Gynandromorph in fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae)

Here we report the gynandromorph in fall armyworm, *Spodoptera frugiperda*. Gynandromorphism is a phenomenon in which an individual develops with sexual mosaic of male and female traits[1]. Gynandromorph is an individual in which one part of the body is masculine and other is feminine[2]. It is a rare phenomenon that has been reported in certain group of organisms, viz. arthropods, birds, reptiles, amphibians, mammals[3]. In arthropods, gynandromorphs have been described repeatedly in natural and laboratory populations. Gynandromorphs are expressed generally in two ways, bilateral and non-bilateral (sexual mosaics). The former is most frequent among insects where a prominent mid-boundary line exists to distinguish between male and female sexual traits. Whereas in mosaics, both the sexual characteristics are intermixed and irregularly distributed over the body giving a patchy appearance[4]. In insects, bilateral gynandromorphs are most frequent, wherein left and right halves are of different sexes[5] and it is being reported from twelve orders of class Insecta. In order Lepidoptera, gynandromorphism is reported from 17 families with highest cases from families Papilionidae, Pieridae and Saturniidae[4].

Lepidopteran gynandromorphs have been observed in the species with sexual dimorphism where the male and female have differences in morphological traits, viz. wing pattern, antennae. The occurrence of gynandromorphism in Lepidoptera is at extremely low frequency, i.e. 0.000125% (one in 8000 reared insects), which is being reported in *Helicoverpa armigera*[5]. In Lepidoptera, gynandromorphism is majorly by double fertilization of a binucleate egg (ZW) by Z sperms[6], with one half of the body having ZZ sex chromosomes (male) while other half possesses ZW sex chromosomes (female). These aberrations operate in preimaginal stage, leading to development of both male and female genitalia at the same time[3]. Other causal factors are *Wolbachia* infection, mutation, genetic incompatibilities and temperature[7].

Among the lepidopteran pests, fall armyworm, *Spodoptera frugiperda* (JE Smith) is one of the important invasive polyphagous pests causing economic loss to more than 350 plant species including maize, rice, sorghum, sugarcane, wheat, cotton and vegetable crops[8]. This pest accounts for annual crop loss of more than US$ 500 million throughout the South-East United States and the Atlantic coast[9]. It is a pest native to tropical and subtropical regions of America[10], till 2015 this pest was endemic to America. In early 2016, severe incidence of fall armyworm (FAW) was reported from African countries[11] and by October 2017 it was present throughout sub-Saharan Africa[12]. This invasive alien pest was first reported in 2018 in southern parts of Karnataka [13], India and it has now spread to the remaining parts of India[14]. It has also been recorded from Bangladesh, Nepal, China, Myanmar, Sri Lanka, Malaysia, Thailand, Indonesia, Vietnam, Egypt and the Republic of Korea[15].

As a routine, we were rearing the *S. frugiperda* for reproductive physiology experiments in insect physiology laboratory at Division of Entomology, ICAR-Indian Agricultural Research Institute (IARI), New Delhi. While looking for the adult emergence from pupae, serendipitously we observed an adult with an uncertainty in wing morphology suggesting it to be a gynandromorph. So the detailed examination of morphological and anatomical structure of the first report of gynandromorph in *S. frugiperda* was attempted.

Larvae of *S. frugiperda* were collected from maize crop cultivated in the experimental fields of ICAR-IARI, New Delhi, during July 2020. These collected larvae were reared individually on chickpea based semi-synthetic diet[16] with modifications and maintained in insect rearing laboratory at 27 ± 2°C, 65 ± 5% RH and photoperiod of 14 : 10 (L : D) h. Incidentally, in F_3 generation we observed a single specimen of gynandromorphic moth in *S. frugiperda.* Genitalia studies were carried out for gynandromorphic moth, normal male and female[17], the abdomen was treated in 10% KOH for 10 to 20 min at 90°C using a Dry Block Heizgerat 2800, subsequently genitalia were cleaned and permanent slides were made using Euparal mountant media. Morphological and anatomical terminologies were used according to descriptions[18], photographs were taken with a Leica DFC425 digital camera mounted on a Leica M205FA stereozoom microscope and processed with automontage software. Photographs of adults were taken using Sony DSLR-A700 digital camera.

