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FIRST OCCURRENCE OF THE APHID PARASITOID, *APHELINUS BASILICUS* (HYMENOPTERA: APHELINIDAE), ON *APHIS GOSSYPII* (HEMIPTERA: APHIDIDAE) COLOR FORMS IN INDIA

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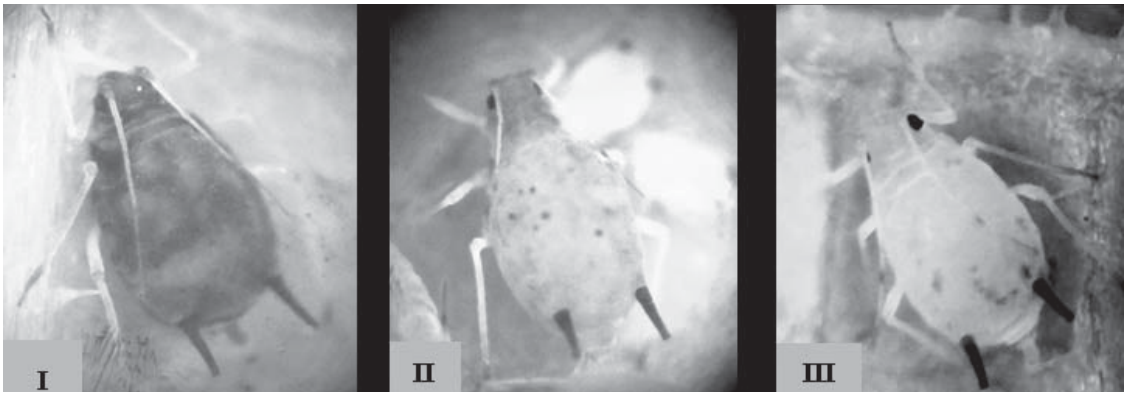
Supplementary material for this article in Florida Entomologist 97(2) (2014) is online at http://purl.fcla.edu/fcla/entomologist/browse

The cotton aphid, *Aphis gossypii* Glover (Hemiptera: Aphididae) is a polyphagous sap sucking aphid on cotton, vegetables, fruits, ornamentals, etc. Besides being a direct pest, it is a potential vector of > 50 plant viruses (Van Emden & Harrington 2007). Both adults and nymphs transmit viruses in either non-persistent or persistent mode. Winged adults (alates) are primarily responsible for the spread of the viruses. There is a direct correlation between alate aphids and virus infection (Kalleshwaraswamy & Krishna Kumar 2008). Contrary to the perceived opinion that biological control is not effective in minimizing the aphid transmission of plant viruses (as the threshold is ≤1), biological control was considered a best option as the formation of alates is directly proportional to aphid density, and natural enemies do not allow the aphid to reach the density that results in the formation of alates that ultimately migrate and spread viruses. Aphid parasitoids are important components of the natural enemy complex because they help to control pest aphid populations on a variety of crops and to reduce transmission of plant pathogenic viruses.

Aphelinid wasps are a major source of biocontrol of economically important pest species of hemipteran coccoids, aphids and aleyrodids (Woolley 1997; Hanson et al. 2006). The number of successes in the control of agricultural pests by the use of aphelinid parasitoids is higher (Noyes 1985). *Aphelinus basilicus* Fatima and Hayat (Hayat 1998) is an important member of this family. It is small, dark brown to black soft-bodied insect measuring approx. 1 mm in length. Its occurrence has been reported from Bangladesh; Sri Lanka and India - Andhra Pradesh, Assam, Bihar, Goa, Daman and Diu, West Bengal (Hayat 1998). Recently, it was reported from Tamil Nadu, India (Menakadevi & Manickavasagam 2011). Hitherto this species was not reported from Karnataka state. Primary hosts reported were aphids and the plant associates included *Ocimum basilicum* (Lamiaceae), *Lantana camara* (Verbenaceae), *Abelmoschus esculentus* (Malvaceae) and *Psidium guajava* (Myrtaceae) (Hayat 1998). The present study reports the occurrence of *Aphelinus basilicus* parasitizing *A. gossypii* infesting *G. hirsutum* (Malvaceae) in Karnataka for the first time. It was observed that the parasitism was based on the host body color and the parasitoid preferred dark green forms more than pale green and yellow forms of *A. gossypii* in this study. Color versions of Plates I-VII, herein designated as Suppl. Plates I-VII, are found in the supplementary document online at http://purl.fcla.edu/fcla/entomologist/browse .

