



ARTHROPOD PESTS AND THEIR NATURAL ENEMIES ASSOCIATED WITH COTTON IN INDIA: A REVIEW[#]

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ABSTRACT

Globally cotton is the most important natural fibre crop being cultivated commercially for domestic textile needs and export. Cotton plays an important role in India's economy, occupies largest acreage and highest production in the world. In India, cotton is being grown in 10 major states divided in 3 distinct zones viz., north, central and south with varying climate and soil. Despite large acreage, cotton productivity in India is far below world average due to variety of reasons. Among them damage caused due to arthropod pests is vital. In this article authors have attempted through extensive literature survey, to provide up to date information on arthropod pests and their natural enemies associated with cotton crop in India. It is observed that, in India, cotton crop is attacked by 251 arthropod pest species (including insect and mites) belonging to 9 insect orders and 1 order from Acarina. Among these, about 12 species of insects are major pests causing significant losses to cotton crop while remaining species are either occasional, sporadic or minor in nature. Overall these pests cause economic damage to cotton crop in a range between 20-60 per cent. The major arthropod pests are sucking insects namely leafhopper *Amrasca biguttula biguttula* (Ishida), aphid *Aphis gossypii* Glover, thrips *Thrips tabaci* Lindeman., whitefly *Bemisia tabaci* (Gennadius), Cotton mealybug *Phenacoccus solenopsis* Tinsley, Papaya mealybug *Paracoccus marginatus* Williams and Granara de Willink, and Indian cotton mirid bug *Creontiades biseratense* (Distant). The bollworm complex is another major group of insects that attack cotton and comprises of American bollworm *Helicoverpa armigera* (Hubner), spotted bollworms *Earias insulana* (Boisduval), *E. vitella* (F.) and pink bollworm *Pectinophora gossypiella* (Saunders). Other pests like stem weevil *Pempherulus affinis* Faust and tobacco caterpillar *Spodoptera litura* F., are also categorized as major pests. A rich fauna of 368 natural enemies (including 174 species of predators and 194 species of parasitoids/ parasites) play significant role as biological control agents to check arthropod pests in cotton ecosystems of India. In this review there is addition of 85 arthropod pests over previously reported 166 arthropod pests. This updated information on cotton pests and their important natural enemies may serve as an important guide to researchers and policy makers in carrying out potential pest risk assessment and devising appropriate management strategies for economically damaging cotton pests.

Key words: Cotton, India, cotton ecosystem, arthropod pests, fauna, insects, mites, sucking pests, bollworms, resurgence, natural enemies, predators, parasitoids

Cotton is the most important natural fibre crop cultivated commercially for domestic textile needs as well as export. Cotton plays a major role in India's economy, both in terms of providing employment directly and indirectly to more than 60 million people. India occupy largest cotton acreage (13.373 m ha) and production (36.5 m bales, 1 bale=170 kg) in the world (CICR, 2020). India is the only country where all the four cultivated species of cotton viz., *Gossypium hirsutum* Linn., *G. barbadense* Linn., *G. arboreum* Linn., and *G. herbaceum* Linn. being grown for lint, oil and feed. In India, cotton is being

cultivated in 10 major states classified into 3 distinct zones viz., north zone comprising of Punjab, Haryana and Rajasthan; central zone comprising of Madhya Pradesh, Maharashtra and Gujarat, and south zone comprising of Andhra Pradesh, Telangana, Karnataka and Tamil Nadu. These three zones have distinct bio geographical features with varying climate and soil. Though, India shares largest area under cotton, however Indian cotton productivity is lowest (464 kg lint/ ha) due to variety of reasons, among them damage due to various arthropod pests is one of the major yield limiting factors.

[#]Table 1-3 available ONLY IN ONLINE PUBLISHED VERSION- see indianentomology.org or entosocindia.org

