trans-fusion was 55.2/0.74, which is different from the δ values of C/H-9 in *cis*-fusion (40.8/1.44).

Another important determinant of the ring fusion type is the 19-CH_3 group which is present at the A/B junction and is always β-oriented. The methyl protons appear at δ 0.62–0.82 in the *trans*- and δ 0.82–0.98 in the *cis*-fused A/B rings. A clearer indication is provided by the ^{13}C resonances of 19-CH_3 where *trans* stereochemistry is shown by chemical shift of δ 11.4–16.9 and *cis* is shown by higher-frequency signals present between δ 23.0 and 24.4. In the case of saponins with *trans*-fused A/B rings, the ^{1}H NMR chemicals shifts for 19-CH_3 groups showed adequate closeness (δ 0.62–0.82) in all cases, except in the case of those reported by Jin *et al.*[18] for compounds **18–21**. These authors have reported chemical shifts higher than δ 0.82 for 19-CH_3 groups of compounds **18** (δ 1.11), **19** (δ 1.11), **20** (δ 0.86) and **21** (δ 0.86), which are contrasting to the values of majority of the compounds. It is noteworthy that the chemical shifts assigned to 18-CH_3 group in compounds **18**–**21** ranged from δ 0.61 to 0.65 (shielded compared to 19-CH_3 in all four cases)[18]. However, the literature suggests that 19-CH_3 appears at a lower frequency than 18-CH_3 group. Therefore, it may be inferred that 18- and 19-CH_3 resonances are oppositely assigned in the compounds **18**–**21**, and should be reinvestigated.

Complete ^{1}H NMR data have not been reported in all cases and the chemical shifts for methyls and signals downfield than 3 ppm are given. However, the reported ^{1}H NMR chemical shifts provide sufficient evidence for deriving the correlation between A/B ring fusion type and NMR chemical shifts. Overall, the A/B ring junction stereochemistry considerably influenced the chemical shifts of C/H-3 to C/H-7, C/H-9 and C/H-19 whereas the chemical shifts of C/H-8 were independent of the type of ring fusion. Figure 2 shows the average chemical shifts of *trans*- and *cis*-fused A/B rings.

Thus, a correlation between A/B ring junction stereochemistry and NMR resonances of spirostanol/furostanol saponins has been established. This can be utilized for ascertaining the $5\alpha/5\beta$ stereochemistry of saponins.