During a regular survey for aphids, color forms of *A. gossypii*, viz., dark green, pale green and yellow (Plates I-III; Suppl. Plates I-III) were observed to feed on *Gossypium hirsutum* cultivated in the experimental plot maintained at the Indian Institute of Horticultural Research, Bengaluru, India (N 12° 58' E 77° 35') during May, 2013. About 30 to 40 infested cotton leaves were labeled and monitored during May through Jul. The aphid numbers was recorded weekly. Mummified apterous females of cotton aphid were observed along with live viviparous aphids during Jul (Plate

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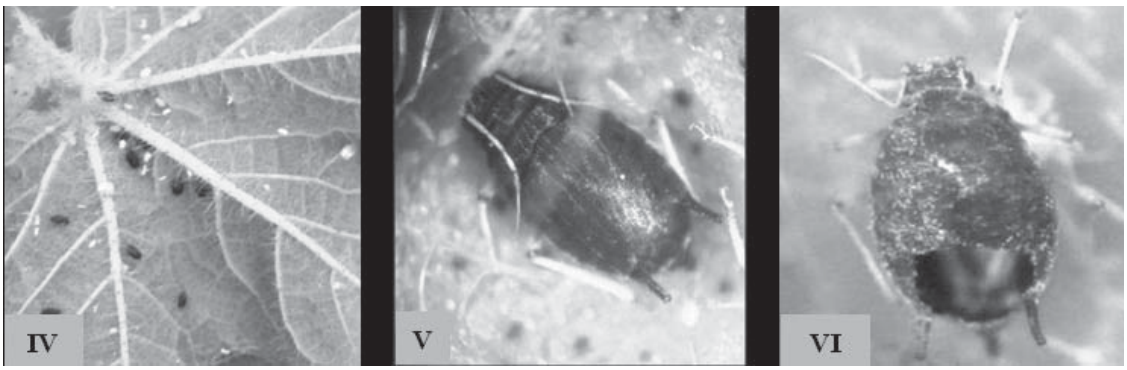
Plates I-III. Color forms of *Aphis gossypii* Glover; dark green, pale green and yellow forms (400x).

IV). Mummies were black in color each with an emergence hole usually at dorsum above the siphunculi (Plates V and VI; Suppl. Plates V and V). Reduction in the number of dark green forms was observed with an increase in the number of mummies. Based on this observation, the present study was conducted to identify the parasitoid and study its host preference.

The experiment was laid out in a Randomized Block Design (RBD). Records giving the proportions of different color forms of *A. gossypii* parasitized by the parasitoid were made on naturally occurring field infestations on cotton during Jul. The plants were kept free from insecticidal sprays to encourage natural infestation of the aphids and parasitoids. Standard farming practices were followed according to regular cropping practices during the study.

Aphid infested leaf samples of same size, age and maturity were randomly selected from 20 cotton plants cultivated in the experimental plot, where the incidence of parasitism was noticed. The selected leaf samples were collected in separate containers, sealed and brought to the laboratory. The mummies were removed. The surviving aphids from each leaf sample were segregated into dark green, pale green and yellow forms; counted and kept along with fresh cotton leaves in plastic rearing boxes covered with cloth mesh for ventilation at 25-30 °C and 60-70% R.H. After 5 days, the number of wasps emerged and mummies formed were counted. Each aphid surviving after 5 days was dissected and viewed under a stereomicroscope to make out the presence of a parasitoid larva. Depending upon the presence or absence of a parasitoid larva, it was counted as parasitized or unparasitized, respectively. After square root transformation, data were subjected to analysis of variance (ANOVA) using PROC GLM of SAS V9.3 (SAS Institute 2010) in order to determine the parasitoid preference towards the 3 different color forms. The significance of body color as a visual cue for parasitism by *Aphelinus basilicus* was tested at the 5% level of probability using Least Significant Difference (LSD) (Gomez & Gomez 1984). The percent of each color form parasitized was also calculated.

For morphological identification, wasps that emerged from mummies were collected using an aspirator, preserved in 70% ethanol and stored at -20 °C. Microscopic examinations showed that the parasitoid characteristics matched with those



Plates IV-VI. Parasitized *Aphis gossypii* Glover on cotton (20x); mummified aphid (400x); mummy with an emergence hole (400x).

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of *Aphelinus basilicus.* The specimens were deposited with the Insect Collections, Department of Zoology, Aligarh Muslim University, Aligarh. Literature searches indicated that this is a new distributional report of *Aphelinus basilicus* from Karnataka.

