program is operated by Oceanic Institute (OI) and relies exclusively on SPF shrimp stocks. Selection for TSV resistance began in 1995 and each year 1-2 cohorts of 20-80 full-sib families have been evaluated in *per os* TSV challenges conducted at USMSFP-member institutions (University of Arizona and Gulf Coast Research Laboratory). The breeding program uses a sib-selection strategy where the decision to cull or select a particular family is based on the performance (i.e. survival) of shrimp in a TSV challenge. Unexposed, SPF siblings from the best-surviving families are then used to propagate the next generation.

Genetic Gain

Heritability for TSV resistance is low to moderate. Estimates from OI studies have typically been < 0.2 and these estimates are in agreement with published estimates for *P. vannamei*. Despite a low to moderate heritability, rapid improvement in TSV resistance has been made through selection, as evidenced by selection responses of 10-20% per generation (expressed as the relative increase in shrimp survival when challenged with TSV) during the first several years of selection.

The ability to improve TSV resistance is attributed to high phenotypic/genotypic variation for TSV survival (i.e. a wide range of family survivals). Having a wide range of family survivals in each cohort allows for a large selection differential (and intense selection) and this has resulted in selection responses above which would normally be expected given the heritability for this trait. However, as selection has progressed, the magnitude of variation for TSV survival has declined. For example, during five generations of selection, survival increased from 44%-84% while the coefficient of variation for TSV survival decreased from 43.3% to 13.6% (Fig. 1).

To date, 15 generations of selection have been completed and recent cohorts have exhibited >80% survival to multiple isolates of TSV, including a highly virulent isolate from Belize. In addition, several families per cohort typically exhibit 100% survival. Since a high level of TSV resistance has been established in the breeding population, and only incremental improvements in survival are achievable at this point, selection efforts have shifted to maintaining TSV resistance while placing more emphasis on other economically important traits such as growth and growout survival.

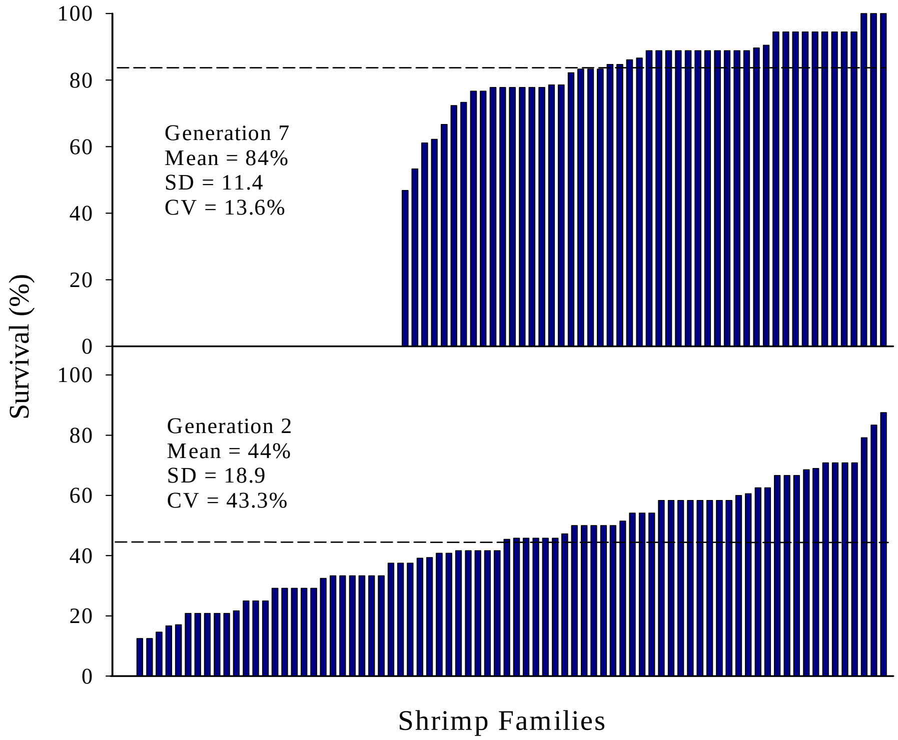

Fig. 1. Phenotypic variation for TSV survival after two and seven generations of selection. Each bar represents a family mean and the dashed line represents mean family survival for each cohort.

Genetic Correlations

Early in the breeding program, there was concern about a negative correlation between TSV resistance and growth. However, over the last several generations, phenotypic correlations between these traits typically have been low and have fluctuated from slightly positive to slightly negative. Similar correlations between TSV survival and growout survival have been found. If there is a true negative genetic correlation between TSV survival and growth (or growout survival), it is likely weak and would not substantially hinder simultaneous genetic improvement for both traits. In fact, stocks selected for TSV resistance exhibit good growth and survival at OI. For example, a recent cohort of TSV resistant shrimp was evaluated for growout performance at a stocking density of 363 shrimp/m^2 in a recirculating raceway system (initial stocking weight = ~1.7 g). After 69 days of culture, mean family harvest weight, growth rate, and survival were 19.3 g, 1.8 g/wk, and 87%, respectively.

Over 30 genetically distinct TSV isolates have been identified, and USMSFP stocks have been exposed to several of these isolates in *per os* challenges. Although mean cohort survival can differ among isolates, genetic correlations for survival to specific isolates have been moderate to high (>0.4). These results suggest that selection for one isolate will result in gains (i.e. in increase in survival) for other isolates.

USMSFP stocks also have been challenged with White spot syndrome virus (WSSV), Yellow head virus (YHV), and Infectious myonecrosis virus (IMNV). Unfortunately, selection efforts to improve TSV resistance have not resulted in enhanced resistance to these other viral pathogens. There appears to be little phenotypic variation for survival to WSSV and YHV, as most families exhibited 100% mortality in *per os* challenges. Results from a recent IMNV injection challenge suggest that there may be sufficient family variation to allow for selection. However, the phenotypic correlation between IMNV and TSV survival was low.

Inbreeding

OI researchers conducted a multiple-generation analysis of TSV-challenge data which revealed that inbreeding has moderate to severe effects on TSV survival. In addition, the magnitude of inbreeding depression (IBD) may be dependent on TSV virulence. Specifically, IBD estimates for the Hawaii and Texas isolates of TSV were -8.3% and -11.1% (expressed as the percent change in phenotype per 10% inbreeding), respectively. However, IBD for the more virulent Belize isolate was -31.4%.

Industry Impacts

OI periodically distributes TSV-resistant germplasm from the USMSFP breeding program to US industry stakeholders. This germplasm typically has been in the form of postlarvae which are offspring of the best-performing families from the previous generation. Over the last seven years, ~700,000 shrimp have been distributed to US farmers and broodstock suppliers, along with a small number of shrimp distributed to US research institutions. Descendants of TSV-resistant stocks have been shipped worldwide by US broodstock suppliers and the use of TSV-resistant stocks of *P. vannamei* is now common in most shrimp farming areas of the world.