ASSESSMENT OF THE POTENTIAL OF *Coccygidium luteum* (HYMENOPTERA: BRACONIDAE) AS A BIOLOGICAL CONTROL AGENT FOR FALL ARMYWORM, *Spodoptera frugiperda*

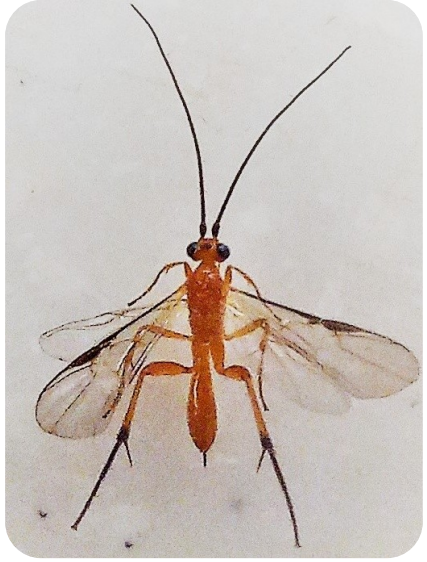
by

PATRICK K. BESEH

OUTLINE

- Background of study
- Problem statement
- Justification
- Objectives
- Materials and methods
- Results
- Conclusion
- Recommendations
- Contribution to knowledge
- Acknowledgement
- Publications

BACKGROUND



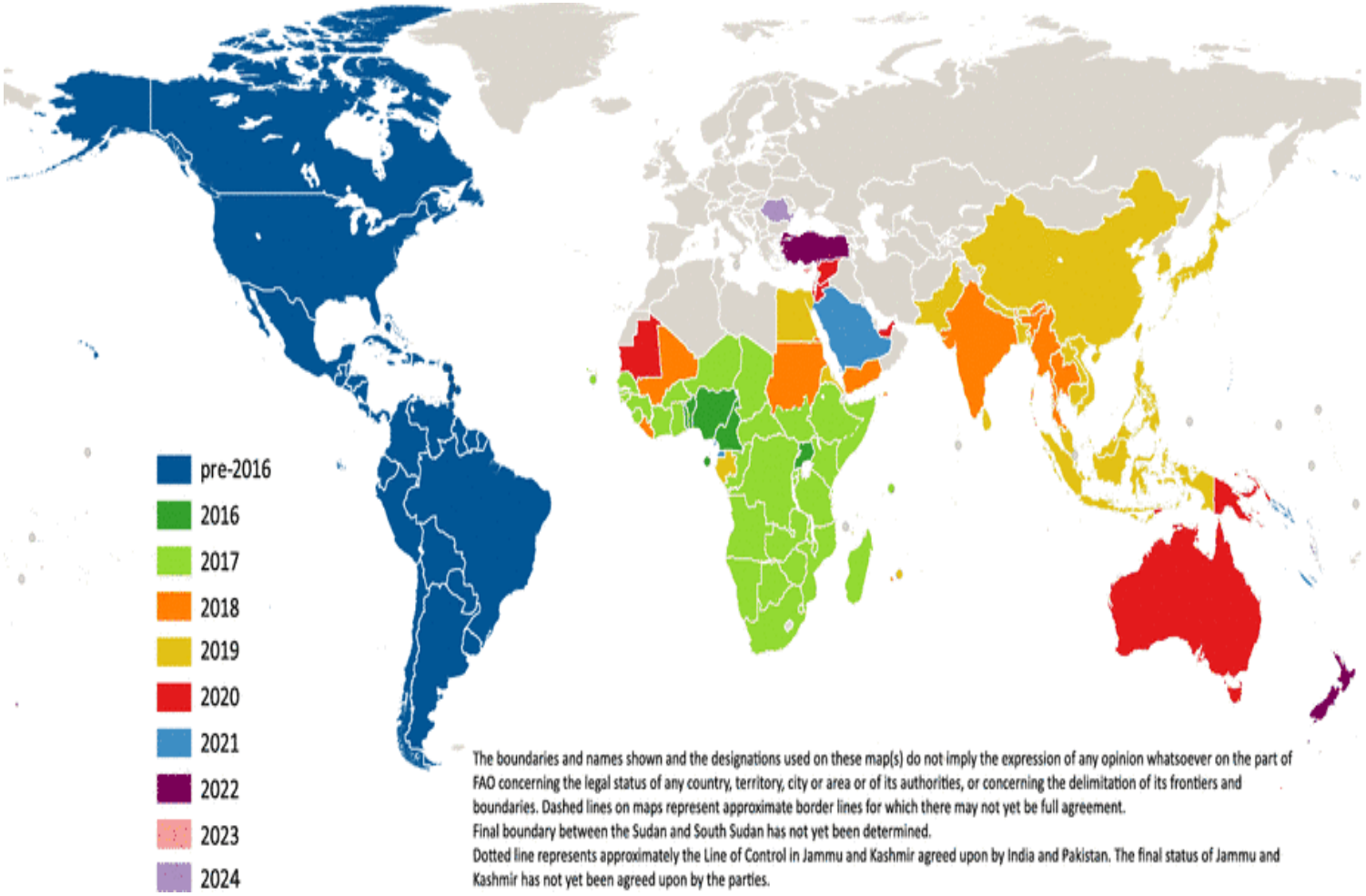
Coccygidium luteum

(Hymenoptera: Braconidae) sub-family Agathidinae

- Solitary koinobiont - larval endoparasitoid which has adapted to fall armyworm (FAW) in Africa
- Present in Western, Central, Eastern and Southern regions of the continent

Agboyi et al., (2020), Insects 11(2), 68; Otim et al., (2021) Insects 12(2), 1–20; Ahissou et al., (2021), Biotechnol. Agron. Soc. Environ. **25**(3),192–207.; Giovanni et al., 2022

DISTRIBUTION OF *Spodoptera frugiperda* (FALL ARMYWORM) (FAW)



- Very damaging pest of maize, a major staple and food security crop

PROBLEM STATEMENT

- FAW management relies heavily on synthetic insecticides:
  - Risk of residue, and insect resistance
  - Increased cost of production
  - Adverse to beneficial/non-target organisms
  - Contamination of farmers and their households

JUSTIFICATION

- Need for sustainable management options
  - Integrated Pest Management (IPM) with **biological control** as central component
- *Coccygidium luteum* has been reported as one of the parasitoids attacking FAW in Ghana
  - Field parasitism rate of 19% has been reported
  - 89% reduction in feeding rate of parasitized FAW larvae
  - These attributes implicate *C. luteum* as possible candidate for biological control of FAW

(Agboyi et al. 2019)

Adult *C. luteum* wasp parasitizing FAW larvae

KNOWLEDGE GAPS

- Very limited information on the genus *Coccygidium* and more specifically the species *C. luteum*
- The lack of information on the reproductive biology, sex ratio, host-age preference, parasitism rate etc of *C. luteum* hinders its exploitation as biological control agent.