Previous records revealed, worldwide, cotton crop is attacked by 1326 species of arthropod pests (Hargreaves, 1948). In India, initial records indicated 109 species of insects and mites infest the cotton crop (Nangpal, 1948). Later, this number increased to a total of 166 species (Khan and Rao, 1960). These pests were reported attacking cotton crop at different stages of growth causing losses ranging between 50-60% (Puri et al., 1999). There is gap of almost 60 years since 1960 (Khan and Rao 1960) on the updating of arthropod associated with cotton in India. Since then updated information on new records of pests on cotton is seriously lacking. The major insect pests documented in above reports include: i. Bollworm complex comprising of American bollworm *Helicoverpa armigera* (Hubner), spotted bollworms *Earias insulana* (Boisduval), *E. vittella* (F.) and pink bollworm *Pectinophora gossypiella* (Saunders); and ii. Sucking pest complex consisting of leafhopper (*Amrasca biguttula biguttula* Ishida), aphids (*Aphis gossypii* Glover), thrips (*Thrips tabaci* Lindeman) and whitefly (*Bemisia tabaci* Gennadius). With the introduction of genetically modified cotton, popularly known as 'Bt cotton' in 2002 for bollworm control, Indian cotton ecosystem experienced a phenomenal change in its pest profile. There have been frequent pest resurgences of already existing pests as well as few recent invasions which were hitherto not reported to be the pests of cotton. In this review, an attempt has been made through an extensive review of literature to provide an up-to-date information on pest fauna associated with cotton in India. Additionally, a comprehensive list of diverse natural enemy complex including both predators and parasitoids that are prevalent in Indian cotton ecosystem have been provided as a ready reckoner for researchers, extension workers and policy makers in assessing the potential pest risks and formulating effective management strategies for various insect pests in cotton.

Arthropod pests

The information updated through extensive literature survey revealed that the number of pests (including insects and mites) attacking cotton crop in India has been increased to 251 from earlier report of 166 species (Table 1)[#]. These 251 species documented here belonged to 9 different insect orders and one order from Acarina. The reported insect pest species attacking cotton crop have been categorised broadly in two groups; one group included sucking pests and another group included chewing, biting

and borer insects. Among sucking pests, insect order Hemiptera contributed 72 species belonging to 18 families viz., Aleyrodidae (1), Aphididae (2), Capsidae (3), Cercopidae (2), Cerococcidae (1), Cicadellidae (8), Coccidae (3), Coreidae (8), Diaspididae (1), Eurybrachidae (1), Fulgoridae (2), Lygaeidae (8), Membracidae (2), Miridae (9), Monophlebidae (1), Pentatomidae (5), Pseudococcidae (11) and Pyrrhocoridae (4). It was followed by 4 species of Thysanoptera belonging to a single family Thripidae. Among chewing, biting and borers insects; insect order Coleoptera contributed 41 species from 11 families which comprised of Anthribidae (1), Bostrichidae (1), Bruchidae (1), Buprestidae (1), Cerambycidae (1), Curculionidae (25), Chrysomelidae (2), Galericidae (1), Meloidae (4), Scarabaeidae (2), Tenebrionidae (2); order Lepidoptera contributed 60 species from 12 different families Arctiidae (6), Cassidae (1), Cosmopterigidae (1), Crambidae (2), Erebiidae (2), Gelechiidae (1), Lymantriidae (5), Lyonetiidae (1), Noctuidae (35), Oracilariidae (1), Pyralidae (3), Tineidae (2); order Orthoptera included 33 species from 05 families viz., Acridiidae (20), Gryllaeridae (1), Gryllidae (10), Pyrogomorphidae (1), Tettigoniidae (1); order Hymenoptera comprised of 9 species from single family Formicidae while order Isoptera had 6 species from family Termitidae. Order Diptera contributed 5 species from four families Agromyzidae (1), Cecidomyiidae (1), Chloropidae (1) and Sarcophagidae (2). The order Dermaptera contributed only 3 species from families Anisolabididae (2) and Forficulidae (1) (Table 1). In mite pests, the only Order Acarina of mites contributed 18 species from six different families viz., Eriophyidae (3), Erythraeidae (1), Phytoseiidae (2), Tarsonemidae (1), Tenuipalpidae (1) and Tetranychidae (10) (Table 1). Over the previously reported 166 arthropod pest species (Khan and Rao 1960) there is addition of 85 arthropod pests in this review.