1. Sparg, S. G., Light, M. E. and van Staden, J., *J. Ethnopharmacol.*, 2004, **94**, 219–243.
2. Rao, A. V. and Gurfinkel, D. M., *Drug Metab. Drug Interact.*, 2000, **17**(1–4), 211–235.
3. Munafo Jr, J. P. and Gianfagna, T. J., *Nat. Prod. Rep.*, 2015, **32**, 454–477.
4. Xu, T. H. *et al.*, *J. Asian Nat. Prod. Res.*, 2008, **10**(5), 415–418.
5. Agrawal, P. K., Jain, D. C. and Pathak, A. K., *Magn. Reson. Chem.*, 1995, **33**(12), 923–953.
6. Agrawal, P. K., Bunsawansong, P. and Morris, G. A., *Phytochemistry*, 1998, **47**(2), 255–257.
7. Agrawal, P. K., *Steroids*, 2005, **70**(10), 715–724.
8. Agrawal, P. K., *Magn. Reson. Chem.*, 2003, **41**(11), 965–968.
9. Agrawal, P. K., *Magn. Reson. Chem.*, 2004, **42**(11), 990–993.
10. Chen, P. Y., Chen, C. H., Kuo, C. C., Lee, T. H., Kuo, Y. H. and Lee, C. K., *Planta Med.*, 2011, **77**(9), 929–933.
11. Yu, H. S. *et al.*, *Helv. Chim. Acta*, 2011, **94**(7), 1351–1358.
12. Eskander, J., Lavaud, C. and Harakat, D., *Fitoterapia*, 2010, **81**(5), 371–372.
13. Zhang, C. L., Gao, J. M. and Zhu, W., *Phytochem. Lett.*, 2012, **5**(1), 49–52.
14. Naveed, M. A., Riaz, N., Saleem, M., Jabeen, B., Ashraf, M., Ismail, T. and Jabbar, A., *Steroids*, 2014, **83**, 45–51.
15. Yokosuka, A. and Mimaki, Y., *Phytochemistry*, 2009, **70**(6), 807–815.
16. Da Silva, B. P., Valente, A. P. and Parente, J. P., *Nat. Prod. Res.*, 2006, **20**(04), 385–390.
17. Jin, J. M., Liu, X. K. and Yang, C. R., *J. Asian Nat. Prod. Res.*, 2003, **5**(2), 95–103.
18. Jin, J. M., Zhang, Y. J. and Yang, C. R., *J. Nat. Prod.*, 2004, **67**(1), 5–9.
19. Mandal, D., Banerjee, S., Mondal, N. B., Chakravarty, A. K. and Sahu, N. P., *Phytochemistry*, 2006, **67**(13), 1316–1321.
20. Sharma, U., Saini, R., Kumar, N. and Singh, B., *Chem. Pharm. Bull.*, 2009, **57**(8), 890–893.
21. Zhang, Y., Yang, C. R. and Zhang, Y. J., *Helv. Chim. Acta*, 2013, **96**(9), 1807–1813.
22. Guo-Lei, Z. H. U., Qian, H. A. O., Rong-Tao, L. I. and Hai-Zhou, L. I., *Chin. J. Nat. Med.*, 2014, **12**(3), 213–217.
23. Zhou, W. B. *et al.*, *J. Asian Nat. Prod. Res.*, 2010, **12**(11), 955–961.
24. Yokosuka, A., Jitsuno, M., Yui, S., Yamazaki, M. and Mimaki, Y., *J. Nat. Prod.*, 2009, **72**(8), 1399–1404.

ACKNOWLEDGEMENTS. We thank the Council of Scientific and Industrial Research, Government of India, for financial support.

Received 25 October 2017; accepted 21 May 2018

JASMEEN SIDANA[1]
BIKRAM SINGH[1]
OM P. SHARMA[2,*]

[1]*Natural Products Chemistry and Process Development Division,*
CSIR-Institute of Himalayan Bioresource Technology,
Palampur 176 061, India
[2]*Near Neugal Chowk,*
P.O. Bandla, Tea Estate,
Palampur 176 061, India
**For correspondence.*
e-mail: omsharma53@yahoo.com

Occurrence of the new invasive pest, fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae), in the maize fields of Karnataka, India

We report here the occurrence of the fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) in India, which is a devastating pest in American continent on several crops[1]. *S. frugiperda* is a polyphagous pest that causes significant losses to agricultural crops. The caterpillars feed on leaves, stems and reproductive parts of more than 100 plant species[2] that include maize, rice, sorghum, sugarcane, cabbage, beet, peanut, soybean, alfalfa, onion, tomato, potato and cotton[2,3]. In Brazil, *S. frugiperda* causes up to 34% reduction in maize grain yield[4] that amounts to an annual loss of US$ 400 million[5]. The pest accounts for annual crop losses in excess of US$ 500 million

