ResearchGate

See discussions, stats, and author profiles for this publication at: https://www.researchgate.net/publication/349605538

CRICKET REARING HANDBOOK SERVICES FOR SCIENCE AND EDUCATION UNITED KINGDOM

Book · February 2021

CITATIONS
0

READS
189

6 authors, including:

Mary Orinda
Jaramogi Oginga Odinga University of Science and Technology, Bondo, Kenya
14 PUBLICATIONS **16** CITATIONS
SEE PROFILE

Henlay Magara
icipe – International Centre of Insect Physiology and Ecology
25 PUBLICATIONS **106** CITATIONS
SEE PROFILE

Monica Ayieko
Bondo University College
59 PUBLICATIONS **615** CITATIONS
SEE PROFILE

Some of the authors of this publication are also working on these related projects:

European Union Adopt View project

Special Issue II Africa on Edible Insects View project

All content following this page was uploaded by Henlay Magara on 25 February 2021.

The user has requested enhancement of the downloaded file.

CRICKET REARING HANDBOOK

MARY A. ORINDA, JACKLINE A. OLOO, HENLAY J.O. MAGARA, MONICA A. AYIEKO, SUNDAY EKESI & NANNA ROOS

SERVICES FOR SCIENCE AND EDUCATION
UNITED KINGDOM

Mary A. Orinda, Jackline A. Oloo, Henlay J.O. Magara, Monica A. Ayieko, Sunday Ekesi & Nanna Roos

CRICKET REARING HANDBOOK

Credits and acknowledgements borrowed from other sources and reproduced with permission in this book appear on appropriate pages within text.

Copyright © 2020, Society for Science and Education (United Kingdom)

Society for Science and Education – United Kingdom (SSE-UK) applies the Creative Commons Attribution (CC BY) license to this book. Under the CC BY license, authors retain ownership of the copyright for their article, but authors allow anyone to download, reuse, reprint, modify, distribute, the published content by SSE-UK, so long as the original authors and source are cited.

DOI: 10.14738/eb.86.2020

Published by:
Services for Science and Education
Stockport, Cheshaire, SK4 2BT
United Kingdom

TABLE OF CONTENTS

LIST OF TABLES ..... **iv**

FOREWORD ..... **vi**

PREFACE ..... **vii**

CHAPTER ONE **1**

1.1 Introduction 1

1.2 Why cricket farming? 1

1.3 Cricket Biology 3

1.3.1 Cricket 3

1.3.2 Cricket Anatomy 3

1.3.3 Cricket Life Cycle 1

1.3.4 Digestion in Crickets 3

1.4 Cricket Behaviour 4

1.4.1 Chirping in Crickets 4

1.4.2 Moulting in Crickets 6

1.4.3 Mating in Crickets 7

1.4.4 Fighting in Crickets 9

CHAPTER TWO **11**

2.1. Getting Started: Input/Materials needed 11

2.2. Rearing House 11

2.3. Materials and Equipment 16

CHAPTER THREE **20**

3.1. Starting up a colony 20

3.2. Species Selection 20

3.3. Eggs 20

3.4. Laying substrate 21

3.5. Egg laying Container 23

3.6. Egg Collection 25

3.7 Egg incubation 25

3.8 Water 25

3.9 Feeds 27

3.10 Provision for Hide-outs 30

CHAPTER FOUR **32**

4.1. Rearing Systems 32

4.1.1 Pen System 32

4.1.2 Plastic Containers and Perspex cages 34
4.2. Production Methods 35
4.2.1. Continuous Production Method 35
4.2.2. Batch Production Method 36
4.3. Production Schedules and Rearing house Set-up 37
4.4. Harvesting 39
CHAPTER FIVE **41**
5.1 Threats to cricket farming 41
5.1.1 In-breeding 41
5.1.3 Parasites 42
5.1.4 Pathogens 43
5.1.5 Diseases 44
5.1.6 Predators 46
CHAPTER SIX **51**
6.1 Cricket Products and Possible Business Enterprises 51
6.2 Gross Margin Analysis and Projected Income 53
BIBLIOGRAPHY **56**