RESEARCH OBJECTIVES

- **Overall objective** - to elucidate the potential of *C. luteum* as a biological control agent for the management of FAW
- **Specific objectives**

1. Review the multi-stakeholder approach to FAW management in Ghana
2. Describe the host-age preference and reproductive biology of *C. luteum*
3. Identify the factors influencing sex ratio in *C. luteum*
4. Evaluate the effect of superparasitism on fitness of *C. luteum*

Objective 1. Review of multi-stakeholder approach to FAW management

METHODOLOGY

- Reviewed minutes/meeting reports of the FAW national taskforce and its subcommittees
- Key informant interviews with members of the FAW national taskforce
- Reviewed activity reports on FAW from donor agencies that played critical roles during the outbreak
- Reviewed published literature on FAW activities in Ghana and
- Data from the national plant protection organization

FINDINGS - Membership of the Multi-stakeholder National FAW taskforce

Government institutions

Ministry of Food and Agriculture

Environmental Protection Agency

Centre for Scientific and Industrial Research

National Disaster Management Organization

Biotechnology and Agricultural Research Institute

Development partners

CAB-International

GIZ

USAID-ADVANCE

FAO

AGRA

NGOs & Private Sector

Farmer Representative

Farm Radio International

STRATEGIC RESPONSE PLAN

- Strategic plan was developed through stakeholder workshop with four thematic areas:
  - Coordination and collaboration
  - Awareness and sensitization
  - Surveillance and early warning
  - Research and management

COORDINATION AND COLLABORATION

- Coordinated all response interventions
  - Three-tier structure:
    - National (strategic) ⟷ Regional (tactical) ⟷ District levels(operational)
    - Resource mobilization and distribution
    - Regular meetings to review response measures and to share information
    - Harmonization of activities of DPs in response to the outbreak
    - Periodic field visits/monitoring

AWARENESS AND SENSITIZATION

- Multifaceted approach was deployed
  - Sensitization of major media houses
  - Regular press briefings
  - Dedicated communication team and hotlines established
  - Targeted messages on identification and management
  - Training of AEAs and farmers
- Medium
  - Workshops, jingles, posters, flyers, live presenter mention, local languages, farmer fora, farmer field schools etc

MANAGEMENT AND RESEARCH

- Selection of effective pesticides based on information from the pest origin
- Research on sustainable alternatives e.g. IPM
  - Biopesticide trials
  - Evaluation of cultural practices and indigenous knowledge
  - Socio-economic impact assessment
  - Studies on the pest's biology
  - Biological control

MONITORING AND EARLY WARNING

- To track changes in the pest's population
  - Deployment of pheromone traps
  - Farmer-based monitoring using signs and symptoms
  - FAW prediction using crop phenology, relative humidity and temperature
  - FAMEWS App deployed among extension officers

LESSONS LEARNT

- Information from research and monitoring were helpful in the evaluation of response measures
- Networking between the actors in the plant health system was enhanced through regular meetings and collaborations
- Synchronization of activities resulted in resource maximization and reduced duplication of efforts
- Limited diagnostic capacity of national institutions resulting in delayed response to the outbreak.

LESSONS LEARNT

- Lack of emergency response plan, response team and dedicated funds for management of outbreaks.
- Citizens approach to pest surveillance as a tool for early detection– there is the need to empower citizens to report suspected new pests.
- Mandated institutions must immediately follow up on suspected cases to confirm species and activate rapid response measures where necessary

OBJECTIVE 2. Describe the host-age preference and reproductive biology of *C. luteum*

- Parasitism of *C. luteum*
- Host age preference
- Oviposition potential and reproductive biology
- Longevity

Bulletin of Entomological Research

cambridge.org/ber

Research Paper

Host age preference and biology of *Coccygidium luteum* (Hymenoptera: Braconidae), a larval parasitoid of the fall armyworm

Patrick Beseh[1,2], John Abraham[2], Lakpo Koku Agboyi[3] and Benjamin Mensah[2]

ESTABLISHMENT OF LABORATORY CULTURES

Field collection of FAW larvae

Rearing in the laboratory

Parasitoid cocoon

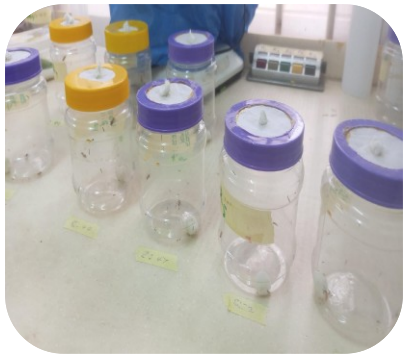
Adult *C. luteum* used for parasitoid culture

FAW Pupae

FAW moth used for host culture

PARASITISM BIOASSAY OF *C. luteum*

3-,4-, 5-, and 6-day old larvae



25 larvae of each category exposed to *C. luteum* for 35 mins. Rep. X9

Reared individually in sauce cups

Parasitoid Cocoon

Adult

C. luteum couples paired 24hr prior to exposure

Data collected on number of cocoons

HOST AGE PREFERENCE

Choice test

Six host age combinations (3d x 4d), (3d x 5d), (3d x 6d) and (4d x 5d), (4d x 6d) and (5d x 6d)

30 larvae (15 of each age group) exposed to mated *C. luteum* for parasitism. Rep: X5

Parasitised larvae reared individually on maize leaves in sauce cups

Number of parasitoid cocoons recorded

OVIPOSITION POTENTIAL AND REPRODUCTIVE BIOLOGY OF *C. luteum*

4-day old larvae

25 larvae exposed to *C. luteum* daily for 35 mins. Rep. X9

Reared individually in sauce cups

Parasitoid Cocoon

Adult

Newly emerged *C. luteum* adults

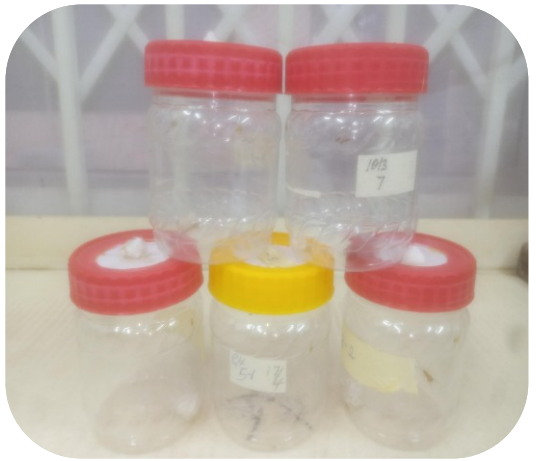
- **Data was collected on:**
  - Pre-oviposition, oviposition, and post-oviposition periods
  - Duration of developmental stages
  - Progenies per female etc

C. luteum LONGEVITY

Newly emerged *C. luteum*

Female

Male



Provided with water, droplets of honey and observed daily. Rep. X18

RESULTS:

Table 1. Parasitism of different instars of FAW

Host age (days)	Mean % parasitism rate ± SE
3	70.22 ± 10.79a
4	80.22 ± 8.35a
5	57.22 ± 30.46b
6	32 ± 20.89c

RESULT:

Table 2. Host age preference of *C. luteum*

Host age combination (days)	Host age (days)	Mean % ± SE	P - value
3 vs 4	3	43.33 ± 2.98a	0.646
	4	44.67 ± 1.69a	
3 vs 5	3	42.00 ± 2.49b	0.047
	5	36.00 ± 1.94a	
3 vs 6	3	44.67 ± 1.70a	< 0.001
	6	25.33 ± 2.26b	
4 vs 5	4	44.67 ± 1.33a	0.080
	5	40.67 ± 2.21a	
4 vs 6	4	40.67 ± 1.25b	< 0.001
	6	23.33 ± 1.49a	
5 vs 6	5	38.67 ± 1.70a	< 0.001
	6	26.67 ± 1.50b	

RESULTS:

Table 3: Oviposition potential and reproductive parameters of *C. luteum*

Parameter	Replicates	Mean ± SE	Range
Pre-oviposition period (days)	8	0.38 ± 0.51	0 – 1
Oviposition period (days)	8	5.13 ± 0.64	4 – 6
Post oviposition period (days)	8	0	0
Number of larvae parasitised/female	8	49.24 ± 24	31 – 66
Male longevity (days)	18	14.44 ± 1.43	11 – 17
Female longevity (days)	18	12.83 ± 1.12	10 – 15
Female progeny/female	9	28.11 ± 8.18	9 – 47
Male progeny/female	9	39.89 ± 4.76	29 – 51

RESULTS:

Table 4. Duration of development stages of *C. luteum*

Parameter	Replicates	Mean +SE (DAYS)	Range
Oviposition to Cessation of host feeding	42	8.35 ± 0.06	7.50 - 9.50
Cessation of host feeding to parasitoid egress	42	1.91 ± 0.07	1.00 – 3.05
Oviposition to last instar of parasitoid egress	42	10.26 ± 0.07	9.00 – 11.28
Duration of cocoon formation	42	1.01 ± 0.00	0.94 – 1.11
Pupal period	42	9.08 ± 0.08	8.00 - 10.50

RESULTS: Life cycle of *C. luteum*

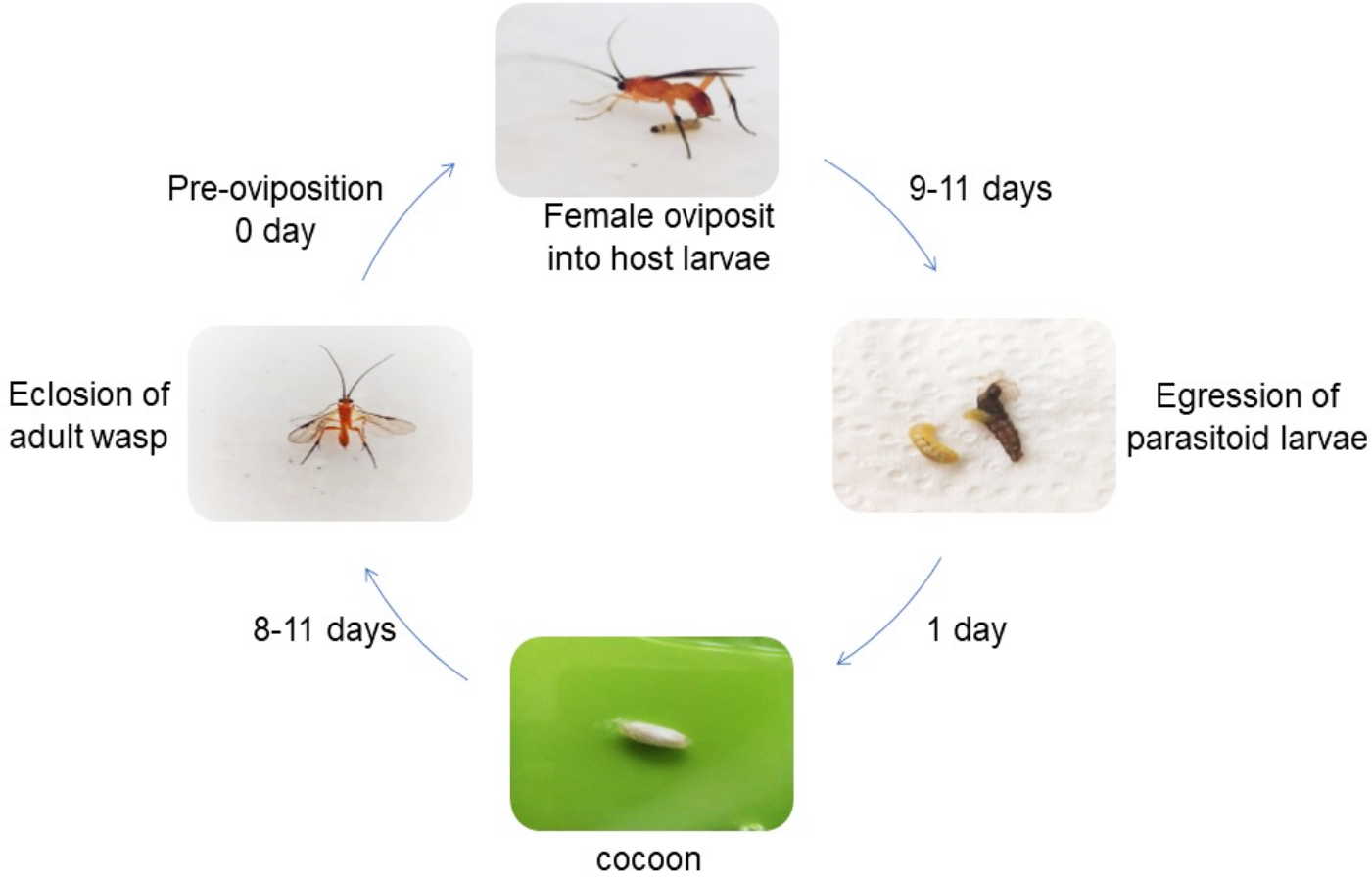


Figure 2 Life cycle of *Coccygidium luteum* reared on Fall armyworm under laboratory conditions.

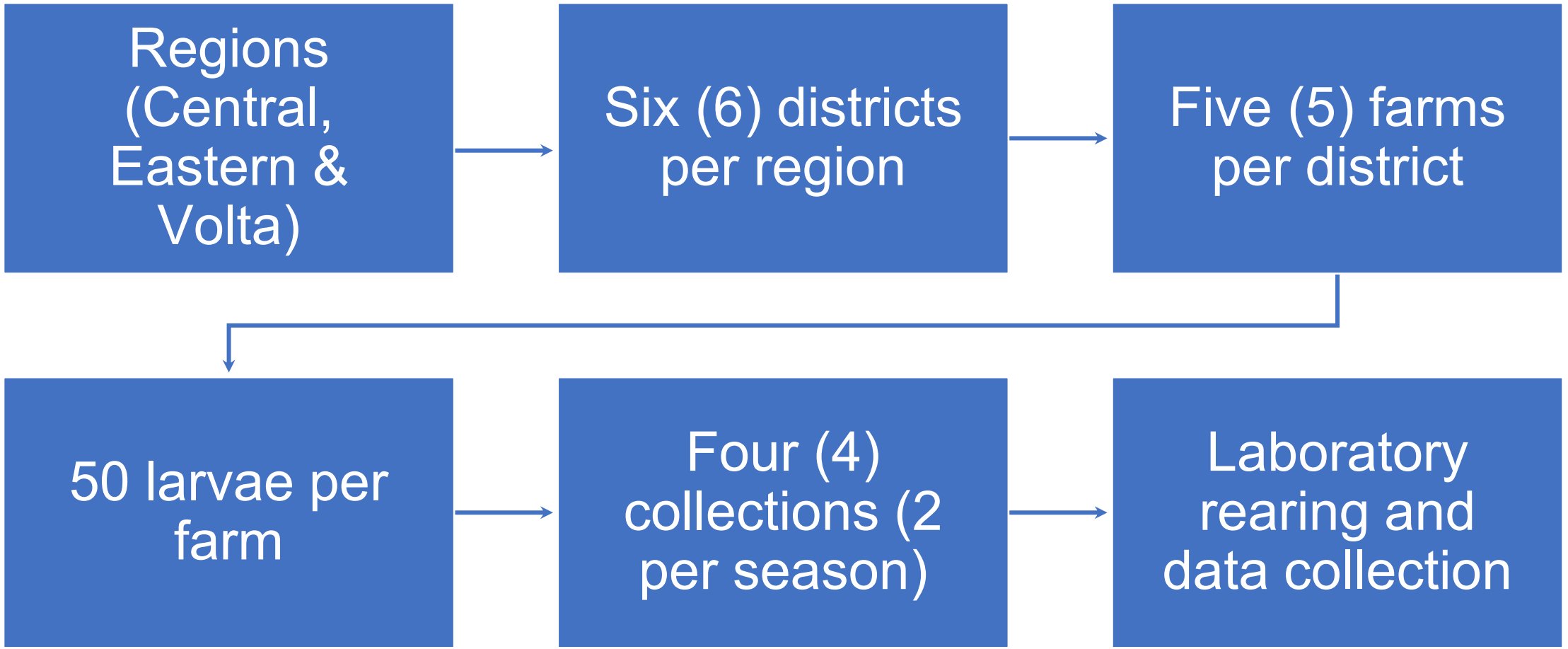
CONCLUSION

- The tendency of *C. luteum* to oviposit in early ages of FAW larvae is advantageous in reducing the damage of the pest
- The male-biased sex ratio is not ideal for biocontrol since it is the female that suppress host population through egg laying. An ideal sex ratio of 1:1 or female-biased sex ratio is desired
- The absence of preoviposition period implies female *C. luteum* may begin oviposition few hours after emergence.