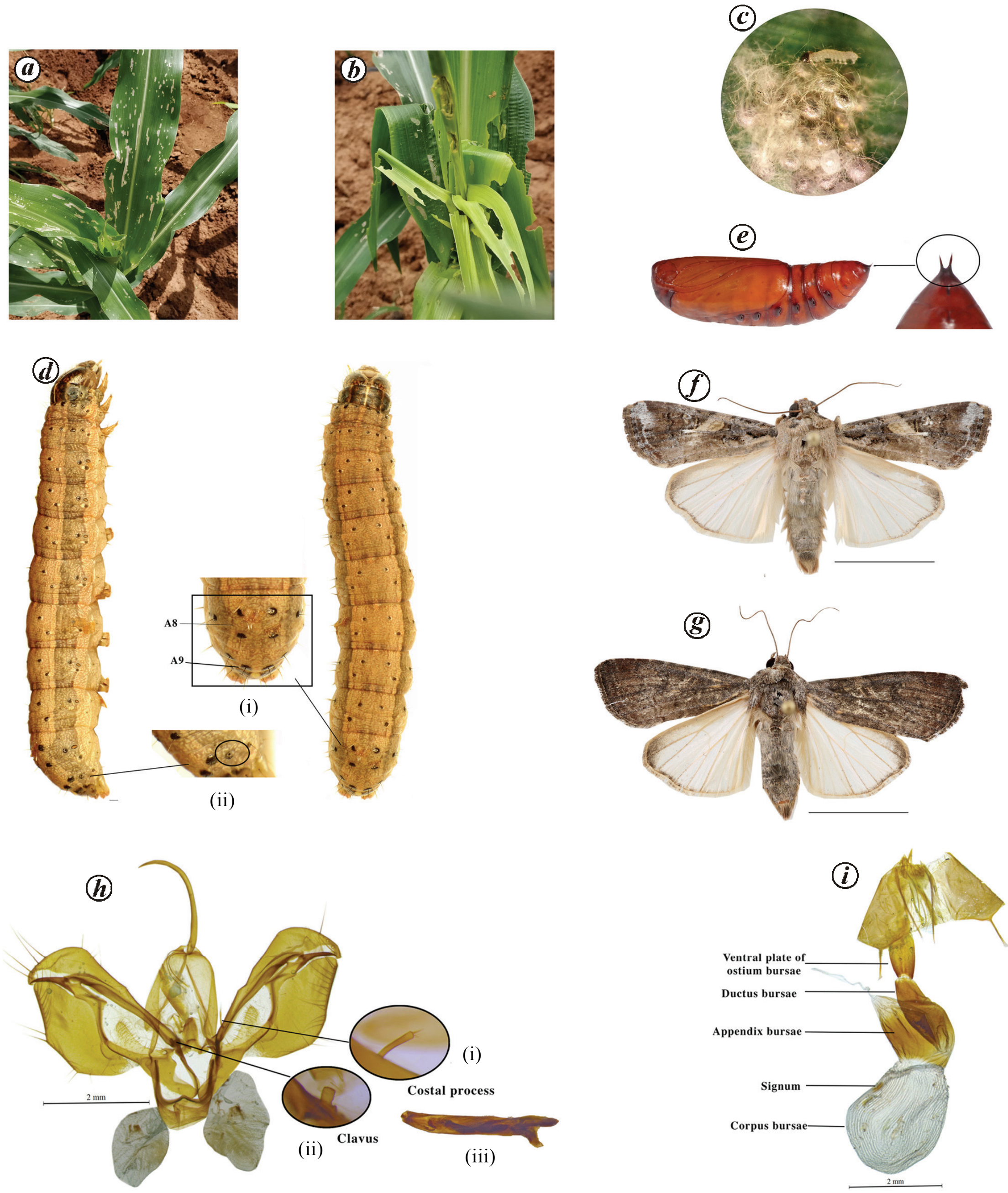

Figure 1. ***a***, Early stage feeding; ***b***, Later stage feeding; ***c***, Egg mass; ***d***, Larval characters; ***e***, Pupal character; ***f***, Male of *Spodoptera frugiperda*; ***g***, Female of *Spodoptera frugiperda*; ***h***, Male genitalia; ***i***, Female genitalia.

throughout the South-East United States and the Atlantic coast[6].

S. frugiperda is found in most parts of the Western Hemisphere, from southern Canada to Chile and Argentina[7]. This species was reported to have spread to Africa – São Tomé, Nigeria, Bénin and Togo[8] in 2016 and to Ghana[9] in 2017, causing widespread crop damage. Until now, there are no confirmed reports on the occurrence of this species in Asia.