LIST OF TABLES

Table 1: Protein analysis data for Common House Cricket (*Acheta domesticus)* and common high protein sources (dry matter) 2
Table 2: Nutritional profile of Common House Cricket (*A. domesticus*) by dry weight. 3
Table 3: Cricket Body parts, Adaptations and Functions 4
Table 4: Comparison of *Acheta domesticus, Gryllus bimaculatus* and *Scapsipedus icipe* 1
Table 5: Different types of cricket Houses 12
Table 6: Materials and Equipment in a Cricket Rearing house 17
Table 7 : Nutritional composition of crickets fed on different feed types 27
Table 8: Gross margin analysis of a pen system in the first year of investment 53
Table 9: Gross margin analysis of bucket system per year 54
Table 10: Projected income statement of a pen system in 4 years 55
Table 11: Projected income statement of bucket system per year 55

LIST OF FIGURES

Figure 1: Anatomy of a cricket 4
Figure 2: Cricket life cycle 1
Figure 3: Gut structure of a cricket 4
Figure 4: A moulted cricket 6
Figure 5: A female cricket mounting a male cricket 7
Figure 6:A male cricket inserting the spermatophore into the female genitalia 8
Figure 7: A female cricket eating the spermatophylax 8
Figure 8: Male crickets fighting 10
Figure 9: Freshly laid eggs on sterilised forest soil 21
Figure 10: A covered laying substrate 22
Figure 11: How to fill a laying container with sterilised forest soil 22
Figure 12: How to place cotton wool for laying 23
Figure 13: Examples of egg laying containers 24
Figure 14: Well labelled egg collection containers 24
Figure 15: A moist blanket used as drinking substrate for pinheads 26
Figure 16: Waterer for adult crickets 26
Figure 17: Leaves that can be fed to crickets; (a) Pumpkin leaves, (b) Sweet potato leaves, (c) Amaranth leaves, (d) Kales (e) *Moringa oleifera* leaves, (f) Wandering jew (*Commelina bangelensis*), (g) Jute (*Corchorus olitorius*), (h) Cassava leaves (i) *Calliandra calothyrsus* 29
Figure 18: Examples of hide-outs that a farmer can use; (a) egg trays, (b) custom made hide out, (c) inside of tissue rolls and (d) improvised carton made hide-outs. 30
Figure 19: Spider invasion 31
Figure 20: Pictorial representation of the inside of a pen 32
Figure 21: A fully arranged pen 33
Figure 22: Examples of plastic rearing containers. (a) A 100L buckets with perforated lids on, (b) A 100L buckets without lids, (c) Crates stacked upwards, (d) Large basins, (e) Perspex box. 34
Figure 23: A rodent 48
Figure 24: Examples of black ants 49
Figure 25: The probable cricket value chain 51
Figure 26: A plate of fried cricket 52

ACKNOWLEDGEMENT

This manual was conceptualized from the knowledge and experiences gained from the cricket rearing project at Jaramogi Oginga Odinga University of Science and Technology (JOOUST) and International Centre for Insect Physiology and Ecology (ICIPE).

The generous financial support provided by DANIDA, through the 'GREEiNSECT' 'Flying Food'and ICCO to implement the cricket rearing project and which has subsequently enabled the development of this manual is highly appreciated.

Special thanks to Prof. Monica Ayieko, the PI in both projects for her invaluable knowledge, guidance and input.

Particular thanks to Prof. Reuben Mosi, and Prof. Fred Amimo for their valuable technical input and professional guidance.

We are very grateful to the late Mr. Lamech Okeyo and Ms. Carolyne Kipkoech for their kind contribution to the editing of this manual.

Lastly, sincere thanks to our respective families.

FOREWORD

Food insecurity concerns continue to occupy the global discourse on agriculture. More so, the access to nutritious animal protein sources presents many challenges. Domestication and mass production of insects may just be the antidote that could provide a sustainable, cost effective and high-quality alternative source of dietary protein. This manual presents a guideline for appropriate technology for scaled-up insect farming.

The manual outlines, explains and demonstrates cricket rearing in a way that is easily understood. This manual has also chattered into a new territory and therefore is a welcome contribution to the body of knowledge in mini-livestock farming.