OBJECTIVE 3
Factors Influencing Sex Ratio of *C. luteum*

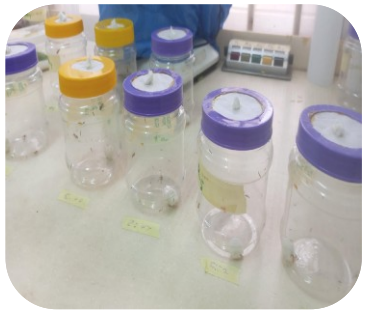
- Field sex ratio
- Mating duration
- Sib and non-Sib mating
- Host size

METHODOLOGY - FIELD SEX RATIO



EFFECT OF MATING DURATION

Male and female *C. luteum* mated for **24, 48, 72, and 96 hours**



30 larvae exposed to *C. luteum* for parasitism Rep. X5

Larvae individually reared in sauce cups with maize leaves

Data: male and female progenies

Parasitoid Cocoon

Adult

SIB VS NON-SIB MATING

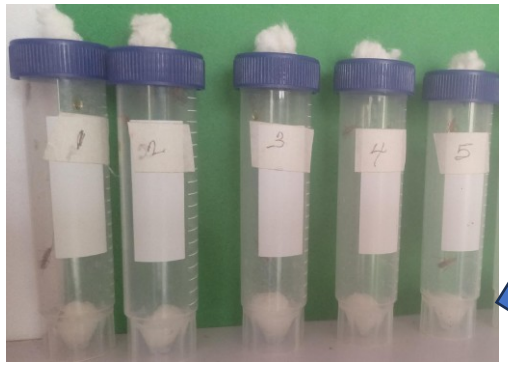
Female *C. luteum* were selected from mixed population

FAW larvae exposed to female *C. luteum* for parasitism

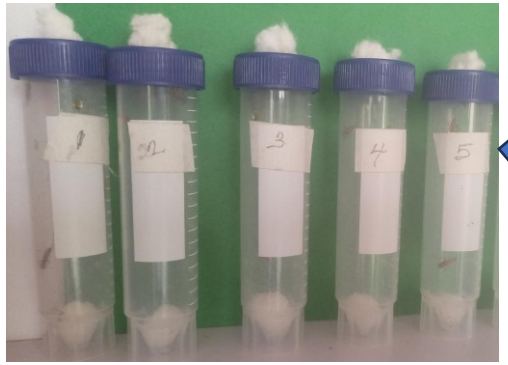
Laboratory rearing. Maternal lines kept separate

Progenies of each maternal line kept separate

SIB VS NON-SIB MATING



Male and female *C. luteum* from same maternal lines paired for 48hrs (**Sib-mating**)



Male and female *C. luteum* from different maternal lines paired for 48hrs (**Non-sib mating**)

50 4-day old larvae exposed to mated *C. luteum* female for oviposition. Rep. x5 for each treatment

Parasitised larvae reared individually on maize leaves in sauce cups

Male and female progenies recorded

EFFECT OF HOST AGE ON SEX RATIO

No choice Test

FAW eggs were incubated for four (4) consecutive days to generate 3-, 4-, 5- and 6-days age groups

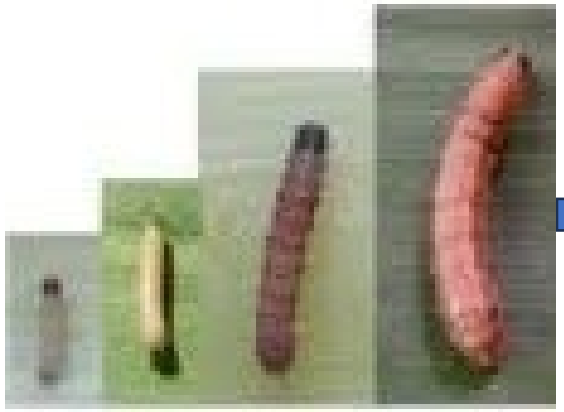
3-, 4-, 5- and 6-days old larvae exposed to mated *C. luteum* for parasitism. Rep: X5

parasitized larvae Individually reared

Data collected on male and female progenies

EFFECT OF HOST AGE ON SEX RATIO

Choice test



Host age combinations (3d x 4d), (3d x 5d) and (4d x 5d)

larvae exposed to mated *C. luteum* for parasitism. Rep: X5

Parasitised larvae reared individually on maize leaves in sauce cups

Data collected on male and female progenies

RESULTS: Field Sex ratio

Region	Mean % female *C. luteum* ± SE
Central	55.00 ± 16.38
Eastern	51.42 ± 13.16
Volta	49.00 ± 13.68

RESULTS: Effect of host size on sex ratio

Host age (days)	Length of the FAW larvae (mm)	Mean % female progeny ± SE
3	4.06 – 5.92	52.89 ± 3.76
4	6.42 – 7.61	42.42 ± 3.47
5	8.84 – 9.46	60.23 ± 3.57
6	10.25– 12.48	43.98 ± 1.39

RESULTS: Effect of relative host size on sex ratio

Host age combination (days)	Host age (days)	Mean % female progenies ± SE
3 vs 4	3	58.96 ± 12.56
	4	50.11 ± 7.27
3 vs 5	3	50.13 ± 13.19
	5	36.00 ± 15.45
4 vs 5	4	44.67 ± 10.55
	5	25.33 ± 10.43

RESULTS: Effect of mating duration on sex ratio

Mating duration (hours)	Mean % female progenies ± SE
24	29.99 ± 18.39
48	49.46 ± 4.93
72	39.04 ± 9.39
96	44.71 ± 7.00

