Int. J. Indust. Entomol. Vol. 1, No. 2, 2000, pp. 143~148

International Journal of *Industrial Entomology*

Biology of *Anagyrus kamali* (Moursi) (Hymenoptera : Encyrtidae) - A Parasitoid of the Mealybug, *Maconellicoccus hirsutus* (Green), with a Note on Its Incidence

R. L. Katiyar, Vineet Kumar*, D. Manjunath[1], A. K. Sen, M. A. Shekhar and R. K. Datta

Central Sericultural Research and Training Institute, Srirampura, Mysore-570 008, Karnataka, India.
[1]Department of Sericulture, University of Mysore, Mysore, India.

(Received 24 September 2000; Accepted 8 November 2000)

The occurrence of *Anagyrus kamali*, a solitary endoparasite of the mealybug, *Maconellicoccus hirsutus* has been reported for the first time from India. The parasitoid was found to parasitising the field population of mealybug to the tune of 10.37 to 42.70% in different months. A comprehensive study on the development of the parasitoid on different stages of mealybug indicated that the parasitoid was able to complete its development in all the stages. Higher parasitism (67.48 - 78.08%) and more female progeny were observed when 3rd instar nymphs and adult female of the mealybug were exposed to the parasitoid. The biology of *A. kamali* was studied at 25 ± 1°C temperature and 60 ± 10% R.H. The parasitoid completes its life cycle in 19.72 ± 1.12 days. The duration of egg, larva (3 instars) and pupa were 2.67 ± 0.42, 8.80 ± 0.43 and 8.25 ± 0.38 days, respectively. On an average each female of *A. kamali* laid 39.0 ± 4.53 eggs. It was found to parasitising 8 - 10 mealybugs and depositing 1 - 3 eggs per host individual. Observations on adult longevity, parasitising potential and sex ratio has also been recorded.

Key words : *Anagyrus kamali*, *Maconellicoccus hirsutus*, Incidence, Biology

Introduction

The pink mealybug, *Maconellicoccus hirsutus* (Green), is a polyphagous pest infesting about 125 plant species in more than 13 tropical and sub-tropical countries of the world including mulberry among 30 host plants reported from India (Mani, 1989).

Association of mealybug with mulberry causes severe qualitative and quantitative damage to the plant. A reduction in leaf yield is estimated to be 4500 Kg/ha/yr thus reducing the cocoon production by 152 Kg/ha/yr leading to a monetary loss of about Rs.30,000/-per year (Kumar *et al.*, 1994).

While monitoring the natural enemy complex of the *M. hirsutus* in the mulberry garden of the Central Sericultural Research and Training Institute (CSRTI), Mysore during 1991 an encyrtid parasitoid *Anagyrus kamali* (Moursi) was found parasitising the populations of mealybug to the tune of 10.37 - 42.70% (unpublished data). This was the first report of *A. kamali* parasiting *M. hirsutus* from India. Earlier Moursi (1948) recorded *A. kamali* parasitising mealybugs around Cairo, Egypt and Noyes and Hayat (1994) listed *A. kamali* from India as *Anagyrus* sp. Quite recently Sagarra and Vincent (1999) presented a brief account on the biology of the parasitoid. In the present investigation an attempt has been made to study the morphology of the immature stages and detailed biology of *A. kamali* besides furnishing an account on its incidence in the mulberry field.

Materials and Methods

Monitoring the incidence of *A. kamali*

The incidence of *A. kamali* was monitored at weekly intervals in the mealybug infested mulberry gardens of CSRTI, Mysore, India, during June, 97 - May, 98. Fifty mealybug infested mulberry twigs were collected from an area of 0.4 ha to record the incidence. Such twigs were placed in the glass cages (60×30×30 cm) having

*To whom correspondence should be addressed.
Central Sericultural Research and Training Institute, Srirampura, Mysore-570 008, Karnataka, India. Tel: 000-0000; Fax: 000-0000; E-mail: csrtimys@vsnl.com

two windows (10 × 10 cm) on opposite side covered with muslin cloth to observe the emergence of the parasitoid. Per cent incidence of the parasitoid was determined based on the total mealybug population on each twig and the number of *A. Kamali* emerging from the above population.