The authors have drawn on their experiences in cricket rearing within the GREEiNSECT and Flying Food projects. They have ably combined their varied experiences to give trainers and farmers the required practical guideline on cricket rearing.

It is our hope that the handbook will generate interest in cricket rearing. We also hope that the authors will update the manual regularly with feedback from farmers and emerging issues.

The handbook is a useful capacity building tool for cricket farmers and, therefore, we highly recommend it.

Prof. Reuben O. Mosi
School of Agricultural and Food Sciences
Jaramogi Oginga Odinga University of Science and Technology

Prof. Fred Amimo
School of Health Sciences
Jaramogi Oginga Odinga University of Science and Technology

2017

PREFACE

This manual provides a clear and elaborate guide on how to rear three species of crickets; *Acheta domesticus*, *Gryllus bimaculatus* and *Scapsipedus icipe*. It focuses on modern rearing or domestication of crickets particularly for food and targets trainers, field workers and farmers. Further, it attempts to upgrade and refine the knowledge of trainers such that the appropriate know-how is transferred to farmers. It is our hope that the manual will improve cricket rearing and spur interest in its farming in Kenya.

The organization of the material in this manual is in the chapter format. In chapter one, the view of a cricket as a delicacy and one with the potential to address the chronic food insecurity experienced in Kenya and beyond, is explored. Further, the chapter also highlights the behaviour and life cycle of crickets.

Chapter two and three give insights into cricket housing and rearing equipment. Different aspects of feeding and laying substrates are explored.

Chapter four deals with farm set up, taking into account the rearing systems and production methods while chapter five focuses on crickets as a living organism that are prone to threats like diseases and predators. It also explores the possible management or prevention measures.

Chapter six explores the innovative edible cricket products and business enterprises that can be developed from the cricket value chain.

While implementing suggestions contained in this manual, we encourage trainers and farmers to also be creative and use locally available materials to cut down on rearing costs. We are also open to new ideas which can be used to improve the manual in future.

Mary A. Orinda
Jackline A. Oloo
Magara J.O. Henlay

CHAPTER ONE

1.1 Introduction

All over the world, there is extensive folklore and tradition associated with crickets. In Brazil, a black cricket in a room is said to foretell illness; a gray one, money; and a green one, hope while chirping is sometimes interpreted as a sign of imminent rain, a financial bonanza, pregnancy, or death. During the Spanish conquest of America, the sudden chirping of a cricket heralded the sighting of new land. The Chinese have practised cricket fighting as a sport for a long time. The Cherokee Indians believed that drinking tea made of crickets would make one a good singer. In Zambia, cricket is believed to bring good fortune to anyone who sees it. Among the Luos of Kenya it is believed that eating crickets improves one's singing prowess.

Crickets are known as *nyenje* in Kiswahili. In Luo language, they are referred to as *Onjiri.* Other local names include *ngiriama* in Meru, *Egesiriri* in Kisii, *Sitsilili* in Luhya, *Ngiria* in Kikuyu and *Ngili* in Kamba.

A part from the traditional folklores and the cultural connotations, different cricket species have been a delicacy in many cultures and from the biblical times. In Leviticus 11:22, it is said that God allowed the Israelites to eat crickets. Research done by FAO (2013), showed that crickets are among the most popular insects eaten around the world. Extensive eating of crickets has been practised in Asian countries like Thailand and PDR Lao but this is changing as several people all over the world are now embracing the practice.

In the past, crickets have widely been procured through collection from the wild. However, given the burgeoning interest in cricket rearing and the need for sustainable production, there is a need to domesticate these crickets. Farming crickets for food is a relatively new concept in Kenya though large-scale production systems are being developed in Thailand. Given that farming of crickets is ecologically, economically and nutritionally beneficial, there is need for a systematic and sustainable production.

1.2 Why cricket farming?

- They are adaptable to mass rearing.
- Crickets multiply faster and form big populations, thus enhancing food production and security.
- Emit low levels of greenhouse gases.
- Poses less risk of zoonotic diseases.
- Production and rearing do not require sophisticated machinery, equipment or inputs i.e cost of production is less compared to other livestock enterprises.