RESULTS: Sib vs Non-sib mating

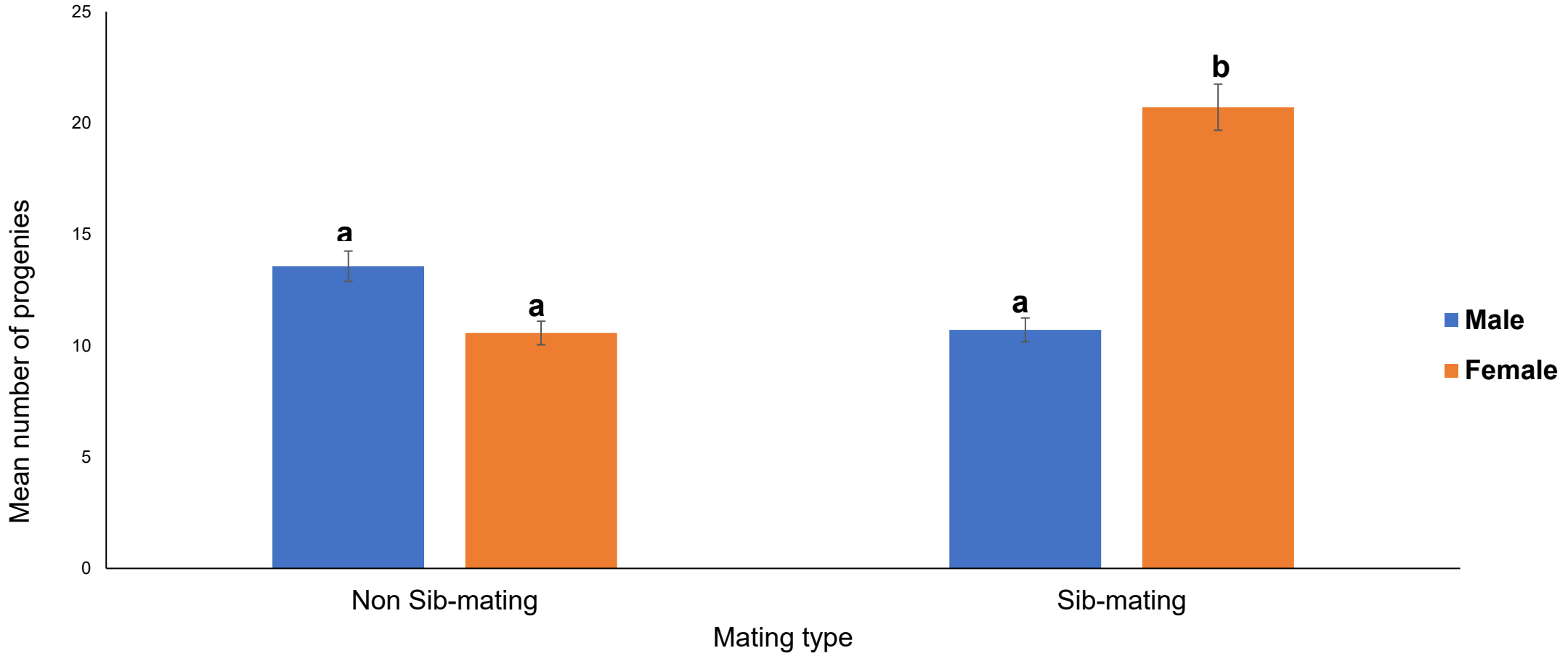


Figure 1. Effect of Siblings and Non-Siblings mating on Progenies sex ratio in *C. luteum*

CONCLUSION

- Field sex ratio of *C. luteum* conforms to **Fisher's theory**.
- Sex ratio of *C. luteum* from host age study deviates from the host quality theory **(Charnov et al.1981).** This likely due to *C. luteum* being a Koinobiont parasitoid
- Mating duration in *C. luteum* did not result in female biased sex ratio suggesting that *C. luteum* is likely monandrous.
- Sib-mating in *C. luteum* agrees with **Hamilton's theory** (LMC) that maternal related or inbreeding in parasitoids yields female biased populations **(Boomsma 1991; Awad et al. 2019; Du et al. 2021).**

OBJECTIVE 4. SUPERPARASITISM AND ITS EFFECTS ON THE FITNESS OF *C. luteum*

- Host quality and oviposition choice
- Ovipositor insertion time
- Influence of superparasitism on progeny development time, cocoon weight and parasitoid size

EUROPEAN JOURNAL OF ENTOMOLOGY
ISSN (online): 1802-8829
http://www.eje.cz
Eur. J. Entomol. **122**: 80–87, 2025
doi: 10.14411/eje.2025.010
ORIGINAL ARTICLE

Superparasitism and its effects on the fitness of the larval parasitoid, *Coccygidium luteum* (Hymenoptera: Braconidae)

PATRICK BESEH[1,*], LAKPO KOKU AGBOYI[2], BENJAMIN MENSAH[3] and JOHN ABRAHAM[3,*]

[1] Plant Protection and Regulatory Services Directorate, Ministry of Food and Agriculture, Accra, Ghana; e-mail: pkbeseh@gmail.com

[2] CAB-International Ghana, P.O. Box CT 8630, Cantonments, Accra, Ghana; e-mail: L.Agboyi@cabi.org

[3] Department of Conservation Biology and Entomology, School of Biological Sciences, University of Cape Coast, Cape Coast, Ghana; e-mails: bmensah@ucc.edu.gh, jabraham@ucc.edu.gh

HOST QUALITY AND OVIPOSITION CHOICE

previously parasitized larvae

Non-parasitized larvae

1

1

Naïve female

Rep: X15

Data:

1. Host choice
2. Ovipositor insertion duration

self parasitized larvae

unparasitized larvae

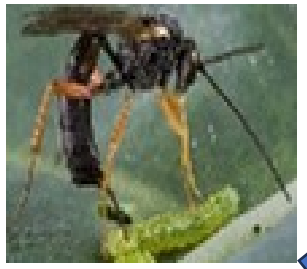
1

1

Same female Rep: X15

(Self-superparasitism)

OVIPOSITION CHOICE BETWEEN PARASITIZED AND NON-PARASITIZED HOST

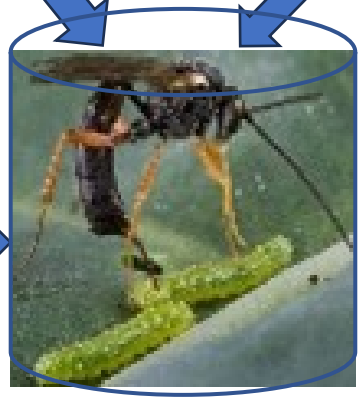


Parasitized larvae

1

Unparasitized larvae

1



Different but experienced female (conspecific)
Rep: x15

Data:

1. Host choice
2. Ovipositor insertion duration

SUPERPARASITISM,PROGENY DEVELOPMENT TIME, PARASITOID FITNESS

larvae exposed individually to *C. luteum*

Reared individually in sauce cups on maize leaves

1hr

larvae exposed individually to *C. luteum*

transferred into 2nd cage for 2x parasitism

Reared individually in sauce cups on maize leaves

1hr

1hr

larvae exposed individually to *C. luteum*

Transferred into 2nd cage for 2x parasitism

Transferred into 3rd cage for 3x parasitism

Reared individually in sauce cups on maize leaves

a. Time to parasitoid larvae egress
b. Time to cocoon formation
c. Time to parasitoid emergence
d. progeny size
e. Cocoon weight

RESULTS: Oviposition choice by *C. luteum* between parasitized and non-parasitized host