Culturing of mealybug

Cultures of the mealybug, *M. hirsutus* were maintained on the ripened sweet pumpkins in the laboratory following the methods outlined by Chaco *et al.* (1978).

Culturing of *A. Kamali*

Cultures of *A. kamali* were maintained on the colonies of mealybug (1st, 2nd, 3rd instar nymphs and adult females) raised on sweet pumpkins. On each pumpkin (1.0 - 1.5 Kg) about 500 mealybugs were maintained and the pumpkins were placed in wooden cages (30 × 30 × 30 cm) fitted with muslin cloth on three sides and a sliding glass on the front. Colonies of mealybug on sweet pumpkins were exposed to 50 mated females of *A. kamali* with a ratio of 10:1 (host-parasitoid) for a period of 6 hrs. Each infested pumpkin was considered as a replication and each stage of mealybug was replicated five times.

Developmental studies

The parasitised mealybugs were removed periodically from the cultures and dissected out in insect saline under stereozoom binocular microscope to study the developmental stages of the parasitoid. Developmental period on each stage of mealybug was calculated from the day of exposure of mealybug for parasitisation to the day of parasitoid emergence. The per cent parasitisation due to *A. kamali* on each stage of the host was determined based on the hardened body of the parasitised host. Sex ratio of the parasitoid was recorded from the populations of adult parasitoid emerging from the parasitised mealybugs.

Adult longevity

The longevity of the adults of *A. kamali* was studied by confining individually the newly emerged adult males and females (n=20) in 2.5 mm diameter glass tubes. A streak of 50% aqueous honey solution was provided daily on the inner wall of the tube as food and water was provided in small glass vials plugged with absorbent cotton. To record the longevity on natural food (honey dew secreted by mealybug), adults were confined to plastic container (1 *l* capacity) possessing mealybug colonies raised on potato sprouts. Observations on survival of the adult parasitoids were made with 12 hrs interval. All the experiments were conducted at 28 ± 1°C temperature and 60 ± 10% R.H in the laboratory.

Results and Discussion

Incidence of *Anagyrus kamali*

The occurrence of *A. kamali* was recorded throughout the year (June, 97-May, 98). *A. kamali* prevails throughout the period of observation and its incidence ranged from 10.37-42.70% in different months. Seasonal incidence of *A. kamali* is furnished in Fig. 1. Maximum incidence (42.70%) of the parasitoid was recorded during April, 98 as against minimum incidence 10.37% during February, 98. The results indicated that parasitoid incidence was maximum (26.94%) during summer (February - May) followed by winter (21.42%) (October - January) and rainy season (15.40%) (June - September). The incidence of the parasitoid during summer was significantly higher than the other seasons.

Developmental biology

The length and width of the parasitoid eggs and larvae

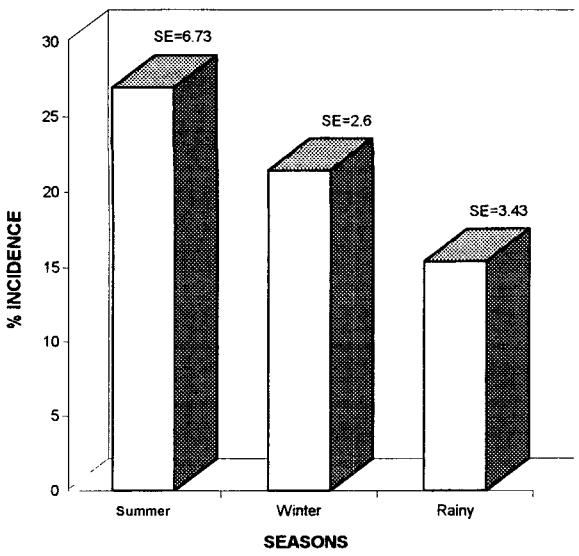

Fig. 1. Seasonal incidence of *A. kamali.*

Table 1. Developmental period, parasitism and sex ratio of *A. kamali* in relation to the stage of mealybug parasitised