- Farming of crickets helps in mitigating the effects of climate change and building of farmers' resilience since it is not directly affected by the poor weather conditions which affect other agricultural enterprises.
- Have high feed conversion ratios i.e. cricket efficiency of conversion of ingested food (ECI) is twice as efficient as pigs and broiler chickens, four times greater than that of sheep and six times higher than a steer.
- Constitute quality food and feed; - contain more protein, fat, and carbohydrates than the same measure of beef or fish; and have higher energy value than soybeans, maize.
- They are believed to have medicinal value by some communities.
- Cricket farming helps in reducing pesticide use. Collection of edible crickets considered as pests can contribute to reduced use of insecticides thereby helping in controlling environmental pollution.
- In some instances, they can be raised as pets.

Table 1: Protein analysis data for Common House Cricket (*Acheta domesticus)* and common high protein sources (dry matter)

Protein sources	**Crude Protein (%)**
Cricket (*Acheta domesticus*)	66.6
Beef	17.37
Pork	15.41
Chicken	17.44
Salmon	19.84
Milk	3.28

USDA National Nutrient Database, 2015

Table 2: Nutritional profile of Common House Cricket (*A. domesticus*) by dry weight.

Parameters	Van Huis & Tomberlin, 2017	Ayieko et al., 2016
Protein	67%	47.1%
Ash	4%	3.8%
Fat	22%	25.8%
Calcium (mg/100g)	132	3,147.7
Phosphorous (mg/100g)	957	331.3
Magnesium (mg/100g)	109	58.7
Sodium (mg/100g)	435	8,502.3
Potassium (mg/100g)	1,127	9,797.5
Iron (mg/100g)	6.27	51.8
Zinc (mg/100g)	21.8	21.97
Copper (mg/100g)	2.01	29.4

1.3 Cricket Biology

1.3.1 Cricket

Crickets are cold blooded nocturnal insects of the order *Orthoptera* and fall in the family of *Gryllidae* (true crickets). They live in moist or damp places under logs or rocks. They are omnivorous scavengers that feed on both animal and plant matter. Occasionally they exhibit or display predatory behaviour upon the crippled or weak crickets or when food source is irregular. Crickets reproduce asexually and lay eggs in a moist medium.

1.3.2 Cricket Anatomy

The body of a cricket is divided into three segments: the head, thorax and abdomen (Fig.1). An adult cricket is about 2-3cm in body length and weighs approximately 1 gram. Table 3 details cricket body parts, their adaptations and functions.

