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Release, recovery and conservation of *Spodoptera frugiperda* parasitoids

Francis Obala and Samira Mohamed on behalf of Biological Control Group

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PLOS ONE

RESEARCH ARTICLE

A deadly encounter: Alien invasive *Spodoptera frugiperda* in Africa and indigenous natural enemy, *Cotesia icipe* (Hymenoptera, Braconidae)

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Abstract

The invasion and wide spread of *Spodoptera frugiperda* represent real impediments to food security and the livelihood of the millions of maize and sorghum farming communities in the sub-Saharan and Sahel regions of Africa. Current management efforts for the pest are focused on the use of synthetic pesticides, which are often economically unviable and are extremely hazardous to the environment. The use of biological control offers a more economically and environmentally safer alternative. In this study, the performance of the recently described parasitoid, *Cotesia icipe*, against the pest was elucidated. We assessed the host stage acceptability by and suitability for *C. icipe*, as well as its ovigenic status. Furthermore, the habitat suitability for the parasitoid in the present and future climatic conditions was established using Maximum Entropy (MaxEnt) algorithm and the Genetic Algorithm for Rule-set Prediction (GARP). *Cotesia icipe* differentially accepted the immature stages of the pest. The female acceptance of 1st and 2nd instar larvae for oviposition was significantly higher with more than 60% parasitism. No oviposition on the egg, 5th and 6th larval instars, and pupal stages was observed. Percentage of cocoons formed, and the number of emerged wasps also varied among the larval stages. At initial parasitism, parasitoid progenies, time to cocoon formation and overall developmental time were significantly affected by the larval stage. Egg-load varied significantly with wasp age, with six-day-old wasps having the highest number of mature eggs. Ovigeny index of *C. icipe* was 0.53. Based on the models, there is collinearity in the ecological niche of the parasitoid and the pest under current and future climate scenarios. Eastern, Central and parts of coastal areas of western Africa are highly suitable for the establishment of the parasitoid. The geographic distribution of the parasitoid would remain similar under future climatic conditions. In light of the findings of this study, we discuss the prospects for augmentative and classical biological control of *S. frugiperda* with *C. icipe* in Africa.

Biological control of the alien invasive fall armyworm

Samira Abuelgasim Mohamed, Francis Obala, Sevgan Subramanian*

Figure 1: Potent native parasitoids of fall armyworm in Africa. (from left to right) (1) egg parasitoid, *Telenomus remus*; (2) egg parasitoid, *Trichogramma chilonis* and (3) larval parasitoid *Cotesia icipe* on FAW in the laboratory. Photos: Robert Copeland, icipe

In Africa, maize is one of the most important sources of food security, income generation and employment for over 300 million people across sub-Saharan Africa (FAO, 2018; La Rovere et al., 2010). However, the production of maize is hindered by several biotic and abiotic constraints. High among the biotic constraints is infestation with insect pests such as native and invasive stemborers. The recent invasion of Africa by fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae), has maize leaves. The eggs hatch into neonate larvae, which hang down with a silk thread and disperse to nearby plants. Some of the larva also migrate onto the leaves and whorls of the same maize plant. The larvae are polyphagous and voracious feeders (Capinera, 2002; Rose et al., 1975). Owing to these traits, coupled with the short generation time, high dispersal ability of adult moth, availability of a wide range of host plants and suitable climatic conditions, fall armyworm rapidly spread across Africa human and environmental health, including negative effects on non-target or beneficial insects. To overcome these challenges of overreliance on synthetic/chemical insecticides, various research institutions, governments and international bodies focus on the implementation of sustainable and effective control measures. Integrated Pest Management (IPM) strategies can be very useful to help farmers suppress the FAW population in both small and large-scale production systems. In pursuit of this need,