Host stage	Duration of Development (Days) (Mean ± S.D.)	% Parasitism	Sex ratio (Male:Female)
First instar	21.52 ± 1.70	1.75	1:0.06
Second instar	20.18 ± 1.06	50.52	1:0.92
Third instar	19.24 ± 1.14	67.48	1:1.43
Adult female	19.15 ± 1.10	78.08	1:1.33

S.E. = 2.26.
CD at 5% = 6.96.

were measured under binocular microscope. Three larval stages were recorded on the basis of moulted skin in the parasitised host body. The mean developmental period of the parasitoid in different stages of mealybug is furnished in Table 1.

Egg

The egg of *A. kamali* is of encyrtiform as described by Clausen (1940). The newly laid egg is transluscent, oblong and possessing a stalk ending to a bulb (panel 1 of Fig. 2). The egg measured on an average in length and width 0.133 ± 0.015 mm and 0.059 ± 0.01 mm, respectively. The stalk with bulb measured 0.26 ± 0.03 mm in length. Generally, the eggs are laid just beneath the cuticle on the dorsal region of the body. On first day of egg deposition the parasitoid egg float out from the mealybug body as the later were dissected out. The egg was found have attached to the host body with the help of a fine stalk (panel 2 of Fig. 2).

On second day, the shape of the egg remain unchanged but increased in size measuring 0.17 ± 0.02 mm in length and 0.99 ± 0.02 mm width. The eggs enlarged in size as the first instar larva grew within the egg. Generally only a single egg was found have deposited in each host and sometimes more number of eggs also deposited. Strangely, never more than one second instar larva was encountered in each of the parasitised host.

Between day 2 and 3, the attachment of the egg with the host cuticle became very firm prior to hatching of larva. The incubation period of the egg was 2.67 ± 0.42 days. Presence of tracheal trunks was noticed in the first instar larva.

Larval instars

The first instar larva is encyrtid form having 10-11 distinct body segments (panels 3 and 4 of Fig. 2). It measured 0.54 ± 0.02 mm in length and 0.40 ± 0.04 mm in width. After hatching, the posterior end of the larva remained firmly attached to host cuticle. The larva bear a hard head capsule with a pair of mandibles. The thorax possessed distinct body segments.

The second instar larva is also encyrtid type. Hardened head capsule was not visible but the head was distinct from the thorax. Body segmentation of the ten abdominal segments is not well demarcated into individual abdominal segments. The posterior end of the abdomen usually