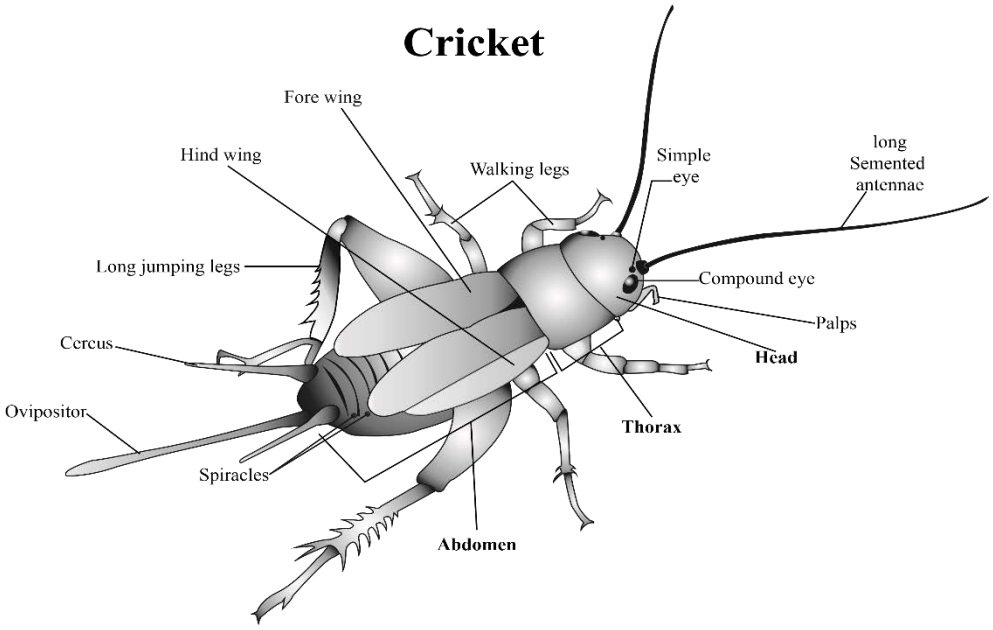


Figure 1: Anatomy of a cricket

Orinda M.A, 2018

Table 3: Cricket Body parts, Adaptations and Functions

Body Part	Description	Adaptation & Function
Antennae	A pair of flexible sensitive organs on the heads of the insect.	Sensory organs Used in smelling, tasting and touching
Compound & Simple eye	Compound eye has several lenses while simple eye (ocelli) has only one lens.	Light detection. Used for seeing.
Palps	A pair of sensory appendages rising from the mouthpart of the cricket	Used as organ of sense and feeding
Fore legs	Two pairs of short legs found on the thorax of the cricket.	Short & has tympanic membranes below the middle joint of each front leg. Used for crawling and hearing.
Wings (Fore & hind wings)	Fore wings are smaller, stiff and leathery while hind wings are bigger, membranous and folds under the forewing.	They have ridges that produce sound (chirping) when rubbed together. They aid in flight and also protects the body.

Spiracles	These are openings on the abdomen.	Have opening and closing muscles which helps in gaseous exchange.
Hind legs	A pair of long jointed legs found on the abdomen of the cricket.	Long and jointed to help in jumping when escaping predators. The long femur and tibia give the crickets a 'pole-vaulting' advantage pushing it forward when jumping.
Cercus	Paired sensory appendages at the posterior of the abdomen	They have tactile hairs which act as receptors. Detect a range of vibrations in the air and substrate. Acts as sound and vibration receptors which help in escape mechanism. It also acts as pinching organ during mating.
Ovipositor	Appendage located at the posterior end of female cricket	It is long and needle-like for ease of insertion into the laying medium. It is used for depositing eggs into the laying medium.

Comparison of salient features between *A. domesticus, G. bimaculatus* and *Scapsipedus icipe* is represented in Table 4.

Table 4: Comparison of *Acheta domesticus, Gryllus bimaculatus* and *Scapsipedus icipe*

Acheta domesticus	***Gryllus bimaculatus***	***Scapsipedus icipe***
  Female Male	  Female Male	  Female Male
It is also called European or Common House cricket because it prefers houses when it is cold. It is believed to have originated from South Western Asia and spread throughout the world through cargo transport.	It is also called Black Field cricket or African/Mediterranean field cricket.	It is also called African House Cricket. It originated from the Kenya and has spread to many other African countries.
Brown or grey in colour.	Black in colour but sometimes adapts the colour of the habitat.	Brown in colour but sometimes adapts the colour of the diet with an abdomen which is black dorsally with yellow spots, yellow ventrally.

Female is brown with smooth wings and an ovipositor at its rear while the male has a rough burnt like wing that extends to its rear.	Female is black with two yellow spots on forewings on the upper back while the male is distinctly black or yellow depending with the on diet and temperature.	Both male and female are brown with a black head moderately but distinctly widened below the eyes; black with a distinct yellow band between the eyes. The forewings not reaching the end of abdomen; dark, with a lighter area around harp in males.
Grows up to 2-3cm in length at adult stage.	Grows up to 3-4cm in length at adult stage.	Grows up to 1-2.5cm in length at adult stage.
		Weighs up to 1g in adult stage
Weighs up to 1g in adult stage	Weighs up to 2g in adult stage	
Smaller in size compared to *G. bimaculatus.*	Bigger in size compared to *A. domesticus.*	Large in size compared to other *Scapsipedus species*
Takes between 8-12 weeks to reach maturity.	Takes between 6-8 weeks to reach maturity.	Takes between 7-8 weeks to reach maturity depending on diet and temperature.
Highly mobile.	Slower and less jumpy.	Highly mobile.
Greatly palatable.	Less palatable due to thick chitin.	Highly palatable.
Highly appealing to consumers because of its brown colour	Less appealing to consumers because of its black colour	Highly appealing to consumers because of its brown colour

1.3.3 Cricket Life Cycle

There are many different species of cricket but each undergoes the same three key life cycle stages: egg, nymph and adult (Fig. 2). The time to complete each stage varies slightly according to species. Crickets go through incomplete metamorphosis, meaning they do not enter into a pupal stage, but hatch from the egg looking like adult crickets except for the wings. There are seven to ten moults (instars) depending with the cricket species. After each moult, the crickets almost double in size.