Diagnostic characters for the identification of *Aphelinus basilicus* are as follows:

Female. Body dark brown to black, with first segment of gaster white to yellow; ovipositor sheaths dark brown; antennal scape yellow to pale brown, pedicel and flagellum infuscate brown; wings hyaline; legs, including coxae, dark brown, with base and apex of mid tibia and hind femur white; basitarsus of hind leg infuscate. Head with frontovertex broad; Antenna with third segment of funicle usually slightly longer than broad; clava about as long as pedicel and funicle combined. Mesosoma is normal for the genus; fore wing proximal to linea calva with a single complete line of setae, occasionally with few setae in an angle between the line and marginal vein. Gaster longer than mesosoma; ovipositor (= second valvifer plus third valvula) subequal in length to mid tibia (Plate VII, Figs. 1–4; Suppl. Plate VII, Figs. 1–4).

Male. Similar to female except for the antenna and genitalia. Gaster sometimes completely dark brown; antenna with third funicle segment are distinctly longer than broad with long setae (Plate VII; Fig. 5).

The parasitoids that emerged from parasitized *A. gossypii* were identified as *Aphelinus basilicus.* Mummies took an average 5-6 days to emerge. Various statistical measures viz. Error Mean Square (SEM); Coefficient of Variation (CV); LSD at 5% and Percentage (%) of color forms parasitized were calculated (Table 1). Results indicated that the number of dark green, pale green and yellow forms parasitized were significantly different. Dark green forms were parasitized more frequently than the other 2 forms significantly at 5% probability level ($F = 728$). Lower values of CV (12.32%) and SEM (0.074) indicated the reliability of conclusions drawn in this study. An average of 88% of dark green forms was parasitized in contrast to 24% of pale green and 2% of yellow forms of *A. gossypii* suggesting that 3 color forms were differentially susceptible to selection by *Aphelinus basilicus.* This in turn led to variable relative abundances of dark green, pale green and yellow forms among cotton plants. Specifically, the proportion of yellow forms increased following high parasitism. The differential susceptibility of the color forms suggested that the parasitoid, *Aphelinus basilicus,* uses prey color as a foraging cue and has an inherent preference for dark green forms.

Similar observations have been reported in the literature by various researchers. Parasitoid, *A. rhopalosiphi* De Stefani Perez parasitized green forms of the aphid, *Sitobion avenae* Fabricius more frequently than the brown forms (Ankersmit et al. 1981, 1986). Parasitoids preferred green forms over red forms of the alfalfa aphid, *Macrosiphon creelii* Davis (Michaud 1995). Green forms of pea aphid, *Acyrthosiphon pisum* Harris were susceptible to parasitoid, *Aphidius ervi* Haliday and red forms to predator, *Coccinella septempunctata* Linnaeus (Losey et al. 1997). A higher preference for the white color form of walnut aphid, *Chromaphis juglandicola* Kaltenbach than the yellow color form was evident by the parasitoid, *Trioxys pallidus* Haliday (Hougardy 2008). Likewise, the aphid parasitoid *A. ervi* was reported to alter its preference for pea aphid colour morphs (Langley et al. 2006). This study indicates that the color variation in aphids affects host acceptance behavior by *Aphelinus basilicus*. Color is the main visual attribute that determine the host's recognition and acceptance by a parasitoid (Rehman & Powell 2010). Aphid color is known to affect host acceptance behavior by *A.*

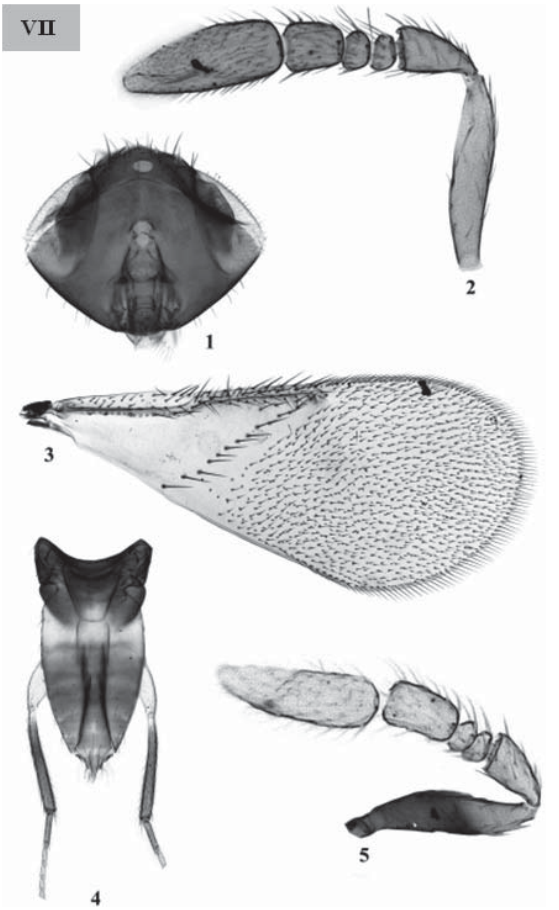


Plate VII. Diagnostic characters of *Aphelinus basilicus* Fatima & Hayat. Figs. 1-4. Female. 1, head, frontal view, 2, antennae, 3, fore wing, 4, propodeum and mesonota; 5, male antenna.