Figure 1. Habitus of normal male (***a*** and ***c***), female (***b*** and ***d***) and gynandromorphy (***e***).

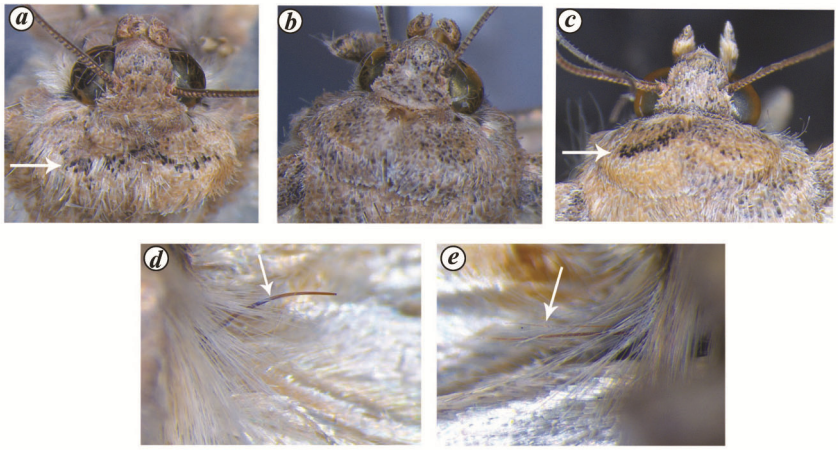

Figure 2. Thorax and frenulum of normal male (***a***), female (***b***) and gynandromorphic moth (***c***, ***d*** and ***e***).