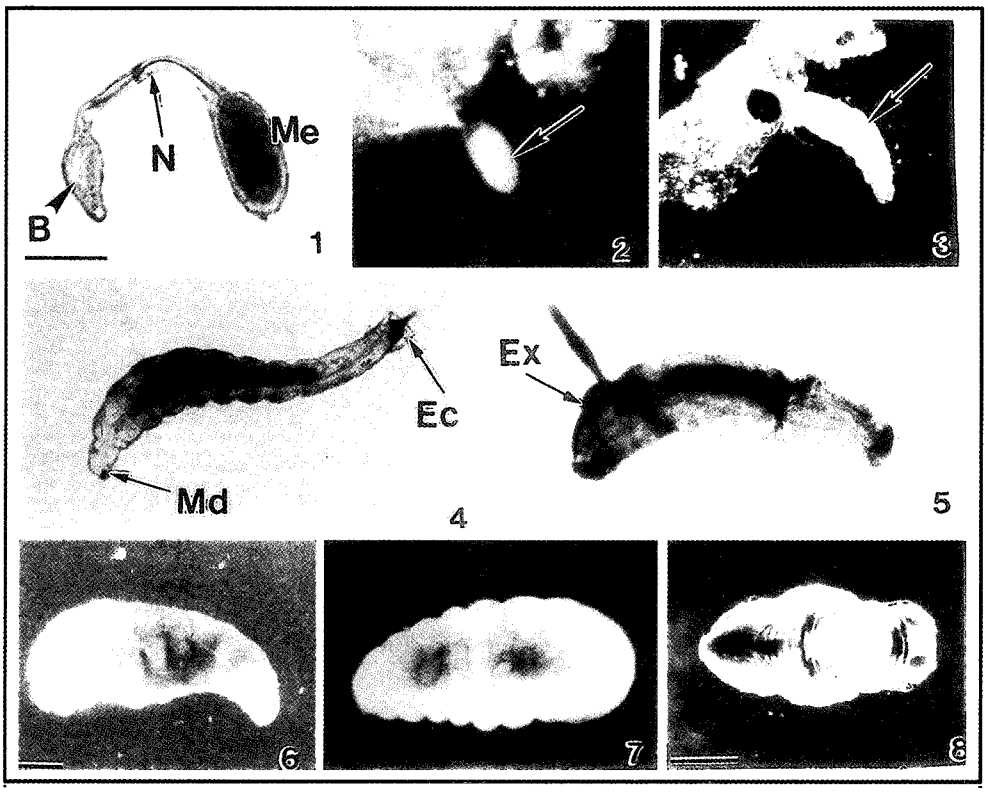

Fig. 2. Immature stages of *Anagyrus kamali.* Panel 1, Ovarian egg of *A. kamali* (N = neck; B = bulb; Me = main egg) (Scale bar = 0.1 mm); Panel 2, Deposited egg (Arrow); Panels 3 and 4, First instar larvae (Arrow indicated newly hatched larvae), (Ec = egg case, Md = mandibles) (Scale bar = 0.5 mm in Fig. 4); Panel 5, Second instar larva (Ex = exuviae)(Scale bar = 0.5 mm); Panel 6, Third instar larva. (Scale bar = 0.5 mm); Panel 7, Prepupal stage; Panel 8, Pupal stage (Scale bar = 0.5 mm).

covered with exuviae whereas the anterior part of the larval body attached to host body (panel 5 of Fig. 2). The larva grew rapidly and increased considerably in both length and width. The body measured 2.16 ± 0.07 mm in length and 1.07 ± 0.05 mm in width.

The third instar larva was hanging freely in the host haemocoel and measured 3.16 ± 0.10 mm in length and 1.10 ± 0.1 mm width (panel 6 of Fig. 2). In this instar, two tracheal trunks become apparent projecting down into the chorion. At the end of the third instar the larva turns itself with its head orienting towards the posterior end of the host body. By that point, the host body contents are completely consumed. Total larval duration recorded is 8.80 ± 0.43 days. In about a week after parasitisation, the cuticle of the host body changes its texure and consistancy and the host looks like a barrel shaped mummy. There is a short pre-pupal period within the mummy before it changes into a pupa.

Pupa

The pupa develops in a sheath within the mummified host body (panel 4 of Fig. 3) which is swollen and filled with air. The pupa is exarate and measured 1.90 ± 0.05 mm in body length and 0.88 ± 0.07 mm in width (panel 8 of Fig. 2). The female pupae are larger than male. Adult appendages become visible during development. Initial body pigmentation begins with the eyes as they become red and rest of the body becomes dark gradually. The pupa is visible through mummified body of the host and its duration lasting for 8.25 ± 0.38 days.

Adult emergence and longevity

The adult completes its development within the mummy before emergence. It emerges by biting a small hole, mostly on the posterior end of the mummy, on either dorsal or ventral surface. The description of the adults (panel 1 of Fig. 3) is similar as reported by Noyes (1990).