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TABLE 1. MEAN NUMBER OF *APHIS GOSSYPII* COLOR FORMS PARASITIZED BY *APHELINUS BASILICUS* ON COTTON AT BENGALURU, KARNATAKA, INDIA.

Color forms	Parasitized Means	%	Unparasitized Means	%
Dark green	15.6 a (3.99)	88	2.1 d (1.57)	12
Pale green	3.05 b (1.84)	24	9.89 e (3.19)	76
Yellow	0.15 c (0.78)	2	6.7 f (2.66)	98
SEM	0.074		0.141	
CV%	12.32		15.13	
LSD at 5%	0.23		0.32	

Values are means of 20 replications; figures in parentheses indicate square root transformed values. In the same column, means followed by different letters are significantly different ($P < 0.05$). SEM = Error Mean Square. LSD = Least Significant Difference. CV = Coefficient of Variation.

ervi (Battaglia et al. 2000). The green form is more parasitized and parasitoids have an inherent preference for green forms (Tomanovic et al., 1996). The role of color cues in the host-finding behavior of parasitoids is poorly understood and requires further investigation.

An accurate identification of aphid parasitoid is a need of an hour, as the species *Aphelinus basilicus* is close to and may be confused for *Aphelinus mali* Haldemann and *Aphelinus paramali* Zehavi & Rosen. Further, success in biological control programs depends on the correct identification of both the biological control agent and the pest species. In addition, a fundamental understanding of host preference behavior, i.e., host recognition, host acceptance and host suitability is necessary to progress with biological control. In this view point, the present study will aid in proper identification of the aphid parasitoid, *Aphelinus basilicus* and in designing future biological control programs. Further, this study also suggests that the dark green forms of *A. gossypii* can be made use in mass rearing programs of *Aphelinus basilicus* to obtain greater numbers of parasitoids.

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SUMMARY

An aphid parasitoid, *Aphelinus basilicus* Fatima & Hayat (Aphelinidae: Aphelininae) is described from material collected in Bengaluru, Karnataka for the first time. It was found to parasitize apterous viviparous females of the cotton aphid, *Aphis gossypii* (Glover) infesting *Gossypium hirsutum* (Malvaceae), during Jul, 2013. Field data indicated that the parasitoid, *Aphelinus basilicus* parasitized dark green forms (88%) of *A. gossypii* more frequently than pale green (24%) and yellow forms (2%) suggesting that the body color strongly influenced the host preference for foraging. The 3 color forms were differentially susceptible to selection by the parasitoid. Statistical analysis revealed that the parasitoid had an inherent preference for dark green forms ($P < 0.05$). Information on the parasitoid's distribution, diagnostic characters, host range and host preference are presented to ease the identification as well as to understand the fundamentals of host selection behavior of this species. This is a new distributional record of *Aphelinus basilicus* parasitizing color forms of *A. gossypii* associated with *G. hirsutum* in Karnataka, India.

Key Words: biological control, color forms, *Gossypium hirsutum,* SAS

RESUMEN

Se describe el parasitoide de áfidos, *Aphelinus basilicus* Fátima y Hayat (Aphelinidae: Aphelininae) de material recolectado por primera vez en Bangalore, Karnataka. Se encontró que las hembras parasitan la forma áptera vivípara de los áfidos del algodón, *Aphis gossypii* (Glover) infestando *Gossypium hirsutum* (Malvaceae) cultivado en la parcela experimental mantenida en el Instituto de Investigaciones Hortícolas de India, Bengaluru, durante julio del 2013. Los datos de campo indican que el parasitoide, *Aphelinus basilicus* parasitó a las formas de color verde oscuro (88%) de *A. gossypii* con más frecuencia que el verde pálido (24 %) y las formas de color amarillo (2%) que indica que el color influyó fuertemente la preferencia de hospedero en la búsqueda de alimento. Las 3 formas de color fueron diferencialmente susceptibles a la selección por parte del parasitoide. El análisis estadístico reveló que el parasitoide tenía una preferencia inherente a las formas de color verde oscuro ($P < 0.05$). Se presenta información sobre la distribución del parasitoide, caracteres diagnósticos, rango de huéspedes y la preferencia de hospedero para facilitar la identificación, así como para comprender los fundamentos del comportamiento de selección del hospedero de esta especie. Este es un nuevo registro de distribución de *Aphelinus basilicus* que parasita diferentes tonos de color de *A. gossypii* asociado con *G. hirsutum* en Karnataka.

Palabras Clave: control biológico, formas de color, *Gossypium hirsutum*, SAS

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