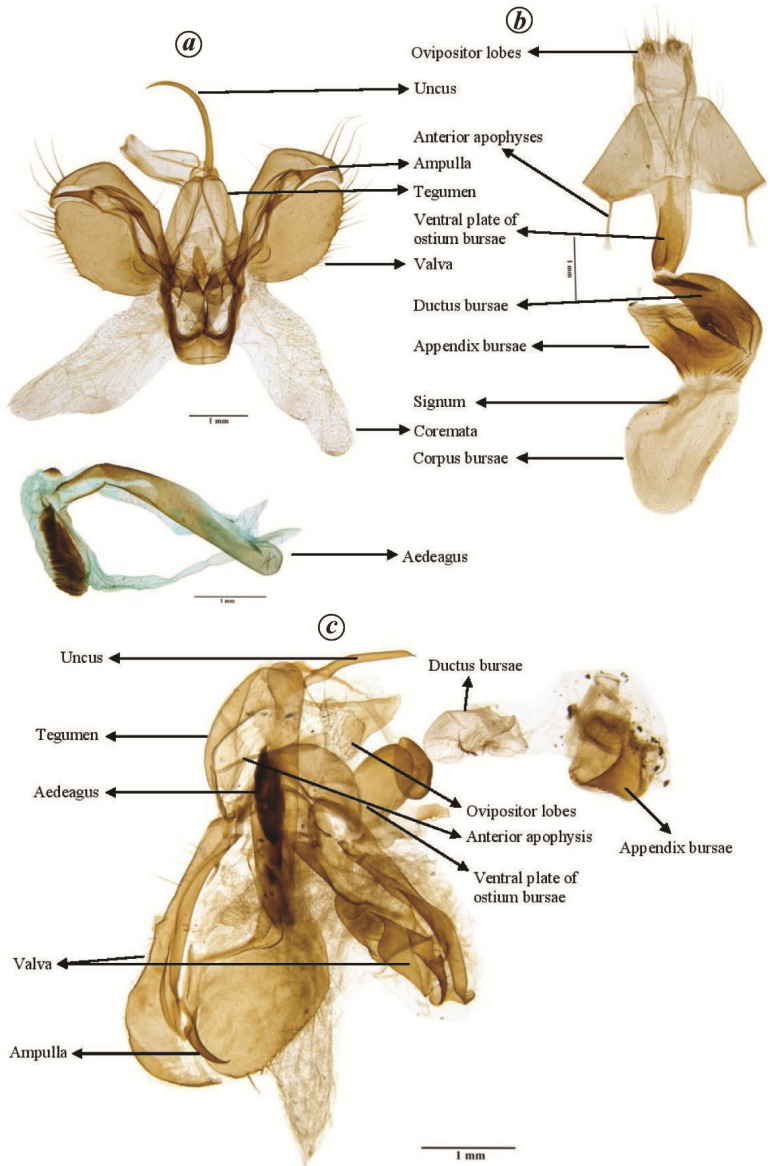

Figure 3. Genitalia morphology of *Spodoptera frugiperda*: ***a***, male; ***b***, female; ***c***, gynadromorph.

Pinned voucher specimen and permanent slides of genitalia are deposited in National Pusa Collection (NPC), Division of Entomology, IARI, New Delhi, India.

Out of 845 reared larvae, a single specimen of gynandromorphic moth was observed. *S. frugiperda* is sexually dimorphic with striking differences in wing patterns of males and females, forewing of male with brown ground colour compared to dark brown in female. In male forewing, prominent longitudinal black dash at the base of Cu vein, reniform spot indistinct with white v-shaped mark at apex, small white scaled patch at veins M_3 and CuA_1 (Figure 1 *a*) and in thorax, patagium light brown with transverse greyish black band (Figure 2 *a*). Contrastingly, in female the longitudinal black dash is less conspicuous, reniform spot absent and represent by only few white scales, white patch at veins M_3 and CuA_1 also absent (Figure 1 *b*) and in thorax, patagia without any distinct grayish black band[18] (Figure 2 *b*). In the present study, the gynandromorph specimen showed a notable variation, wherein the wing pattern of left and right resembled that of male and female respectively (Figure 1 *e*) and in thorax, patagium on left side was prominent like male while on the right side it was inconspicuous like female, depicting the bilateral type (Figure 2 *c*). In lepidopterans, the wing coupling mechanism is through jugum and frenulum. In *S. frugiperda*, it shows sexual dimorphism in the number of frenulum, with single frenulum in male and three in female. In gynandromorphic moth, left half consisted of single frenulum and right half consisted of three frenulum (Figure 2 *d* and *e*).

Dissection of gynandromorphic moth genitalia revealed that genital structure is asymmetrical with male genitalia structures observed on one half and female genitalia structures on the other half, male structures are well developed representing, distinct uncus, valvae, aedeagus, tegumen and ampulla as compared to the female. The right valvae also partially developed with distinct ampulla. In female genitalia, the ovipositor lobes, anterior apophysis, ventral plate of ostium bursae, ductus bursae, appendix bursae were well developed (Figure 3) and corpus bursae was not distinct, based on the genitalia coverage it could be said the male and female proportion was in the ratio of 60 : 40.

In Lepidoptera, the first case of gyandromorph was observed in *Smerinthus ocellata* and *S. populi*[19] and the first bilateral type of gynandromorphism was recorded in *Yponomeuta cagnagellus*[20], in which the right side was completely masculine and the left side showed a clear reduction of the male component and presence of female structures, such as anal papillae and apophyses. This bilateral type of gyandromorphism has also been observed in polyphagous insect pest, *Helicoverpa armigera*[5] with presence of both testis and ovary on the trans-lateral positions of moth. Similarly, this phenomenon is also reported in other major insect pests, viz. *Lymantria dispar*[21] and *Agrotis ipsilon*[22]. A number of examples of gynandromorphism are reported in Lepidoptera exhibiting highly diverse genitalia structure[4]. Occurrence of natural gynandromorphs is a rare phenomenon, they usually do not reproduce, even if they mate and lay eggs, the eggs do not hatch[22].