Maize fields in Bangalore Rural and Chikkaballapur districts were devastated by caterpillars during May and June, 2018, which led to this study. Severe damage by *Spodoptera* spp. was recorded in several villages of Gouribidanur, Chikkaballapura and Doddaballapura taluks. Maize plants damaged by the early instar larvae showed characteristic pin holes symptoms on the leaves (Figure 1 *a*). Grown up larvae were confined to the deep whorls and fed extensively on inner whorl. Such plants appeared to have been torn (Figure 1 *b*). As the larvae could not be immediately related to any of the known noctuid species in India, they were brought to the laboratory for detailed observation.

The larvae were reared in the laboratory till adult stage, adults were allowed to mate and all the stages in the next generation (egg, larval, pupal and adult stages) were closely examined. Species were identified based on the larval morphology[10–12] and genitalial characters of male and female adults[2,7,10].

Larvae ($n = 18$) were killed in KAAD mixture[13] and preserved in 80% ethanol for observations. Characters such as colour of the body parts, pinacula, relative sizes of the pinacula and the spiracles, seta SD1 on different thoracic segments, mandible type and sutures on the head region were observed. In adults, both external morphology, male and female genitalial characters were noted. Markings on the wings, legs and abdomen were closely noted for both male ($n = 12$) and female moths ($n = 5$). Ten male and four female moths were dissected and their genitalia were separated using standard procedure[2] and photographed. Morphological and genital character descriptions for the observed specimen were prepared and were compared with the original available identification keys specific to *Spodoptera* spp. for confirming the genus and species[7]. The examined specimens have been deposited at the Department of Entomology, UAS, GKVK, Bengaluru, Karnataka, India.

Eggs were creamy white and covered with greyish coloured scales (Figure 1 *c*).

The grownup larva was dark brown with granulated cuticular texture all over the body (Figure 1 *d*). The dorsal pinacula present on one to eight abdominal segments were large and greater than the diameter of the corresponding spiracle[11,14]. The dorsal pinacula on the 8th abdominal segment were arranged in a square (A8)[13] and the pinacula on the 9th segment were arranged in a trapezoid pattern (A9), typical of *S. frugiperda*[10] (Figure 1 *d*(i)). Hair-like seta SD1 was present on the second and third thoracic segments. On the 9th abdominal segment, a pinaculum with a ring-shaped dark sclerotization was visible (Figure 1 *d*(ii)). The larval mandibles were serrate. Thus all the larval characters resembled those of *S. frugiperda*[10,12]. The pupa was brown in colour, with the cremaster having two spines (Figure 1 *e*).

Male adults were greyish brown; forewings light brown, oval or oblique orbital spots, with less contrasting transverse lines; reniform spot indistinct, partially outlined in black, with a small, sideways v-shaped marking; white patch like markings near apical margin of the forewing (Figure 1 *f*).

Unlike males, female forewing lack distinct markings. Forewings uniformly greyish brown with indistinct pale brown markings and dark grey coloured oval-shaped spots along the outer margins (Figure 1 *g*). Reniform spot and white patch at apical portion absent; foreleg with second and third tarsi dark brown; ventral abdomen with four pairs of black spots.

The valve in male genitalia is broad (Figure 1 *h*), almost quadrate; clavus short (Figure 1 *h*(i)); costal process narrow, elongate, straight, inclined hair structure at tip (Figure 1 *h*(ii)); ampulla slightly curved; juxta concave at base and with a dorsal process; coremata with a single lobe, aedeagus well developed (Figure 1 *h*(iii)).

The hair mass associated with the female genitalia was well developed (Figure 1 *i*). Ventral plate of ostium bursa with height greater than width; ventrolateral ductus bursae short (length less than twice the width); completely sclerotized. Appendix bursae partially sclerotized. Corpus bursae bulbous, length less than twice the width; striate convolutions. Signum present in basal half of corpus bursae.

The above larval and adult characters were compared with the taxonomic literature[2,7,10–12] and the species was confirmed as *Spodoptera frugiperda* (J.E. Smith).