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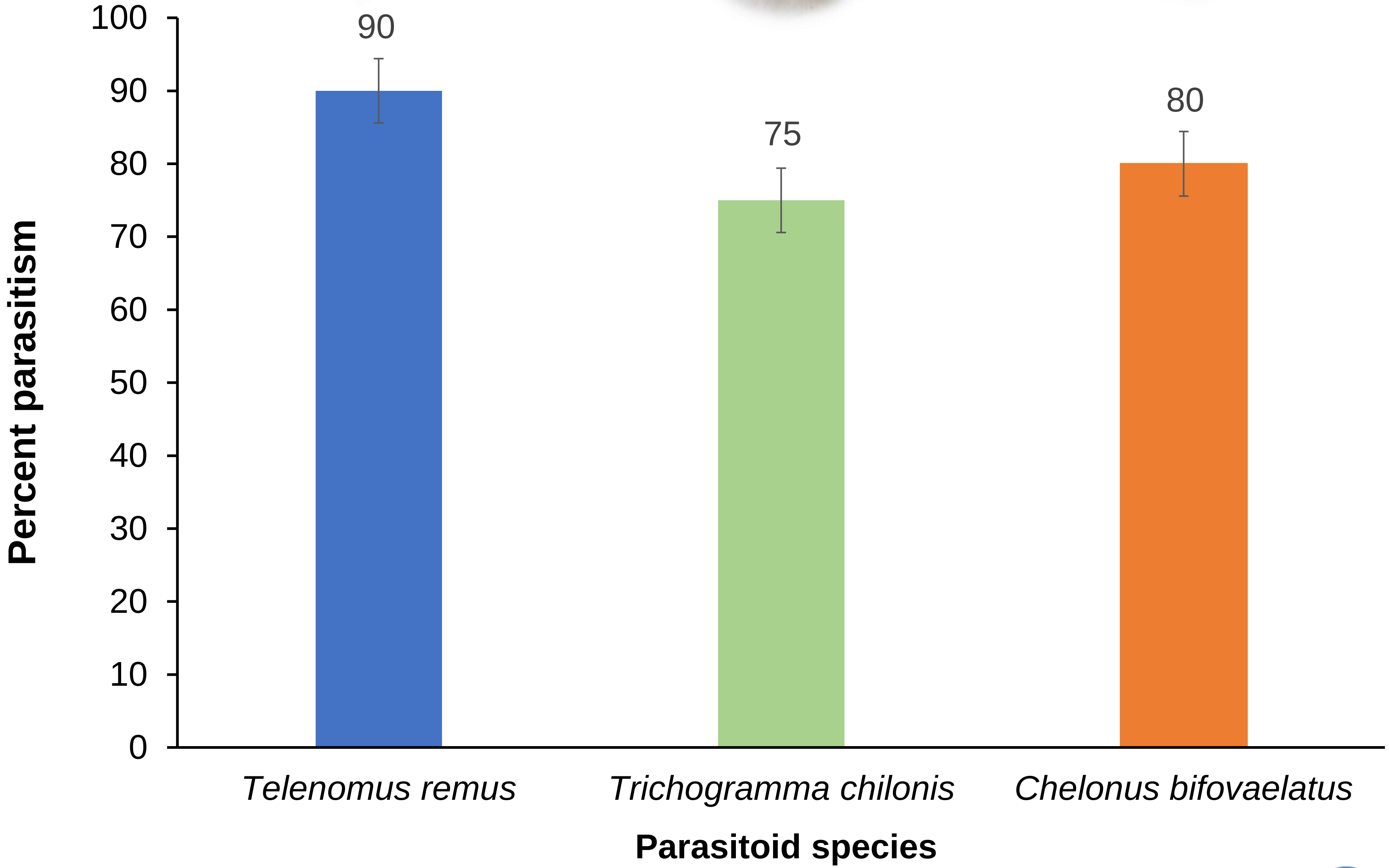
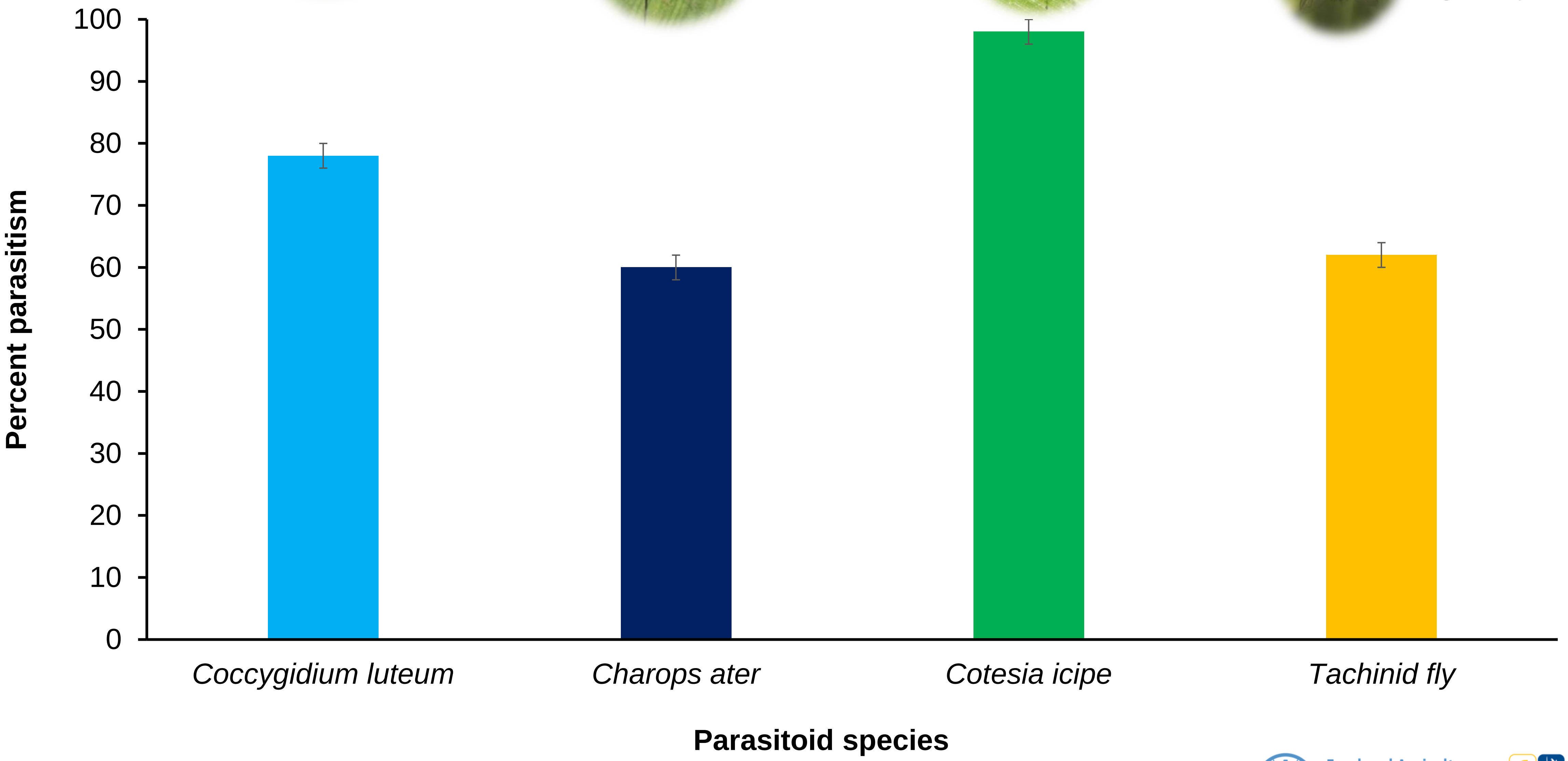
Performance of egg and egg-larval parasitoids on *Spodoptera frugiperda*