Among the 251 arthropods species, 12 species of insects are major pests causing significant losses to cotton crop while remaining species are occasional, sporadic or minor in nature. The sucking insect pests (leafhopper, aphid, thrips, whitefly, cotton mealybug, papaya mealybug and Indian cotton mirid bug), the bollworm complex (American bollworm, spotted bollworms and pink bollworm) and the other pests like stem weevil *Pempherulus affinis* Faust and tobacco caterpillar *Spodoptera litura* F., are the major pests of cotton in India. These arthropod pests cause yield

[#]Table 1-3 available ONLY IN ONLINE PUBLISHED VERSION- see indianentomology.org or entosocindia.org

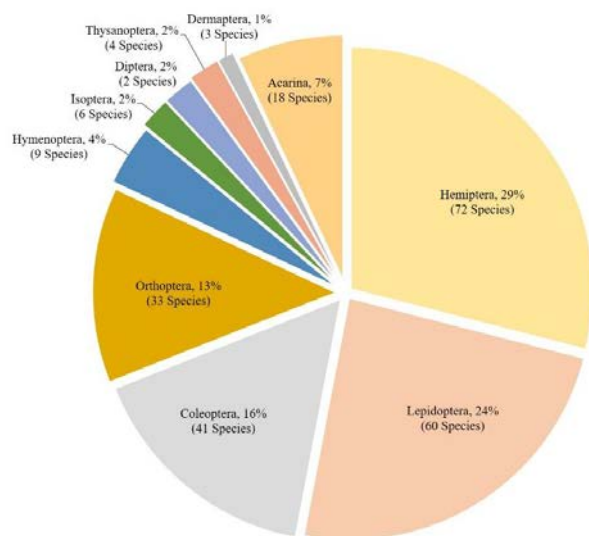


Fig. 1. Number of arthropod species and its relative proportion from ten different orders recorded on cotton ecosystems of India

losses ranging from 20-60 %. Current status of these pests is given in later part of this article. The relative proportion of insect species from different orders is presented in Fig. 1.

Natural enemies

Interestingly, a rich fauna of 368 natural enemies have been recorded on various insect pests of cotton from different cotton growing zones of India (Table 2 and 3)[#]. These natural enemies are key component of cotton ecosystem and are playing a vital role in natural suppression of insect pests therein. Thus, looking at the vast diversity of predators and parasitic fauna associated with pests of cotton ecosystem, there is a great potential for implementation of environment friendly biological control of cotton insect pests.

Predators

The predatory fauna appetizing on various cotton insect pests comprised of 174 species (Table 2). Predators from insect order Coleoptera contributed 23 species mainly from Coccinellidae (22) and Staphylinidae (1); order Neuroptera contributed 9 species from Crysopidae (8) and Hemerobidae (1); order Diptera contributed 14 species from Asilidae (1), Cecidomyiidae (1), Chamaemyiidae (3), Drosophilidae (1) and Syrphidae (8); order Hemiptera contributed 20 species from families Anthocoridae (4), Geocoridae (4), Miridae (2), Pentatomidae (1), Pyrrhocoridae (1), Reduviidae (8); order Lepidoptera contributed 3 species from Lycaenidae

(1), Noctuidae (2); Mantodea contributed 3 species from Mantidea; order Hymenoptera contributed 16 species from Aphelinidae (1), Formicidae (3), Scoliidae (1), Sphecidae (8), Vespidae (3); order Odonata contributed 4 species from Libellulidae (4); Araneae contributed 76 species (44.25%) from Araneidae (11), Clubionidae (2), Dictynidae (1), Eutichuridae (1), Gnaphosidae (1), Lycosidae (6), Oxyopidae (19), Parassidae (1), Pisauridae (1), Salticidae (14), Sparassidae (1), Tetragnathidae (5), Theridiidae (3), Thomisidae (9), Uloboridae (1); Mite order Acarina contributed 5 species of predatory mites from two families Phytoseiidae (4) and Pyemotidae (1). The relative proportion of predatory species from different orders is presented in Fig. 2.

Parasitoids/ Parasite

There are total 194 different species of parasitoids associated with insect pests of cotton ecosystems in India (Table 3). The Hymenoptera, a single insect order contributed 163 species which accounts for about 83.85% of the total parasitic fauna. The Hymenopteran parasitic families included Aphelinidae (13), Braconidae (53), Chalcidae (21), Elasmidae (5), Encyrtidae (31), Eulophidae (9), Eurytomidae (1), Ichneumonidae (14), Mymaridae (2), Pteromalidae (3), Scelionidae (2), Thysanidae (1) and Trichogrammatidae (8) (Fig. 3). Another insect order Diptera contributed remaining 30 species (15.63%) from two families Chloropidae (1) and Tachinidae (29). Only one parasite from Acarina belonging to family Pyemotidae has been reported.

