Review Article

GYNANDROMORPHISM IN SERICULTURE: A REVIEW

ABSTRACT

Sericulture is an agro-based industry. It is based on cultivation of host plants, rearing of silkworms and production of silk. There are four types of commercial silkworm i.e., mulberry, eri, muga and tasar. Among them, mulberry is only monophagous and rest ~~of the three~~ are polyphagous. In sericulture, gynandromorphism is too rare. Gynandromorphs are aberrant behaviours or traits that show both male and female features in a certain ~~organism~~individual. There are mainly three types of gynandromorph- 1. Bilateral 2. Anterior-posterior 3. Sex piebald. Till now gynandromorphic moth is found only in tasar, muga, mulberry and Attacus moth. If we compare the normal one with gynandromorphic moth then it is found that gynandromorphic moth is less active (characteristics) than normal ones. In 2010 only one muga gynandromorph ~~is~~ was found at Lahdoigarh. There is no any evidence of eri gynandromorph. The causes of the Gynandromorphism are varied. It occurs due to mutation, uv radiation, temperature, or in interspecific hybrid cross. In 2018, new research ~~has~~ was published by Rathore and he found a gynandromorph where one side is male and other side is female but it shows femaleness (~~lay~~ laid eggs). In 1993, P~~l~~eigler reported a false gynandromorph. At first, he believed it to be a gynandromorph, when they looked at it magnificently, they saw it was a normal male moth with defective antennae. ~~Having all the opposite personalities may not be gynandromorph. Through proper magnification, gynandromorphs are visible.~~

Keywords:

Sericulture, Silkworms, Eri, Muga, Mulberry, Tasar, Attacus, Gynandromorph, Mutation, Inter-specific hybrid cross.

1. INTRODUCTION:

Although gynandromorphism is a rare phenomenon (Rajkumar *et al.*, 1998), it has been widely documented in animal taxa (Bernardino *et al.*, 2007). Since the early 20th century, researchers have been examining the factors that led to the emergence of this phenomena (Craig and Crosby, 2008) which was initially seen in birds and insects (Nihei and Carvalho, 2002). A gynandromorph is a genetically male-female hybrid that arises from the deletion of a sex chromosome during early development, as seen in Drosophila (Morgan and Bridges, 1919). Alternatively, it could result from a bi-nucleate egg being fertilised twice, as observed in female heterogametic Lepidoptera. Consequently, a real gynandromorph's anatomy is made up of genetically distinct tissues with clearly defined male and feminine components (Morgan and Bridges, 1919, Morgan, 1907; Cockayne, 1935; Allen, 2011).

Sericulture, an agro based cottage industry often known as silk farming, is the raising of silkworms for the production of silk (Ssemuenze, *et al*., 2021). Silk was believed to have first been produced in China (Czaplicki *et al.*,2021). Sericulture is based on rearing of four silkworms i.e., mulberry ~~silkworm~~, eri ~~silkworm~~, muga ~~silkworm~~ and tasar silkworm. Mulberry silkworm is monophagous and other three i.e., muga, eri and tasar is polyphagous. In sericulture, gynandromorphism is too rare.Gynandromorphs are aberrant behaviours or traits that show both male and female features in a certain organism (Joshua *et al*., 2015). Till now, only one muga gynandromorph has been found in CMER&TI, Lahdoigarh, Assam (Rajkhowa *et al.*,2010) and only one Attacus moth has been found in Java (Lempke, 1981). Obara and their team examined the matting behaviour of experimentally produced gynandromorphy in *Bombyx mori* (Obara and Tamazawa, 1982). It might not be gynandromorphic to have all the opposing personalities. Gynandromorphs can be seen under the perfect magnification (Peigler, 1993).

2. SEX DETERMINATION IN SILKWORM:

A sex determination system is a biological system that determines the development of sexual characters in an organism. The determination of sex always involves genetics. There are various sex determination mechanisms like- male heterogametic *Drosophila melanogaster* with genetic combination of “XY” in male while “XX” in female, female heterogamety in silkworm, haplodiploidy in honeybees where “2n” genetic combination fertilized eggs become female while unfertilized “n” become male, paternal genome loss,

polygenic and environmental sex determination etc. that are being used for sex determination in arthropods (Werren and Beukeboom, 1998; Heimpel and De Boer, 2008).

The silkworm has sexual reproduction. It has 28 pairs of chromosomes in haploid form, of which 2 pairs are involved in determining sex. Tanaka made the first scientific demonstration of sex chromosome-related inheritance in silk worms in 1916 and he found that the type of sex chromosome in the silkworm is 'ZZ' in males and 'ZW' in females (Katsuma *et al.*, 2018).

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To know the occurrence of gynandromorph we need to understand the sex determination mechanism of the silkworm.