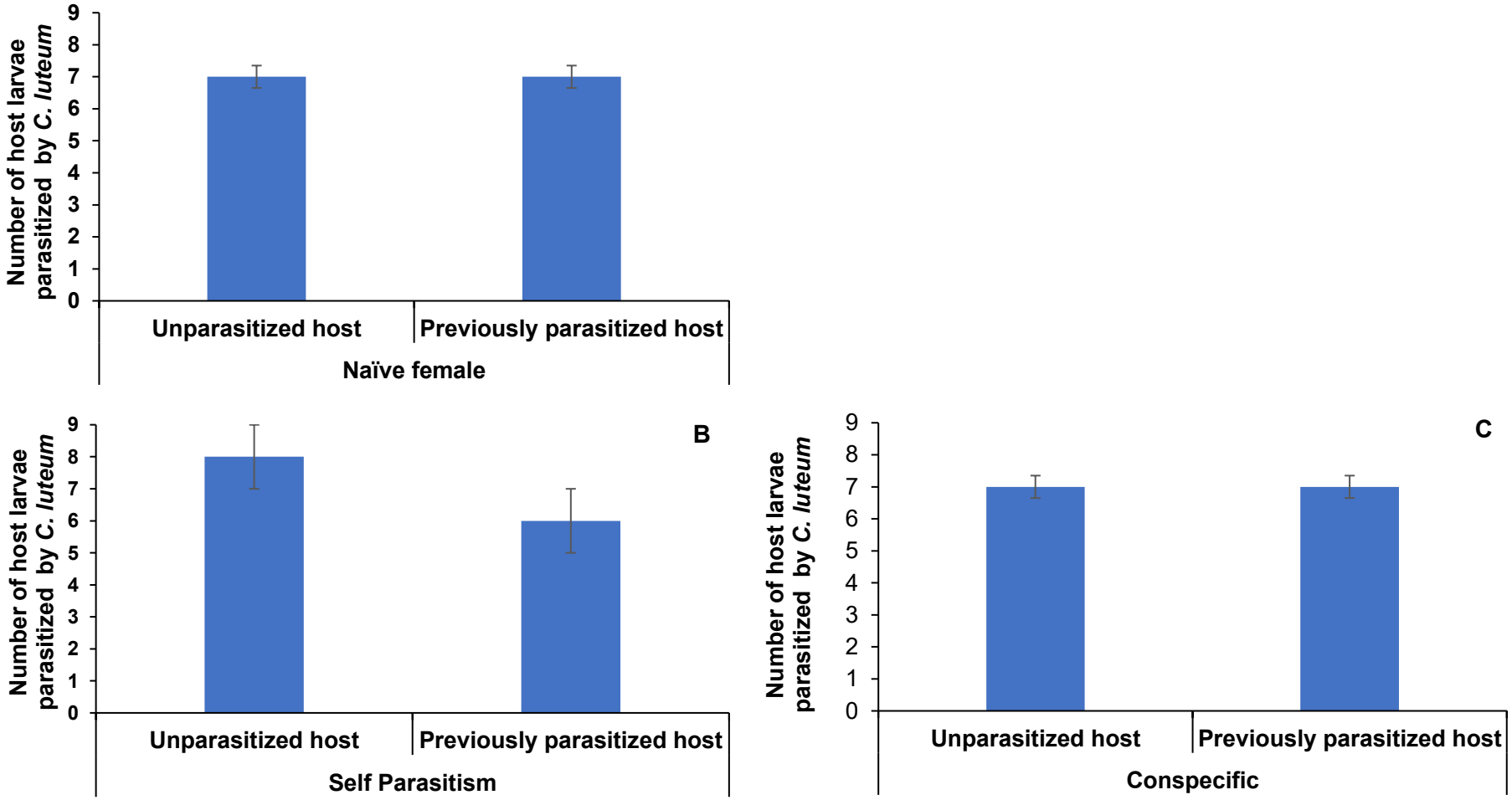


Figure 2. Host quality and oviposition choice of *C. luteum*

RESULTS: Ovipositor insertion time, parasitized vs non-parasitized host

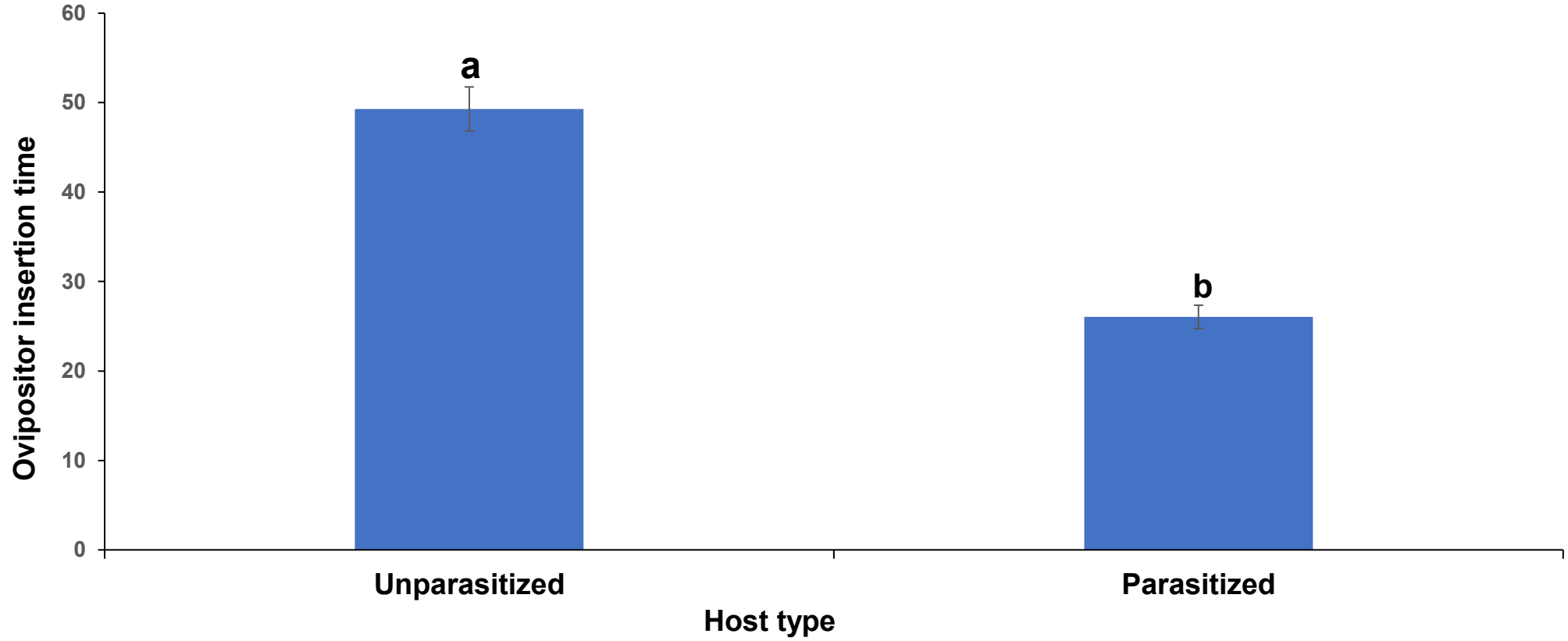
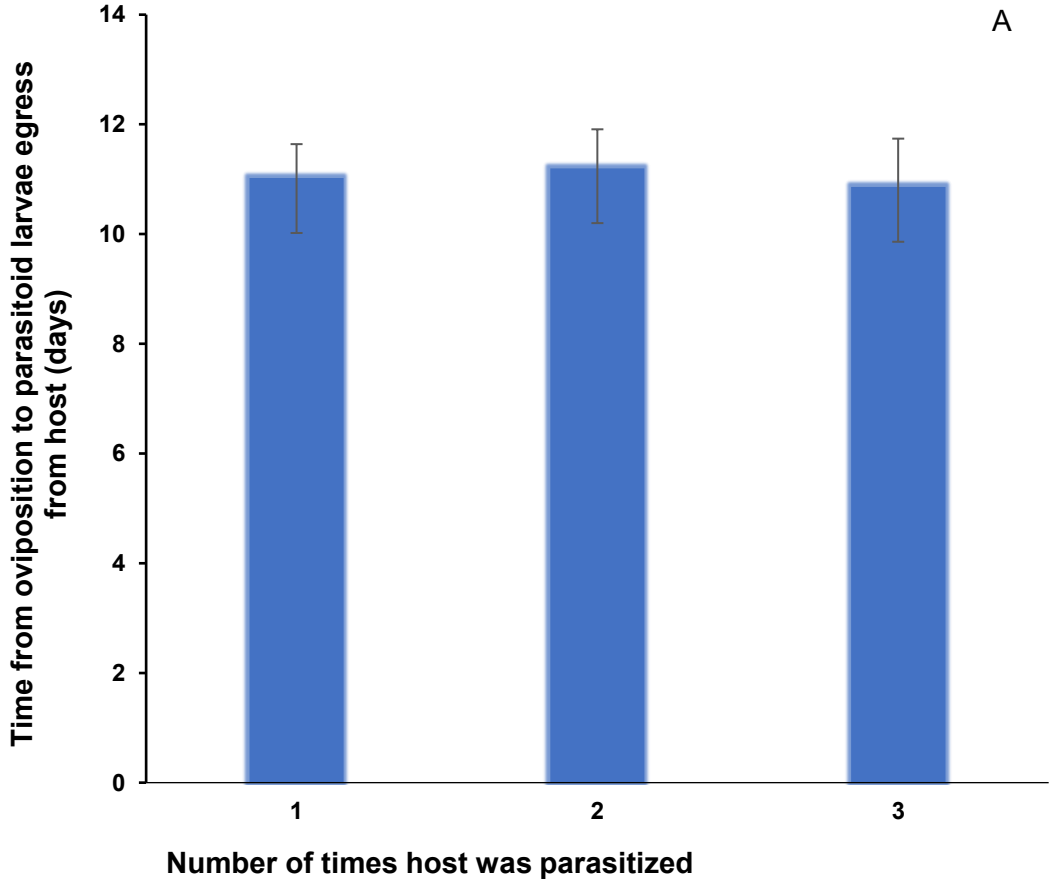