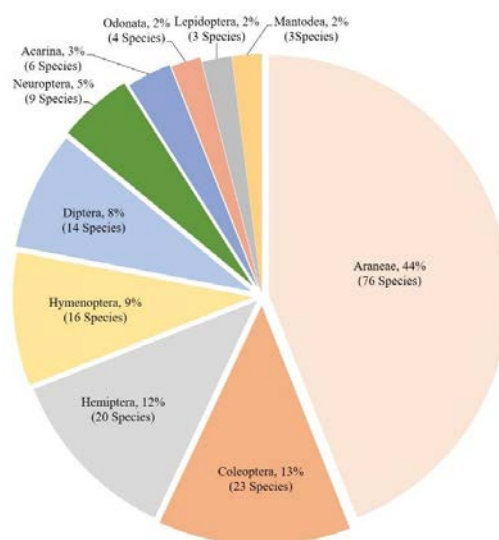


Fig. 2. Number of predatory arthropod species and its relative proportion (%) from ten different orders recorded in cotton ecosystems of India

[#]Table 1-3 available ONLY IN ONLINE PUBLISHED VERSION- see indianentomology.org or entosocindia.org

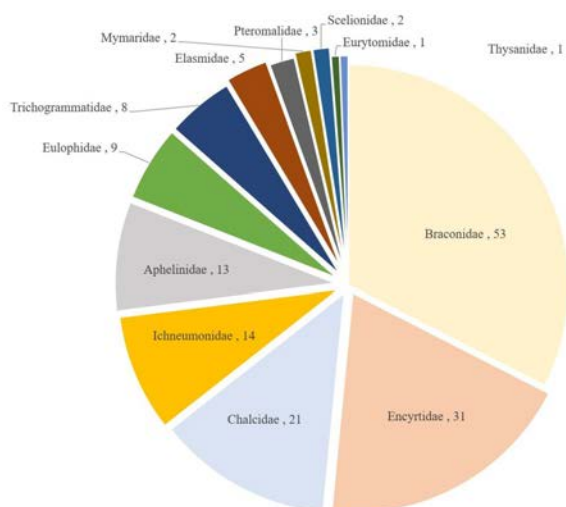


Fig. 3. Distribution of number of species in each family of order Hymenoptera

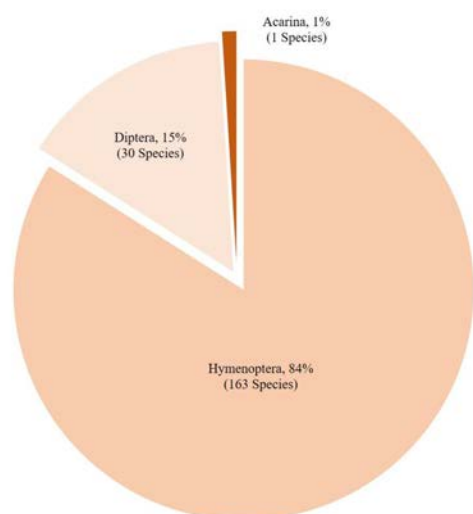


Fig. 4. Number of parasitoid species and their relative proportion from three orders recorded in cotton ecosystems of India

The relative proportion of parasitoid species from different orders is presented in Fig. 4.

Present status of major pests

Sucking insects

1. Leafhopper *Amrasca biguttula biguttula* (Ishida)

Leafhopper *Amrasca biguttula biguttula* (Ishida) is one of the most important pests of cotton in India (Pruthi, 1940; Husain, 1937; Shivanna et al., 2009; Murugesan and Kavitha, 2010). Leafhopper is a major and regular pest feed on the sap of mesophyll and vascular tissues through cell rupture and cause phytotoxic symptoms known as causes 'hopperburn' consequently leading to reduction in crop vitality and

cotton yield loss up to 30%. The pest is distributed in all the three cotton growing zones and is a regular pest. It is a polyphagous insect pest of Asia and Southeast Asian countries. Genetic divergence analysis of leafhopper population across India confirmed the presence of single species. North India populations were dominated by single haplotype while, the south and central Indian populations show dispersion of different haplotypes across the region (Kranthi et al., 2017).

2. Aphid *Aphis gossypii* Glover

Aphid has been reported as a major pest of cotton causing significant damage to the cotton crop. This species has been reported as a vector of Pulerovirus infecting cotton in India (Mukherjee et al., 2012). Nagrare et al. (2019) studied the temperature effects on phenology of *A. gossypii* and reported that temperatures between 22 - 27°C favoured its optimum development. Further, they estimated through fitting of non-linear models to temperature dependent development data, the lower and upper thresholds temperatures of 6.24°C and 34°C, respectively for *A. gossypii* development.