Table 1: Sex determination with special reference to the ratio of sex chromosome to autosome

AUTOSOME	Z-CHROMOSOME	W-CHROMOSOME	SEX EXPRESSION
AA	Z	-	MALE
	ZZ	-	MALE
	ZZZ	W	FEMALE
AAA(3A)	ZZ	-	MALE
	ZZ	W	FEMALE
	ZZ	WW	FEMALE
AAAA(4A)	ZZZ	W	FEMALE
	ZZ	WW	FEMALE

3. GYNANDROMORPH:

A gynandromorph are individuals that contains both male and female characteristics. The term comes from the Greek word; gyne (female), andro (male), and morph 'form', and is used mainly in the field of entomology(Butler, 2017). Gynandromorphism has been observed in a wide range of organisms, but it is most typically found in species of butterflies, spiders, and birds that exhibit high sexual dimorphism(Werner, 2012). They gynanders are normally sterile and have less life period than normal ones.

3.1 TYPES OF GYNANDROMORPH [11]:

I. **Bilateral gynandromorph:** Sometimes one half of the body shows female characters while other half shows male characters.

II. **Anterior-posterior gynandromorph:** Anterior region of the animal body has the characteristics of one sex and posterior half region has the characteristics of other sex.

III. **Sex piebalds:** Body consists of female tissue having spots of male tissue scattered irregularly.

3.2 OCCURRENCE OF GYNANDROMORPH:

I. Loss or damage of a sex chromosome (Narita *et al.*, 2010):

Example includes *D. melanogaster*, where one of the basic factor in sex determination is the number of "X" chromosomes and autosomes. During mitotic division, if one "X" chromosome gets lost, then it will give rise to individuals with XX and XO cells. Hence, if the loss of X chromosome occurs in the 1st mitotic division, appearance of individuals with 50-50% male & female tissues occurs. The size of male part is directly proportional to the time of disappearance of "X" chromosome. The later the disappearance, smaller the male part in that individual.

II. From binucleated eggs (Narita *et al.*, 2010):

Double fertilization is another reason for occurrence of gynandromorphy in insects like *D. mMelanogaster* (Hollingsworth, 1955) & *Bombyx mori* (Goldschmidt and Katsuki, 1927). During oogenesis process in *B. mori*, if the polar body nucleus may accidently remain in the egg together with the egg nucleus. These eggs will therefore have two nuclei (ZW). Two sperm cells that contain the Z chromosome fuse independently with the Z and W chromosomes as a result of fertilisation, producing male (ZZ) and female (ZW) tissues, respectively.

III. By Symbionts (Narita *et al.*, 2010):

Wolbachia bacteria are pervasive endosymbionts of arthropods and female arthropods affected by this bacteria lays unfertilized eggs that finally develops into female parthenogenetically. Elimination of this bacteria is done by application of antibiotics as well as high temperature which can produce male progeny (Fein *et al.*, 1992).

4. GYNANDROMORPHISM IN SERICULTURE:

4.1. TASAR SILKWORM:

The tasar word derived from the Sanskrit word **'trasara'**(Vishakha *et al*., 2020)**.** Tasar silkworms are polyphagous in nature and they feed leaves of arjun, asan, ber, sal etc. In India it is available in the states of Jharkhand, Chhattisgarh, ~~Orissa~~Odisha, Andhra Pradesh and West Bengal.

In the year 2021, a bilateral gynandromorph ~~has been~~was seen in Central Tasar Research and Training Institute, Ranchi, Jharkhand. This particular study has demonstrated that the gynandromorph's genitalia are identical to the female reproductive system, allowing it to mate with a normal male and produce fertile offspring. Further, the research on the progeny of gynandromorphs also demonstrated that their life cycles showed normal growth and development, and their economic traits has been well-documented (Mala *et al.*, 2021).

- **Characters observed**(Mala *et al*., 2021)**: This portion may be deleted as the values are repeated in Table 2**

1. Mean larval weight: 30.204g
2. Total larval life cycle: 35 days
3. Cocoon weight: 9.648 g
4. Pupal weight: 7.990 g
5. Shell weight: 1.652 g
6. Shell ratio: 17.12~~0~~%
7. Moth servivability: up to 10 days

Table 2:Comparison of Gynandromorph and normal Tasar moth (Mala *et al*., 2021)

CHARACTER	NORMAL TASAR	GYNANDROMORPHIC TASAR
1. Egg laid	150-250 no.	133 no.
2. Hatching ~~%~~percentage	78.99%	77.44%
3. Weight of egg~~s~~	9.8 mg	8-12 mg
4. Larval duration	28-36 days	35 days
5. Maximum larval weight	36g	30.2g