Performance of larval parasitoids against FAW in the lab



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Protocol for release and recovery of parasitoids

Materials/equipment required for field release

- ❖ Tape measure
- ❖ Transporting plastic jars with egg cards
- ❖ Marking cloth pieces
- ❖ Envelopes for hanging egg cards
- ❖ Marking sticks
- ❖ Marker pen
- ❖ Stapler and Pins
- ❖ Meter and rope
- ❖ Stickum or grease

Pre-release of egg and larval parasitoids in the field

- **Assessment for:**
  - Farmers' knowledge on natural enemies; and train them accordingly
  - Use of synthetic pesticides
  - Level of FAW infestation in the field and the host stage (egg/larva/adult)
  - Presence of the natural enemies (which parasitoids are present?)
  - Stage of the crop
  - Distance between the rearing facility and the field for transport of either cocoons or wasps

Synthetic pesticides used by farmers in Kenya

Assessing farmers knowledge and training

Stage of the crop and level of damage

Pre-release assessment of the maize field

Assessment of the farm, growers sensitization and creation of awareness of impacts of the parasitoids release

- Prior to the release of parasitoids, growers should be sensitized on the safety and role of the parasitoid on the suppression of FAW
- The release site should be a maize field with at least 4-6 weeks old crops; this stage is highly likely to get higher FAW infestation
- The target field SHOULD NOT BE SPRAYED with synthetic pesticides prior to, during or after the release of the parasitoids