Adult life span of both male and female of *A. Kamali* remained almost similar provided with 50% aqueous honey solution, honey dew, water or none (Fig. 4). The longevity of both sexes was significantly higher when provided with 50% aqueous honey solution or honey dew as

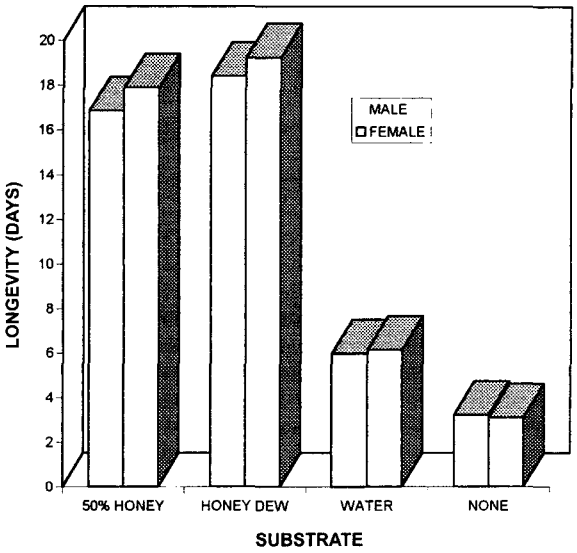

Fig. 4. Longevity of adult *A. Kamali.*

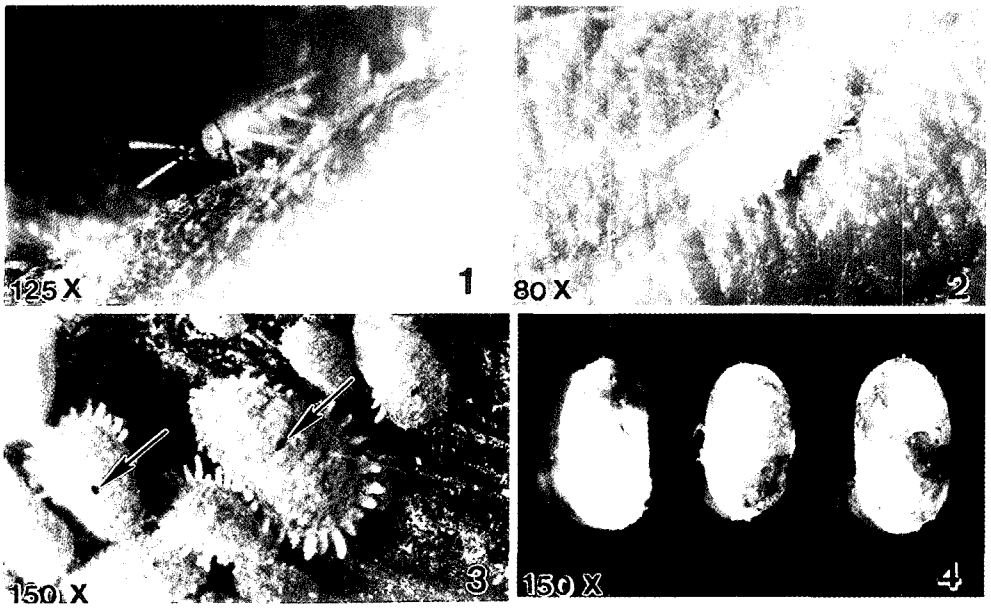

Fig. 3. Adults of *Anagyrus kamali* and parasitised mealybugs. Panel 1, Adult female of *A. kamali*; Panel 2, Examination of host by *A. kamali*; Panel 3, Parasitised mealybugs (Arrow indicate the sites of parasitisation); Panel 4, Mummified mealybugs.