6. Cocoon weight	12.753g	9.648g
7. Pupal weight	10.646g	7.990g
8. Shell weight	2.106g	1.652g
9. Shell ratio	16.512%	17.120%
10. Moth colour	Male: light to dark brown Female: Grey to metallic brown	Brown and yellow
11. Antennae	Broad in male, narrow in female	Broad in male, narrow in female
12. Moth survivability	Male:4-6; female:8-10	10 days
13. Fat content in male	Male moth is smaller than female	Fat content is more in male
14. Life cycle	61-79 days	75 days

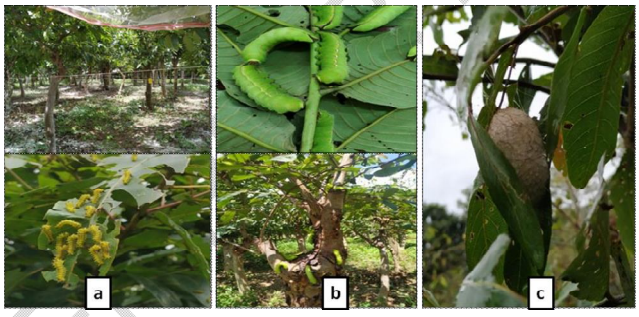


Fig1: Rearing of hatched out worms from gynandromorphous moth laid eggs under nylon net at CTR&TI, Ranchi (a) ~~Chowki~~ Chawki rearing (b) Late age rearing (c) Cocoon formation (Mala *et al*., 2021)

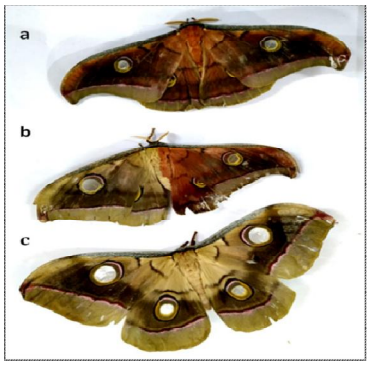
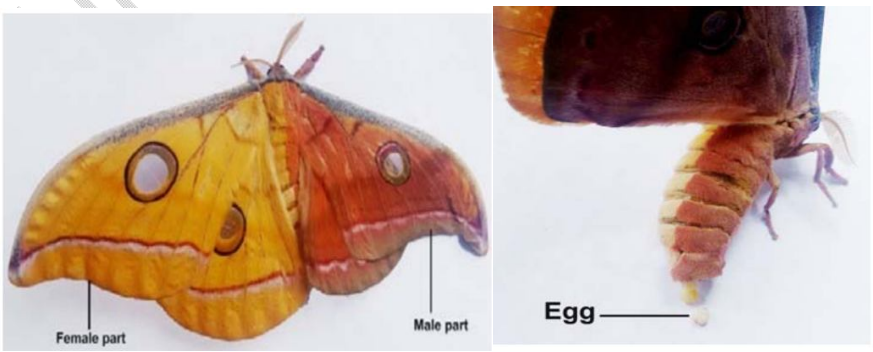


Fig2:Female tasar moth(a), gynandromorphic tasar moth (b), male tasar moth(c) (Mala *et al.*, 2021)

In 2018, a female gynandromorphic tasar moth ~~has been~~was found in BTSSO, Bilaspur, Chhattisgarh. After mating with a normal male with the gynandromorphic female, it laid about 116 eggs, 20 of which developed into larvae and were raised up to the third instar (Rathore *et al.*, 2018).

CHARACTERS	FEMALE SIDE	MALE SIDE
Antennae	narrow	broader
Colour	yellow	brown
~~wings~~ Wings and eyes spot	more prominent and broad	less prominent and broad
Forewings	sub triangular	sub triangular
~~apical~~ Apical angle	pointed and termen is almost straight	prominently curved and termen appears to be s-shaped
~~apical~~ Apical margin	apical margin not extended	apical margin is extended

Table 3: Characters observed in female gynandromorphy in DABA bi-voltine (Rathore *et al.*, 2018):



a b

Fig 3: a. Female Gynandromorphic moth, **b.** Ovipositing female gynandromorph (Rathore *et al.*, 2018)

4.2. MUGA SILKWORM:

The scientific name of muga silkworm is *Antheraea assamensis.* It is a polyphagous insect. ~~They feed mainly on Som and sualo.~~ It is available in Assam.Till now, only one muga gynandromorph has been found in CMER&TI, Lahdoigarh, Assam (Rajkhowa *et al.*,2010).

- **Characters observed** (Rajkhowa *et al.*,2010):
  1. Wings expanse:Male: 75mm, Female: 80mm
  2. Colour: larger and darker.
  3. Antenna: Quadripectinate
  4. Male antenna dark brown, with their bases reddish pink, but female antenna is paler.
  5. Abdomen: Chestnut brown.