Storage, package and transportation of *T. remus* and *T. chilonis*

- Optimum storage condition (temperature) for parasitized FAW eggs is at 10°C for 7-9 days
- Adult parasitoids can be stored under 10°C for <7 days.
- The parasitoids can be released in the form of parasitized FAW eggs or wasps
- They should be released at a rate of 100,000-150,000/Ha
- The number of parasitoids released can either be increased or decreased depending on infestation level
- Parasitoids should be transported in cool boxes either by road or air
- Parasitized eggs should reach the release site(s) on the expected day of emergence to avoid being prayed upon if left in the field for longer period

Storage, package and transportation of *C. icipe*

- *Cotesia icipe* (or any other larval parasitoid) can be released in the form of cocoons and/or wasps

- Cocoons should be placed into jars according to the number vs size of the farm/level of infestation

- For the wasps, they are placed into Perspex cages with sliding doors or netted cages with a zip

Storage, package and transportation of *C. icipe*

Transparent jars for transporting *C. icipe* cocoons

- For field sites of distances over 100Km from the rearing facilities, release of cocoons in jars with meshed lids should be considered

- Transportation of the parasitoid cocoons should be done in vehicles, under AC to prevent mortality of any emerging wasp during transportation

- Cool boxes are preferred for the transportation of cocoons.

Time and release techniques for both egg and larval parasitoids

Release of *C. icipe* (sliding the door open to allow the wasps escape

Time:

- Release should be done in the morning (emergence, mating, oviposition happens in the morning hours)
- However, release can also be done in the evening, under cooler temperature (Host egg laying; to find freshly laid eggs)

At the site: release techniques

- Measure the size of the infested field
- Mark a release point in the middle of the identified field site with a stick

Handling of Tricho/Tele cards or wasps at the egg parasitoid release sites

- ❖ At the marked midpoint; Tele/tricho cards in the envelops should be hanged onto maize plants
- ❖ From the midpoint, the cards should be placed at equidistance covering North, South, East and West directions
- ❖ High infestation i.e., 3 parasitized egg masses per plant; cover NE, SE, NW and SW directions to increase the wasp coverage area.
- ❖ Envelops should placed in such away that the surface with parasitized eggs should be facing outside to allow wasp to escape
- ❖ Date of release and quantity released recorded
- ❖ The GPS coordinates of the release sites should be recorded

Monitoring, recovery and assessment impact of *T. remus* and *T. chilonis* establishment

- Seven days post-release of the parasitoids, sampling of FAW egg masses on a weekly basis is recommended
- Monitoring and augmentative releases should be done until the desired bio-control results are achieved
- For recovery, do not collect more than half of the FAW eggs present in the farm

Recovery and assessment of *T. remus* and *T. chilonis* establishment

❖ Place the collected egg masses in individual vials, incubate in the laboratory and assess for percent parasitism and number of FAW larvae formed

❖ To determine the parasitoid establishment, identify the recovered species of parasitoids, estimate their parasitism level, and compare the release and control site.