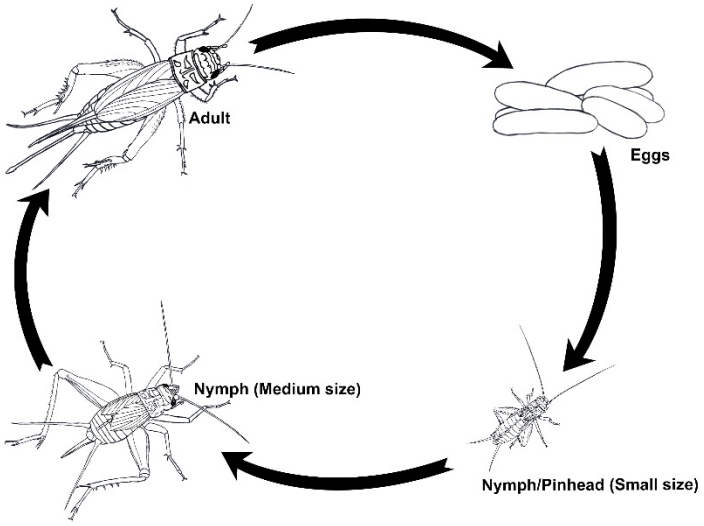


Figure 2: Cricket life cycle

Eggs

The female cricket deposits eggs into a moist medium, usually about half an inch deep using a special organ known as an "ovipositor" on its rear. A female cricket can lay up to 200 eggs at a time. A cricket egg is pale yellow and cylindrical in shape measuring about 2-3mm in length. The female cricket stores sperms from different males in her body and chooses the one to fertilize each egg as it passes through the seminal receptacle. The eggs hatch in about 6-14 days but this will depend with the temperature and cricket species. At temperatures of between 28-35°C, the eggs hatch between one and two weeks. At low temperature eggs take a longer period to hatch, 20-21 days at 25°C and 76 days at 15°C. An egg that is about to hatch has a black dot on one side.

Nymphs

Nymph crickets are very small when they first emerge from their eggs, measuring only about 1/8 inch (2mm) in length. The nymphs are also known as pinheads because they measure

approximately the size of the head of the pin. Cricket nymphs commonly become prey for larger crickets. Though the cricket nymphs appear like adult crickets in many ways, they are not as developed. The female nymphs do not have an ovipositor for egg-laying, and neither the male nor the female nymphs have a developed set of wings. The nymphs (pinheads) start nibbling at 14 days (two weeks) after hatching. Their metabolic system starts to function at this age, however, prior to this they can depend majorly on the nutrients from the egg. The nymphs go through between seven to ten instars before reaching adulthood depending on species, diet, humidity and temperature. At low temperatures the cricket nymphs undergo more moultings while at high temperatures the moultings are a few. Crickets start to develop wings at about 1 month of age.

Adults

Adult crickets are identified by distinctively fully developed wings and usually measure about 2-3cm in length. Their bodies have three distinct segments: the head, the thorax and the abdomen. They also have three pairs of legs and two antennae. In most species of cricket, the adults have wings. Adult crickets can jump up to 60cm above the ground. Male crickets tend to emerge beforehand in order to facilitate mating (protandry). Female crickets are usually bigger, approximately 15-25% bigger than males because:

- They accumulate more food for egg production.
- They have a longer development time and, in many cases, extra instar.

Did You Know?