Figure 3. Effect of host quality on oviposition insertion time in *C. luteum*

RESULTS: Influence of superparasitism on parasitoid development time and cocoon formation



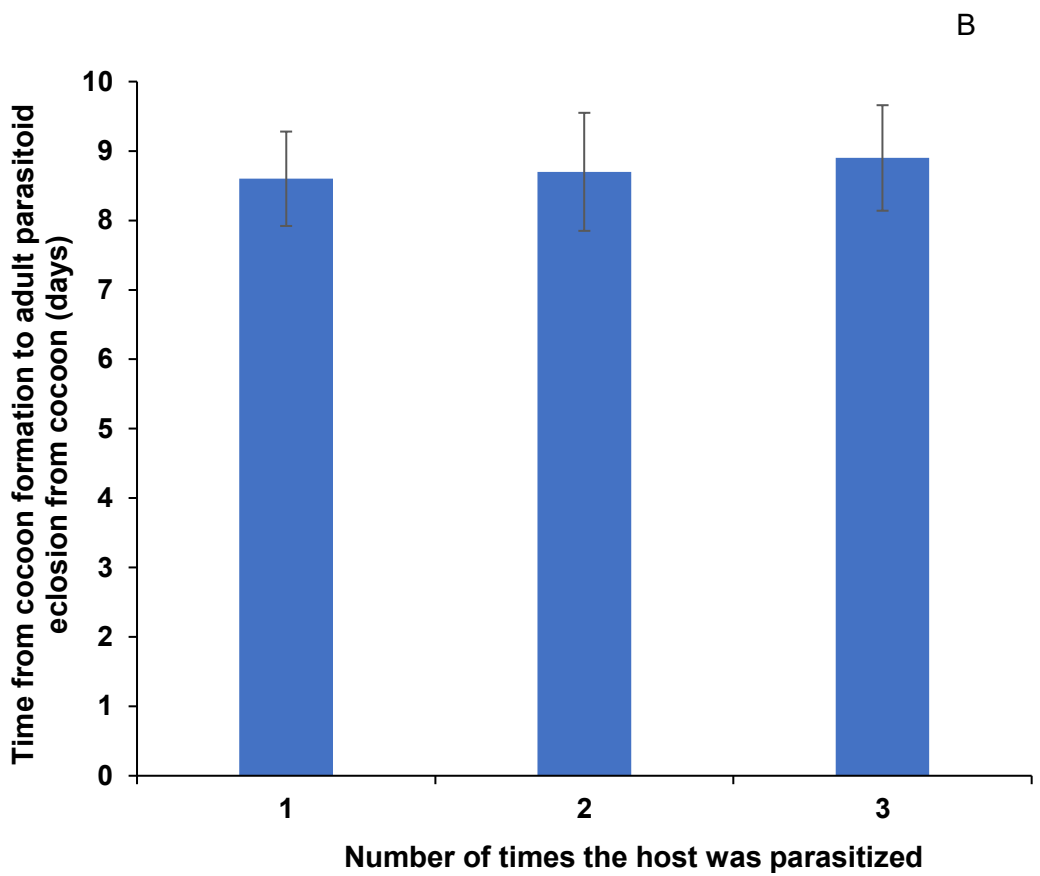
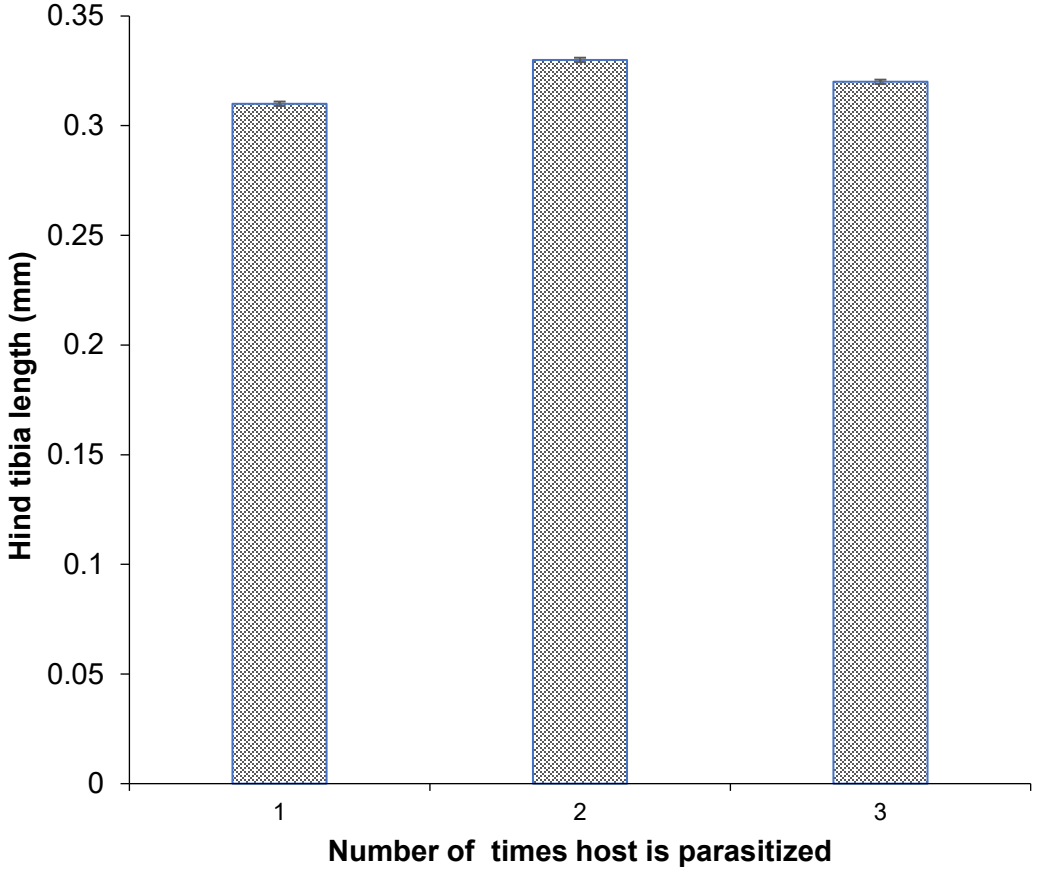