Recovery and assessment of *Cotesia icipe*

Recovery of the released *C. icipe*

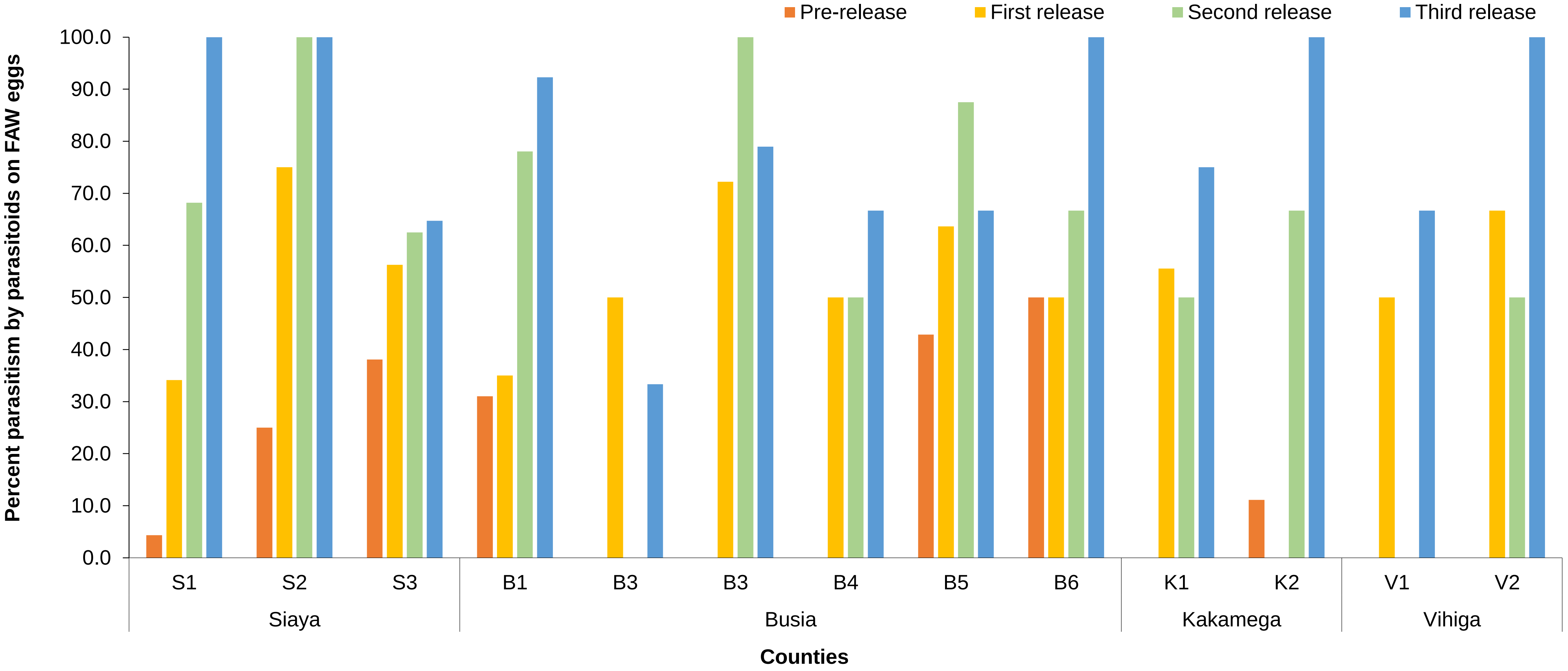
- ❖ Use zig zag/or W-shape method to sample early instar larvae (100) ha-1 4-5 days after the date of release.
- ❖ For other larval parasitoids, sampling should consider all stages of FAW larvae
- ❖ Sampled larvae should be sorted out as per the guidelines for rearing of larval parasitoids as explained in the previous presentation

Handling of cocoons or wasps at the larval parasitoid release sites

Netted cage for release of adult parasitoids

- The release should be done in the morning or after 5pm; when temperatures are cool
- At the release site, measure and put a mark at the midpoint
- From the measured and marked midpoint, place the Perspex/netted cage and open the sliding door (or unzip) to allow the parasitoids escape to the maize field
- For highly infested maize field, release 500~600 cocoons or adults (1:1 ♀:♂)/Ha

Establishment and impact (% parasitism) of the field released parasitoids



Conservation of parasitoids

Conservation strategies for FAW parasitoids in the field

Creation of awareness on conservation biological control

Stop spraying of crops with synthetic insecticides

Source: Ali et al. (2019)

- Providing of refugia for the natural enemies in the field

The use of augmentorium

Conservation of parasitoids in the field

Augmentorium for conservation of FAW egg parasitoids in the field

The use of augmentorium: Structure

- Tent-like structure that is designed to receive pieces of maize leaves with egg masses collected within the FAW infested maize field.
- The augmentorium comprises net mesh with a mesh opening that is small enough to sequester FAW larvae and moths, but large enough to allow the parasitoid wasps to escape back to the field.