- Newly laid and viable eggs are yellowish, firm and not flaccid 2mm long.
- Pinheads are really very small crickets of 1 to 5 weeks old.
- At pinhead stage, crickets do not have developed reproductive organs and therefore all look like male crickets without wings.
- The stages of growth of a cricket can be summarized into:
    - Pinheads (2-3mm long)
    - Small crickets (up to 10mm body length)
    - Medium crickets (10 to 20mm body length)
    - Large (Adult) (20-30mm body length)
- Cricket adult size is determined by:
    - Temperature
    - Type of diet.

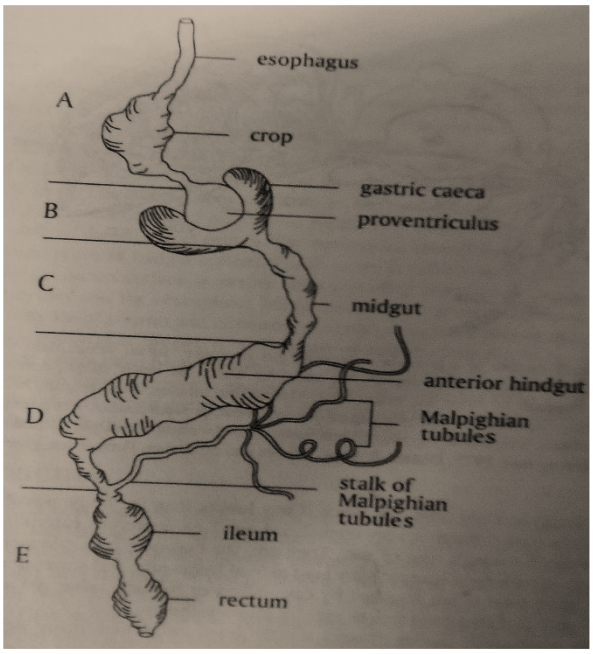
- Humidity
- Underlying genetic variation(species of of cricket).
- Level of crowding

- Transition into adulthood takes between 3-10 days within a penultimate colony.
- Higher temperature above the threshold (>35°C), leads to faster moultings and therefore smaller crickets and shorter lifespan. It further encourages cannibalism/predation on weak ones as a source of water (behavioral way of cooling the body).
- Temperature, humidity and feed determines how many crickets turn into males or females in the long run. At high temperatures, most crickets will be males. High temperatures inhibit production of aromatase enzyme responsible for conversion of sex hormones i.e androgen (male hormones) to oestrogen (female hormones).
- An instar is the different growth stages the nymph cricket undergoes before reaching adulthood.
- In low temperature conditions, crickets tend to have more instars.
- Every moult moves the cricket to a new instar.
- Male crickets emerge first before females.
- Female crickets are bigger due to their reproductive responsibility.

1.3.4 Digestion in Crickets

Digestion is the process of breaking down feed in the digestive tract and assimilation of nutrients. The digestive system of a cricket is divided into foregut (pharynx, oesophagus, crop), midgut and hindgut (ileum, colon, rectum, anus). Crickets respond to food through biting using mandibles. Prior to biting, crickets taste their food with chemical sensors on their mouth parts. Their mouths are made of the labrum, labium, maxillae, and mandibles. The labrum, or upper lip covers and protects the subsequent mouth parts. The rest of the mouth parts support the mandibles in their purpose of chewing. When food is swallowed, it enters into the cricket's monogastric digestive system. Food will go through the pharynx, down the oesophagus, into the crop where the food is stored and hydrolysis occurs. Digestion in crickets occurs in the crop but most enzymes, with the exception of salivary enzyme are secreted from the midgut which are present in fluid that is regurgitated from the midgut into the crop. As the food moves, the crop becomes the proventricular whose interior walls contain tiny cuticular teeth which function as a grinding organ and in combination with the secreted enzymes breaks down food into smaller particles. The food moves into the intestines, colon, and finally the rectum. Most of the absorption of the nutrients occur at the anterior end of the midgut as the digested food

enters from the crop. Once food reaches the rectum, it is dehydrated and faecal pellets are formed. The rectum can retain 90% of the water in the faecal matter, an adaptation that allows the cricket to live in even dry areas.