Figure 4. Effect of superparasitism on parasitoid development time

RESULTS: Effect of superparasitism on parasitoid fitness



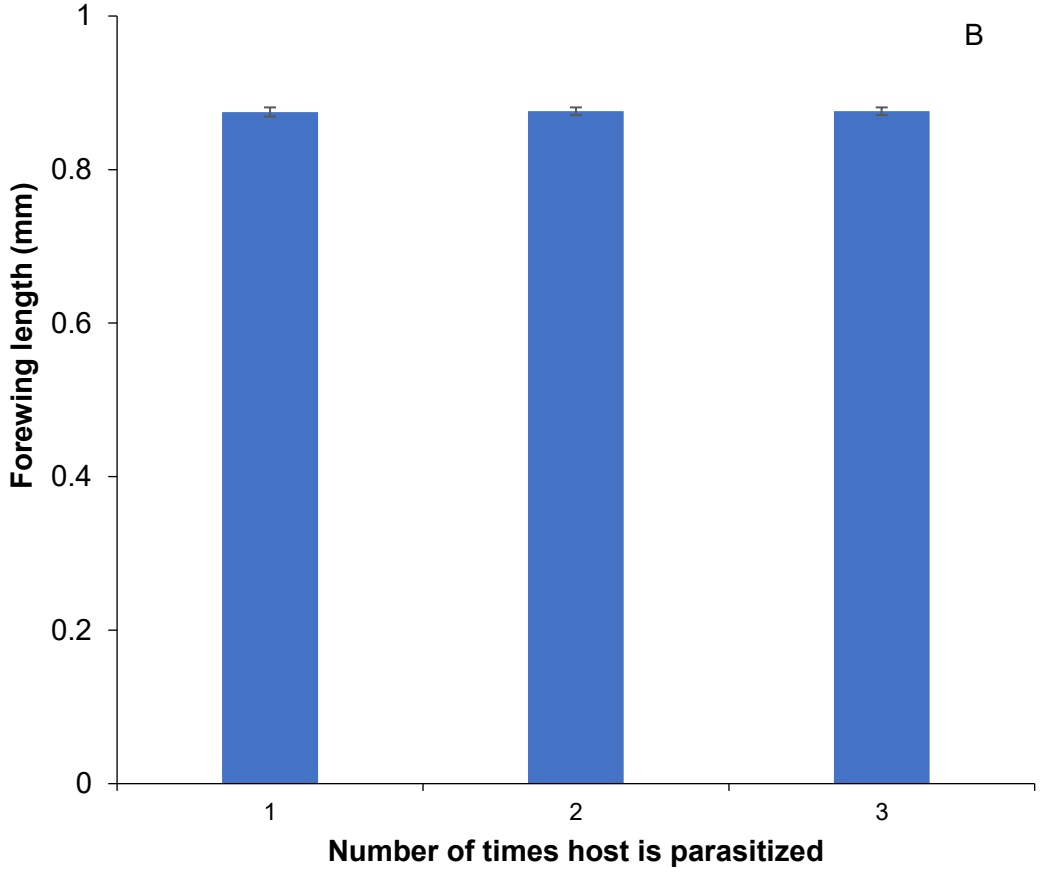


Figure 5. Superparasitism and parasitoid fitness

RESULTS:
Effect of superparasitism on cocoon weight

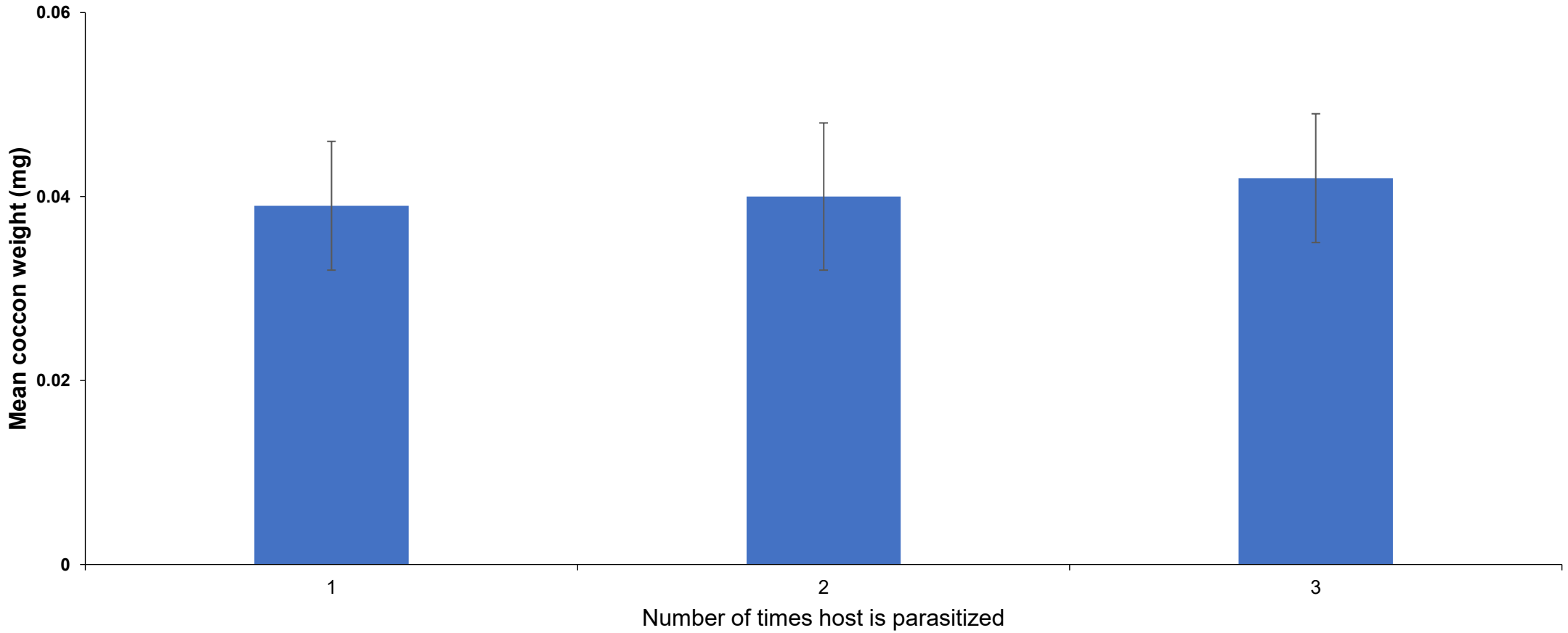


Figure 6. Effect of superparasitism on Cocoon weight

CONCLUSION

- Host discrimination is an acquired trait and may also be influenced by the physiological state (e.g. longevity, egg load etc) of the parasitoid. This might influence the inability of the naïve female to reject previously parasitized host.
- The inability of experienced females to discriminate host suggest that this attribute may be absent in *C. luteum* or if present, may be based on internal cues which require time to develop.
- The deployment of physical defense mechanisms by unparasitized larvae to avoid parasitism might account for the differences in ovipositor insertion time
- The observed non-negative effect of superparasitism on the development and fitness of *C. luteum* offspring is advantageous in mass parasitism for field releases

OVERARCHING CONCLUSIONS

- Citizens approach to pest detection and multi-stakeholder involvement are important in effective management of invasive species
- *Coccygidium luteum* prefers early host instars (1^{st} -3^{rd}) which minimizes the impact of the host on the crop
- Sib-mating in *C. luteum* produces higher female progenies and this can be exploited in mass rearing
- Superparasitism in *C. luteum* had no statistically significant effect on the fitness of parasitoid progeny

RECOMMENDATIONS

- The multi-stakeholder approach should be the primary strategy in managing invasive species in the country
- Study factitious hosts for mass rearing of *C. luteum*
- Develop mass rearing protocol for *C. luteum*
- Assess the optimal release density and frequency of *C. luteum*

CONTRIBUTION TO KNOWLEDGE

- Demonstrated the importance of multi-stakeholder approach in invasive species management and citizens participation in early pest detection
- *Coccygidium luteum* is one of the least studied parasitoid species which hinders its use in biological control. This study provides useful information on:
  - Host age preference and reproductive biology of the parasitoid
  - Factors influencing its sex ratio
  - Effect of superparasitism on the fitness of the parasitoid offsprings
- These findings are critical for understanding the evolutionary strategies of *C. luteum* and other biological control insects and have direct relevance for optimizing rearing and release programs.

ACKNOWLEDGEMENT

- Supervisors
- PPRSD management for the opportunity
- Staff of Biological control unit, PPRSD for their support during the data collection
- CAB-International for funding and the encouragement
- Staff and management of DCBE
- OHCS for granting me the permission to carry out this research

THANK YOU