We conclude that *S. frugiperda* has not only entered India, but is already building pestiferous populations. As an immediate alert, we have also reported the occurrence of this new invasive pest in the state level meeting of 'Karnataka State Pest Surveillance and Advisory Unit' held on 28 July 2018 at the Karnataka State Department of Agriculture, Bengaluru. Incidentally, this is the first confirmed report of *S. frugiperda* from Asia. The geographical extension of this pest into India is a matter of great concern to the farmers and to the overall food production. Although populations were recovered only from maize, it is possible that it may spread to other crops also. In this context, we call for a swift survey of the pest and to contain it at the earliest.

1. Sparks, A. N., *Florida Entomol*., 1986, **69**(3), 603–614.
2. Pogue, M. G., *Mem. Am. Entomol. Soc*., 2002, **43**, 1–202.
3. CABI, Data sheet. *Spodoptera frugiperda* (fall army worm). Invasive species compendium, 2016; http://www.cabi.org/isc/datasheet/29810
4. Lima, M. S., Silva, P. S. L., Oliveira, O. F., Silva, K. M. B. and Freitas, F. C. L., *Planta Daninha*, 2010, **28**(1), 103–111.
5. Figueiredo, M. L. C., Penteado-Dias, A. M. and Cruz, I., Danos provocados por *Spodoptera frugiperda* na produção de matéria seca e nos rendimentos de grãos, na cultura do milho (Comunicado Técnico, 130). Embrapa/CNPMS, Sete Lagoas, Brazil, 2005, p. 6.
6. Young, J. R., *Florida Entomol*., 1979, **62**, 130–133.
7. Todd, E. L. and Poole, R. W., *Ann. Entomol. Soc. Am*., 1980, **73**, 722–738.
8. Goergen, G., Kumar, P. L., Sankung, S. B., Togola, A. and Tamò, M., *PLoS ONE*, 2016, **11**(10), e0165632; doi:10.1371/journal.pone.0165632.
9. Cock, M. J. W., Beseh, P. K., Buddie, A. G., Cafâ1, G. and Crozier, J., *Sci. Rep*., 2017, **7**, 4103; doi:10.1038/s41598-017-04238-y.
10. Bulletin OEPP/EPPO Bulletin, PM 7/124, *EPPO Bull*., 2015, **45**, 410–444; doi:10.1111/epp.12258.
11. Passoa, S., *Insecta Mundi*., 1991, **5**(3–4), 185–195.
12. Gilligan, T. M. and Passoa, S. C., Lep-Intercept – An Identification Resource for Intercepted Lepidoptera Larvae. Identification Technology Program (ITP), USDA-APHIS-PPQ-S&T, Fort Collins (US), 2014; www.lepintercept.org (accessed on 1 September 2014).
13. Peterson, A., *Larvae of Insects*, Edwards Brothers Inc. Arbor, Michigan, 1962, p. 732.
14. Levy, R. and Habeck, D. H., *Ann. Entomol. Soc. Am*., 1976, **69**(4), 585–588.

ACKNOWLEDGEMENTS. We are grateful to Prof. C. A. Viraktamath, Emeritus Scientist, Department of Entomology, University of Agricultural Sciences, Bengaluru for guiding us during the process of identification. We thank Prof. V. V. Belavadi, Department of Entomology and Dr Prabhakar, Project Coordinator, AICRP on Small Millets for the guidance and support, Mr Y. B. Srinivasa for going through the manuscript and making valuable suggestions.

Received and accepted 2 August 2018

P. C. GANIGER[1,*]
H. M. YESHWANTH[2]
K. MURALIMOHAN[2]
N. VINAY[2]
A. R. V. KUMAR[2]
K. CHANDRASHEKARA[2]

[1]*AICRP on Small Millets, and*
[2]*Department of Entomology,*
University of Agricultural Sciences,
GKVK,
Bengaluru 560 065, India
**For correspondence.*
e-mail: prabhuganiger@gmail.com