Table 4: Characteristic comparison between normal & Gynandromorph muga moth (Rajkhowa *et al.*,2010):

CHARACTER	NORMAL MUGA	GYNANDROMORPHIC MUGA
Wing size	Larger in female and smaller in male	One side larger than other
Colour	Male: copper brown to dark brown Female: Yellowish light brown	One side darker than other
Antennae	Male antennae are darker than female	Male: dark brown Female: paler
Abdomen	Light to dark brown	Chestnut brown

Fig 4: Gynandromorphic muga moth (Rajkhowa *et al.*,2010)

4.3 GYNANDROMORPH in *Bombyx mori*(Obara and Tamazawa, 1982):

In 1982, some abnormal sexual behaviour of gynandromorph has been found in Japan. There, 232 artificial gynandromorphs were created utilising the egg cooling process, where the eggs were placed in a freezer at -~~10~~^{0}~~c~~ 10^{0}C for 24 hours following oviposition. This leads to unusual nuclear fusion and the formation of gynandromorphs. Out of 232, 32 gynandromorphs had uncommon bisexual behaviours. This unusual bisexual behaviour can be categorised into four categories:

1.Dual personality:15 dual personality gynandromorphs displayed one sex's mating behaviour at one time and the other sex's behaviour at another time.

2. Schizophrenics personality: In here 22 schizophrenic moth has been found where simultaneously exhibited male and female behaviours in various body regions.

3.Intersexual personality: ~~4 g~~Gynandromorphs displayed copulation and oviposition concurrently in the same body part.

4.Sequence- crossed personality: There are 3 sequence- crossed moth have been found when the behaviour of the other sex (i.e., male) would have typically been appropriate, they performed the inappropriate sexual behaviour (i.e., female) in the context of one sex (i.e. male).

4.4 GYNANDROMORPH IN *Attacus atlas* (Lempke, 1981):

It is a largest moth in the world. It belongs to the family ~~saturniidae~~Saturniidae. In 1981, Balvers reported an *A. atlas* ~~9~~Gynandromorphy from Java.

Characters observed:

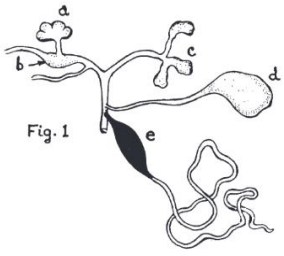
1. Wing size: Larger in female side
2. Antennae: Narrow in female side
3. Colour: One side is slight lighter than other

Fig 5: Gynandromorphic Attacus moth (left side-male, right side-female) (Lempke, 1981)

Fig 6: False gynandromorphic *Attacus atlas* (Peigler, 1993)

But in Perak Malaysia, Peigler's (1989) investigation, thousands of Attacus genus specimens were studied in museums, but no ~~10~~Gynandromorphy were discovered. He initially believed it to be a ~~10~~Gynandromorphy, but proper magnification reveals that it was actually a male moth with female antennae owing to sexual mosaic (Peigler, 1993).

5. REPRODUCTIVE MORPHOLOGY OF GYNANDROMORPHIC TASAR MOTH (Chaudhuri *et al*., 1992):



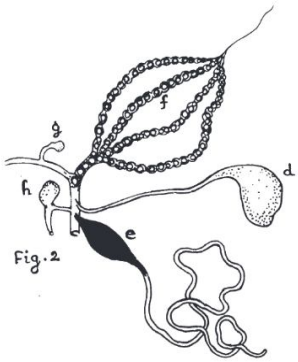


Fig 7: Reproductive morphologyof gynandromorphic moth **(**Chaudhuri *et al*., 1992)

Fig A: Predominant male gynandromorph Fig B: Predominant female gynandromorph

a) mature testis b) male accessory gland c) atrophied ovary d) female accessory gland e) colleterial gland f) mature ovary g) atrophied testis h) bursa copulatrix

6. ~~RESULTS AND DISCUSSION~~CONCLUSION:

Sericulture rarely encounters gynandromorphic situations. The same insect is shown to have both male and feminine characteristics. However, they will display differently. Some individuals may exhibit bilateral, anterior-posterior, or sex piebald features. Till now, gynandromorph has been clearly found in tasar moth, muga moth and Attacus moth. In case of mulberry, gynandromorphic moths are produced artificially by egg cooling method to check the matting behaviour between the moths. Previously, gynandromorphic moth was thought to be infertile, but recent study has shown that gynandromorphs can also be female. ~~But having different~~

7. FUTURE ASPECTS:

In future, some research should be conducted on gynandrogenesis. Such as-

1. Rearing behaviour of gynandromorphic moths
2. Study on physiological behaviour on gynandromorphic insect
3. Study on sex determination and breeding techniques of the gynandromorphic moths

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