Table 2. Oviposition of *A. kamali* on different stages of *M. hirsutus*

Host stage	No. of host parasitized* (Mean ± S.D.)	No. of parasitoid eggs (Mean ± S.D.)	No. of eggs per Host (Mean ± S.D.)
First instar	2.0 ± 1.05	2.80 ± 0.98	1.44 ± 0.39
Second instar	6.3 ± 0.90	10.40 ± 2.94	1.64 ± 0.27
Third instar	7.1 ± 0.83	14.70 ± 2.15	2.02 ± 0.27
Adult female	7.8 ± 0.98	21.60 ± 1.74	2.81 ± 0.39

*For parasitisation 10 individuals of each stage of host were exposed to Parasitoid for a period of 6 hrs.

against water or none. Though there was no variation in the longevity among 50% aqueous honey fed and honey dew fed adults, slight increase in adult longevity was observed in the case of the latter. The findings of the present study differ from those of the Cross and Moore (1992) who reported an increase in the life span of female in comparison to male when provided with honey dew. However, the actual host fed individual did not show such a variation among males and females of *A. kamali.*

Developmental period

A. kamali was able to complete its development on second and third nymphal instars and adult female of *M. hirsutus.* The developmental duration of the parasitoid decreased with the increase in the age of the mealybug. The mean development time for male and female of *A. kamali* on first, second and third instars and adult stages of mealybug was 21.52 ± 1.7, 20.18 ± 1.06, 19.24 ± 1.14 and 19.15 ± 1.10 days, respectively. However, there was no significant difference in the duration of parasitoid development on various stages of mealybug (Table 2). Similar observations also were made by Avidov *et al.*, (1967) and Chander *et al.*, (1980) in *P. pseudococci* and Mani and Thontadarya, (1989) in *A. dactylopii.* The delay in the development of parasitoid was reported by Moursi (1948) and Sagarra and Vincent (1999) in *A. kamali* and Nechols and Kikuchi, (1985) in *A. indicus* when diffrent stages of mealybug were exposed for parasitisation.

Percent parasitism

The rate of parasitisation of *M. hirsutus* by *A. kamali* was found to be significantly influenced by the age of the mealybug (Table 2). Highest parasitisation of 78.08% was recorded when adult female was exposed to the parasitoid, and it was 67.48% in 3rd instar and 50.52% in 2nd instar nymphs. Before parasitisation the female observed host carefully and parasitised. The presence of black scar on the body of mealybug was considered as the sign of parasitisation (panel 3 of Fig. 2). The present findings are in agreement with Chandler *et al.*, (1980) who have recorded the highest (67.8%) parasitisation when 3rd instar female nymphs of *P. citri* were exposed to *A. pseudococci* and Mani and Thontadarya (1989) in *A. dactylopii* (81.11%) when the adult females were exposed. Similar observations were also recorded by Riherd (1980) where *A. ontoninae* preferred the gravid females of the mealybug, *Antonia graminis* .

Sex ratio

Male to female ratio in the progeny produced by *A. kamali* increased with increase in age of the host (mealybug) used. Host parasitised in the 2nd instar nymphal stage yielded more male parasitoids whereas 3rd instar nymphal stage and adult female mealybug produced more female progenies (Table 1). Similar observations were made by Avidov *et al.*, (1976) and Chandler *et al.*, (1980) in *P. pseudicocci*, Riherd (1980) in *A. antoninae*, Nichols and Kikuchi (1985) in *A. indicus* and Mani (1995) in *Leptomastrix dactylopii.* The difference in sex ratio may be due to size and sex of the parasitised host.

Based on the above results, it is obvious that female of *A. kamali* can parasitise first, second and third nymphal instars and adult stages of *M. hirsutus* and it shows a distinct preference to the latter stages, which is important in the management of *M. hirsutus* as majority of these stages are females which contribute to rapid colonisation of *M. hirsutus.*

Acknowldegments

The authors are grateful to Dr. K. M. Harris, Director, C.A.B. International Institute of Entomology, London for identification of the parasitoid.