3. Thrips *Thrips tabaci* Lindeman

Thrips lacerate the tissue and de-sap the plants from the upper and lower surfaces of leaves, resulting in silvery or brown necrotic spots. Infested plants demonstrate hampered growth, loss of vigor. Leaves turned into wrinkled and distorted, curl upward with white shiny patches, resulting in dropping of squares, delayed crop maturity and reduction in yield. Tobacco streak virus disease transmitted by *T. tabaci* has been recorded in central and south zone of India (Bhat et al., 2002; Jagtap et al., 2012).

4. Whitefly *Bemisia tabaci* (Gennadius)

Whitefly is a major pest occurring in all the three cotton growing zones of India, but it is the most important sucking pest in North Indian cotton growing states of Punjab, Haryana and Rajasthan by virtue of its capability to transmit cotton leaf curl virus disease (CLCuD), especially in *hirsutum* cotton. Several outbreaks of whitefly were reported in India (Basu, 1986; Jayaraj et al., 1986) but the recent one was witnessed during 2015 in north India (Kranthi, 2015b). *Bemisia tabaci* is a vector of begomoviruses (family *Geminiviridae*). *Bemisia tabaci* is reported to transmit 111 viruses (Tiwari et al., 2013). Whitefly causes direct damage by sucking phloem sap from plant tissues, while indirect damage through the excretion of sticky honeydew which promotes a fungal sooty mould that

interfere in photosynthesis in leaves and deteriorate the quality of cotton.

5. Cotton mealybug *Phenacoccus solenopsis* Tinsley

Widespread outbreak of invasive species of mealybug occurred on cotton in India during 2007 which caused economic damage, thereby reducing yields up to 50% in affected cotton fields (Nagrare et al., 2009). The infestation was recorded in nine major cotton growing states of India. Infestation of cotton mealybug at most of the places in north and central zones was high during 2007 and 2008 but it was reduced to a minor pest from 2009 onwards. *Phenacoccus solenopsis* suck sap from all parts of the plant, resulting stem distortion, twisting and bushiness of the affected portion and death of plant in severe infestation. Since its invasion in India, *P. solenopsis* is the most extensively studied insect pest of cotton so far with respect to various aspects like host range and infestations levels (Tanwar et al., 2007; Jhala et al., 2008; Nagrare et al., 2009; Fand et al., 2010; Venilla et al., 2011), important biological control agents including predators and parasitoids (Tanwar et al., 2008; Rishi et al., 2009; Fand et al., 2010b, c; Fand et al., 2011; Suroshe et al., 2013) and potential geographic distribution, temperature dependent biology, within plant distribution (Rishi et al., 2013) and climate change impact on future invasiveness (Fand et al., 2014a-c). A detailed account of this mealybug with a major focus on its origin and distribution, biosystematics, bioecology, host range, management options and its potential threat under future climate change has been reviewed by Fand and Suroshe (2015).

6. Papaya mealybug *Paracoccus marginatus* Williams and Granara de Willink

Papaya mealybug was recorded in a severe form for the first time on cotton in Coimbatore in 2008-09, infestation leads to drying of the sympodial branches (Dhara Jothi et al., 2009). The mealybug also found in other districts like Erode, Tirupur, Salem, Namakkal and Karur districts of Tamil Nadu (Tanwar et al., 2010). The pest is now seen in traces.

7. Indian cotton mirid bug *Creontiades biseratense* (Distant)

Infestation of Indian cotton mirid bug was observed in Karnataka (Patil et al., 2006). An epidemic form in Coimbatore on cotton during 2006 (Surulivelu and Dhara Jothi, 2007) led to significant reduction in seed

cotton yield of Bt cotton. The pest feeds on the flower bud result in oozing out of yellow fluid from the buds and staining of this yellow fluid on the inner surface of the bracts. Cotton mirid bug is a major pest restricted to Tamil Nadu and Karnataka states of South Zone.