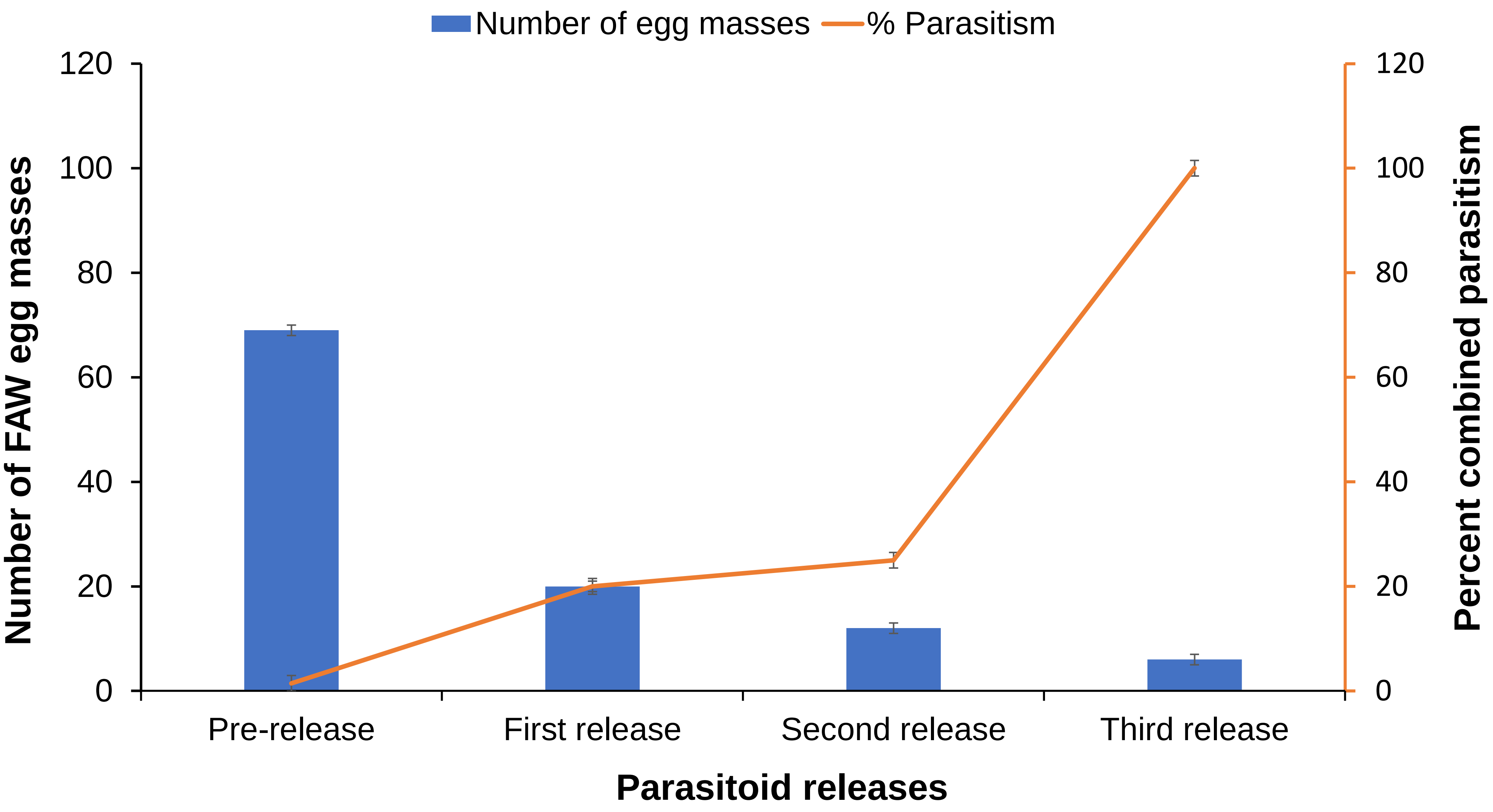
Efficiency of the augmentorium in conservation of egg parasitoids

Field-trial site in Embu, Kenya.

- Laboratory evaluation of the efficiency of the **augmentorium** showed up to 100% FAW larvae (L1) mortality and 0% parasitoid recovery. over 9

- Field trials shows 100% mortality of unparasitized eggs (FAW larvae), and an estimated percent recovery of over 80%.

Conservation of natural enemies: Use of Augmentorium



- >80% recovery of *T. remus* and *T. chilonis*
- 100% mortality of FAW larvae

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Conservation of parasitoids in the field

Advantages of using augmentorium:

- ❖ Low cost, simple and zero toxicity
- ❖ 100% mortality of the pest, and over 80% recovery of the parasitoids, contributing to suppression of FAW populations in the same field
- ❖ Protects the parasitoids (in form of parasitized FAW eggs) from predators.

Challenges of using augmentorium:

- ❖ Labor intensive and time consuming for large-scale farming
- ❖ Inefficient for the larval parasitoids.

Way forward:

- ❖ Dissemination of the technology to smallholder farmers across East Africa.

Farmers' awareness

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