Looking into variations in wing pattern, patagium on thorax, frenulum number and genitalial morphology, it can be concluded that this is the bilateral type of gynandromorphism in *S. frugiperda*. To the best of our knowledge, this is the first report of gynandromorphism in fall armyworm.

1. Wcislo, W. T., Gonzalez, V. H. and Arneson, L., *J. Nat. Hist*., 2004, **38**, 1443–1457.
2. Mayr, E. and Ashlock, P., In *Systematic Biology* (ed. Kevin de Queiroz), McGraw Hill Inc., London, 1991, p. 475.
3. Jahner, J. P., Lucas, L. K., Wilson, J. S. and Forister, M. L., *J. Insect Sci*., 2015, **15**; doi:10.1093/jisesa/iev020.
4. Narita, S., Pereira, R. A. S., Kjellberg, F. and Kageyama, D., *Terr. Arthropod Rev*., 2010, **3**, 63–96.
5. Josephrajkumar, A., Subrahmanyam, B. and Ramamurthy, V. V., *Entomol. News*, 1998, **109**, 288–292.
6. Robinson, R., *Lepidoptera Genetics*, Pergamon Press, Oxford, 1971, p. 321.
7. Pereira, R. A. S., Prado, A. P. and Kjellberg, F., *Entomol. News*, 2003, **114**, 152–155.
8. Ganiger, P. C., Yeshwanth, H. M., Muralimohan, K., Vinay, N., Kumar, A. R. V. and Chandrashekara, K., *Curr. Sci*., 2018, **115**, 621–623.
9. Young, J. R., *Florida Entomol*., 1979, **62**, 130–133.
10. Cruz, I., Figueiredo, M. L. C., Oliveira, A. C. and Vasconcelos, C. A., *Int. J. Pest Manage*., 1999, **45**, 293–296.
11. Goergen, G., Kumar, P. L., Sankung, S. B., Togola, A. and Tamo, M., *PLoS ONE*, 2016; doi:10.137/journal.pone. 0165632.
12. Day, R. *et al.*, *Outlooks Pest Manage.*, 2017, **28**, 196–201.
13. Sharanabasappa *et al.*, *Pest Manage. Hort. Ecosyst.*, 2018, **24**, 23–29.
14. Sisodiya, D. B., Raghunandan, B. L., Bhatt, N. A., Verma, H. S., Shewale, C. P., Timbadiya, B. G. and Borad, P. K., *J. Entomol. Zool. Stud*., 2018, **6**, 2089–2091.
15. FAO, 2020; http://www.dextrainternational.com/fao-against-the-world-spread-fall-armyworm/ (accessed on 17 October 2020).
16. Gujar, G. T., Mittal, A., Kumari, A. and Kalia, V., *Entomol. Exp. Appl*., 2004, **113**, 165.
17. Robinson, G. S., *Entomol. Gaz*., 1976, **27**, 127–132.
18. Pogue, M. A., *Mem. Am. Entomol. Soc*., 2002, **43**, 1–202.
19. Morgan, T. H., *Am. Nat*., 1909, **43**, 251–253.
20. Kuijten P. J., *Entomol. Ber*., 1973, **33**, 221–222.
21. Goldschmidt, R., *Bibliogr. Genet.*, 1934, **11**, 1–185.
22. Gemeno, C., Anton, S., Zhu, J. W. and Haynes, K. F., *Int. J. Insect Morphol. Embryol*., 1998, **27**, 185–191.

Received 19 October 2020; revised accepted 4 November 2020

D. SAGAR*
P. R. SHASHANK
T. ISAIYAMUDHINI
G. S. SUJATHA
J. KOMAL

Division of Entomology,
ICAR-Indian Agricultural Research Institute,
New Delhi 110 012, India
**For correspondence.*
e-mail: garuda344@gmail.com