Cotton bollworms

8. American bollworm *Helicoverpa armigera* (Hubner)

It is considered as a major and most notorious and obnoxious pest of cotton in Indian sub-continent. Heavy infestation of American bollworm witnessed during 1995-2000 in view of the injudicious use of insecticides, especially synthetic pyrethroids that led to problems of insecticide resistance. Subsequently, after 2000, with the introduction new technologies like Bt-cotton, new chemistry insecticide, etc. (Kranthi and Russell, 2009), *H. armigera* infestation reduced significantly and in the last two decade it hardly ever exceeded economic threshold levels in majority of the cotton growing regions on Bt cotton of India. However, infestation of *H. armigera* observed on non-Bt cotton. The pest feed on squares/ bolls and results in yield loss up to 40% in non-Bt cotton.

9. Spotted bollworms *Earias insulana* (Boisduvel)

Spotted bollworm *Earias vittella* (Fabricius) and spiny bollworm *E. insulana* (Boisduvel), (Lepidoptera: Noctuidae) are the major pests of cotton in India. *Earias vittella* is seen in Central and South India while *E. insulana* is predominant species in North India. At present both these species are under control on Bt cotton (Rishi et al., 2019). Larvae of the pests initially bore into terminal shoot that dry and wither away when the larvae bore into the pre-squaring plants. As like *H. armigera*, *Earias* spp hardly exceeded economic threshold level on Bt cotton, however, seen to damage non Bt cotton.

10. Pink bollworm *Pectinophora gossypiella* (Saunders)

Pink bollworm *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae) is destructive pest of cotton in India. Larvae mainly feed on developing cotton seeds. Quality of lint deteriorated due to the presence of larvae and lint get stained by the pest. Up to 61.9 per cent loss in seed cotton yield, 47.10 per cent loss in oil content and 59.20 per cent loss in normal opening of bolls was reported (Patil, 2003). Presently, Bt technology is unable to protect cotton crop from *P. gossypiella* due to development of resistance against Cry1Ac and Cry 2Ab toxins in India. Widespread infestation of pink bollworm on Bt cotton was reported

from major cotton growing Indian states like Gujarat, Maharashtra, Andhra Pradesh, Telangana, Karnataka and Madhya Pradesh starting from 2015 onwards (Kranthi, 2015; Naik et al., 2018, 2020, Fand et al., 2019). The pest also seen infesting Bt cotton during 2018-2019 and 2019-2020 in north zone especially in Jind district of Haryana (Rishi et al., 2020).

Other insects

11. Tobacco caterpillar *Spodoptera litura* Fabricius

During eighties to late nineties, Tobacco caterpillar, *Spodoptera litura* Fabricius (Lepidoptera: Noctuidae) was one of the economically important polyphagous pests of cotton which exhibited high resistance levels when pyrethroids were first introduced in India in 1982 (Ramakrishnan et al., 1984; Kranthi et al., 2002). The pest was severe in most parts of Andhra Pradesh (Armes et al., 1997).

12. Stem Weevil *Pempherulus affinis* Faust

Stem weevil *Pempherulus affinis* Faust (Coleoptera: Curculionidae), is an endemic pest in some parts of south India, particularly Tamil Nadu, causes 65.8% plant mortality, 72.0% reduction in boll production and 78.9% reduction in yield of seed cotton (Parameswaran and Chelliah 1984). Grub tunnel the stem which damages the vascular tissues. Infested plant gets killed in the course of time either due to blockage of plant nutrients or break down at the gall region due to strong winds. The pest is mostly prevalent in irrigated tracks.

CONCLUSIONS

Over the period of time, Indian cotton ecosystem has witnessed a sea change in its cultivation practices and pest profile. In the context of climate change and introduction of Bt cotton for commercial cultivation, the cotton crop has experienced very frequent invasions of some new insect pests as well as resurgence of already existing insect pest. There is gap of almost 60 years since 1960 on the updating of arthropods associated with cotton in India. Our efforts to provide an updated list of insect pests and natural enemy fauna associated with cotton brought to the forefront an important information that presently the cotton crop in India is attacked by 251 arthropod pest species (including insect and mites) belonging to 9 different insect orders and 1 acarina. Among these species, about 12 species of insects are major pests during last two decades causing overall losses to the tune of 20-60% to cotton crop while remaining species are occasional, sporadic

or minor in nature. A rich fauna of 368 natural enemies (174 predators and 194 parasitoids/ parasites) found to play a significant role in regulation of arthropod pests of cotton in India, indicating a great potential for conservation and promotion of eco-friendly biological control in cotton ecosystem.

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