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Complementary Sex Determination mechanism (CSD) in parasitic hymenoptera and its implication on biological control

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Hymenoptera is the largest order comprising great many insects, which are beneficial to man. Parasitic hymenoptera are the most important group of biological control agents for insect pests. Haplodiploid is a mode of sex determination, in which female developed from fertilized eggs and are diploids, whereas male developed from unfertilized eggs and are haploids. However, there is other sort of sex determination, widely distributed among the parasitic hymenoptera is called as complementary sex determination (CSD), which impose the production of diploid males especially under matched matting. CSD is likely to occur through ancestral single locus complementary sex determination system. CSD known to be occurs over 60 species of hymenopterans insects and it causes male biased sex determination via production of diploid males. As it is undesirable to mass culture of parasitoids it has great implication in the field of biological control.

Complementary sex determination (CSD)

Model of complementary sex determination (CSD) was first proposed by Whiting. It was based on the regular occurrence of diploid males when B. hebetor was inbred and which is also called as allelic diversity model. Under CSD, sex is determined by multiple alleles located at one or more loci. Heterozygous diploid individuals are female and homozygous become haploid or diploid male. Occurrence of diploid males is due to matched matting, where the individuals share an allele in the sex determination locus, whereas in the random matting, frequency of diploid male production depends on the allelic diversity present within the population. Based on allelic compositions at sex determination loci, the CSD is categorized into single locus CSD (sl-CSD) and multilocus CSD (ml-CSD).

Single locus CSD (sl-CSD)

sl-CSD is observed in numerous species of hymenoptera. It occurs through three different modes and changes the sex ratio abruptly following one generation of inbreeding. It is stabilizes through multilocus CSD mechanism. Three mating models under sl-CSD are (i) unmatched matting, where the females and haploid males do not share sex alleles and all diploid offspring are female (ii) matched mating, where female mates with a haploid male that carries a sex allele identical with one of her own, 50% of diploid offspring are diploid male (iii) diploid male mating, where mated females lower fecundity and haploids are produced.

Multilocus CSD (ml-CSD)

Under the ml-CSD, the sex is determined by multiple loci with multiple allele. Diploids are female, if one or more sex loci are heterozygous, diploids are male, only if homozygous at all loci. Inbreeding leads to diploid male, unlike sl-CSD, the production of diploid male is slow.

Implication of CSD on Biological control

Diploid male production potential thread to biological control attempt, it impose the genetic load on populations and reduces the population growth. Diploid male production increase drastically when population size is small. They are known to occur in several Braconid and Ichneumonid species. The cost of CSD is especially high under inbreeding because more diploid males are produced than under random mating. Limited field collections, genetic drift, population crashes in mass rearing are reasons for inbreeding.

Under the CSD model of sex determination

1. Females lose control over offspring sex ratio
2. It impose more genetic load on the populations, as well increase the female mortality.
3. Diploid males are sterile, do not mate with counterpart
4. It encourage male biased sex ratio
5. If the mating process takes place, it fails to transfer the genes, so mated females are constrained in production of haploid sons
6. Diploid males usually produce triploid offspring. They are produced instead of fertile diploid females, so they represent a strong cost to a population
7. Diploid male production may increase extinction risk and could potentially reduce the efficiency of biological control.

Therefore, production of diploid males under the CSD is one of bottleneck of augmentative release of biological control agents and it could be avoided by maintaining allele diversity, subsequent collection and incorporation of field collected natural enemies with laboratory culture and wide area collections. There are molecular tools available to detect the diploid males that can be employed to identify males and it would be useful for successful mass culturing under laboratory.