References

Avidov, Z., Y. Rossler and D. Rosen (1967) Studies on an Israel strain of *Nagyrus pseudococci* (Girault) (Hymenoptera : Encyrtidae). II. Some biological aspects. *Entomophaga* **12**, 111-118.

Chacko, M. J., P. K. Bhat, V. Ananda Rao, M. B. Singh, E. P. Ramanarayan and K. Sreedharan (1978) The use of the ladybird beetle, *Cryptolaemus montrouzieri* for the control of coffee mealybugs. *J. Coffee Res.* **8**, 14-19.

Chandler, L. D., D. E. Meyerdirk, W. G. Hart and R. G. Garcia (1980) Laboratoty studies on the development of the parasite *Anagyrus pseudococci* (Girault) on insectary reared *Planococcus citri* (Risso). *South West Ent.* **5**, 99-103.

Clausen, C. P. (1940) Entomophagous insects. pp. 168-139. New York, Hafner Publishing Company.

Cross, A. E. and D. Moore (1992) Development studies on

Anagyrus mangicola (Hymenpptera : Encyrtidae), a parasitoid of mealybug, *Rastococcus invadens* (Homoptera : Pseudococcidae). *J. Ent. Res.* **82**, 307-312.

Kumar, P., K. S. Prasad, R. Kishore, R. L. Katiyar, M. M. Ahsan and R. K. Datta (1994) IPM approach to optimising silkworm cocoon production. *Proccedings of the International Conference on Sericulture* pp. 252-257.

Mani, M. (1989) A review of pink mealybug *Maconellicoccus hirsutus* (Green). *Insect Sci. Appl.* **10(2)**, 157-167.

Mani, M. (1995) Comparative development, progeny production and sex ratio of the exotic parasitoid *Leptomastix dactylopii* Howard (Hym., Encyrtidae) on *Planococcus lilacinus* and *P. citri* (Homop., Pseudococcidae). *Entomon* **2(1)**, 23-26.

Mani, M. and T. S. Thontadarya (1989) Development of the encyrtid parasitoid *Anagyrus dactylopii* (How) on the grape mealybug, *Maconellicoccus hirsutus* (Green). *Entomon* **14(1 & 2)**, 49-51.

Moursi, A. A. (1948) Contributions to the knowledge of the natural enemies of mealybug. 2. *Anagyrus kamali* Moursi a parasite of the Hibiscus mealybug, *Phenacoccus hirsutus* Green (Hymenoptera : Encyrtidae). *Bull de la Societe Fouad ler 'd' Entomologique* **32**, 9-16.

Nechols, J. R. and R. S. Kikuchi (1985) Host selection of spherical mealybug (Homoptera : Pseudococcidae) by *Anagyrus indicus* (Hym. : Encyrtidae)-Influence of host stage on parasitoid oviposition, development, sex ratio and survival. *Environ Ent.* **14**, 32-39.

Noyes, J. S. (1990) A new species of *Anagyrus* (Hymenoptera : Encyrtidae) From India attacking *Rastrococcus invadens* (Homoptera : Pseudococcidae), a pest of mango and citrus in West Africa. *J. Ent. Res* **80**, 203-207.

Noyes, J. S. and M. Hayat (1994) Oriental mealybug parasitoids of the *Anagyrini* (Hymenoptera : Encyrtidae). pp. 554, Willigford, U.K., CAB International.

Riherd, P. T. (1980) Biological notes on *Anagyrus antoninae* Timberlake (Hym : Encyrtidae) and its host, *Antonina graminus* (Maskell) (Homoptera : Coccicidae). *Fla. Ent.* **83**, 18-22.

Sagarra, L. A. and C. Vincent (1999) Influenec of host stage on Oviposition, Development, Sex Ratio and survival of *Anagyrus kamali* Moursi (Hymenoptera : Encyrtidae), a parasitoid of the Hibiscus Mealybug, *Maconellicoccus hirsutus* Green (Homoptera : Pseudococcidae). *Biological Control* **15**, 51-56.