A - Foregut
B - Two large gastric caeca
C - Midgut
D - Hindgut
E - Posterior hindgut

Figure 3: Gut structure of a cricket

Adapted from Nation, 2002

Did You Know?

- Crickets are monogastric (have one stomach).
- Crickets are poor at digesting fibre (lignin, cellulose and hemicellulose) rich food.
- Too much protein is toxic to adult crickets as they use a lot of energy to excrete them in form of uric acid.
- Crickets require a diet with 16-30% protein content.

1.4 Cricket Behaviour

1.4.1 Chirping in Crickets

The sound made by male crickets is called chirping**.** Chirping of the crickets is also called stridulation. The sound is emitted by the stridulatory organ located on the forewings. The chirping sound is produced when the crickets rub their wings together. The forewings have ridges which are shaped like a scraper and file that produces the chirping sound when rubbed fast against each other. As the male cricket does this, the wings are held up and open, so that the wing membranes can act as acoustical sails. Male chirps serve the following purposes during mating and fighting:

- **Calling:** attracts females and repels other males and is fairly loud.

- **Courtship:** the courting song is used when a female cricket is near prior to mating and is a very quiet song. Courtship song is a requirement for normal inducement of female mounting and subsequent sperm transfer.
- **Aggression**: an aggressive song is triggered by chemoreceptors on the antennae that detect the near presence of another male cricket. Male crickets fight over mating territory (Fig. 4).
- **Copulation**: a copulatory song is produced for a brief period after a successful mating. This is to still scare away predatory males from removing the spermatophore from the female genitalia.
- **Inhibits** an opponent's tendency to attack if it is sung aggressively in the middle of the fight.
- Aggressive songs at the end of a fight, may function as **advertisement displays** to other crickets.

Rate of cricket chirps depend on the cricket species and temperatures. Crickets chirp more when it is warm but the rate depends on the species. Chirping sound is species-specific allowing females to reliably identify males.

Chirping of the crickets may also attract predators such as snakes, rodents, and notorious parasitic tachinid fly *Ormia ochracea* which is attracted to the song of the male cricket, and uses it to locate the male in order to deposit her larvae on him.

Did You Know?

- Only adult male crickets chirp.
- The chirping sound is species-specific.
- Chirping is a sign that male crickets are ready to mate. Provide egg laying containers in cages where crickets have started to chirp to enable fertilised female crickets to lay their eggs.
- Chirping purposes are; aggression-for marking territory (male-male fights), calling songs-for attracting females during mating season and courtship- used prior to mating once a female has located the male.
- Chirping sound is produced by the forewings.
- Calling (chirping) is energetically expensive as a result; males are smaller in size than the females.
- Chirping rate or frequency is affected by temperatures.

- Chirping attracts predators and as such a farmer should ensure that all openings that might aid entry of predators are sealed.

1.4.2 Moulting in Crickets

This is the process of shedding off the external skeleton by immature crickets. It is also referred to as ecydysis. As the nymphs grow the exoskeleton gradually becomes too small for the growing body tissues of an immature cricket and is shed off. The process of sloughing off the exoskeleton starts from the head and moves towards the abdomen. The insect inhales a lot of air or takes in a lot of water to increase the body size. As the water or air passes through the body, the outer skin sloughs off.

A freshly moulted cricket is whitish in colour (Fig.5). It is a vulnerable time for the moulted crickets because they are:

- easy prey for predators (even fellow crickets) and
- subject to environmental hazards e.g. desiccation. The new cuticle must harden quickly to resist the muscle action that can cause skeletal deformation and result in permanent restriction of movement.

Moulting consumes a lot of nutrients and energy and as such most crickets rest quietly for some minutes even hours. The crickets remain immobile to recover lost energy and also to wait for the exoskeleton to harden.

Figure 4: A moulted cricket

Did You Know?

- A freshy moulted cricket should not be disturbed or touched as the skin is soft and sensitive.
- Moulting is an energy and nutrient costing process.
- A lot of activities are reduced during moulting process as most energy is channelled towards moulting.

- Crickets compensate for the loss of energy and nutrient by reabsorbing and consuming the internal layers of the old layer of cuticle before moulting.
- A moulted cricket will have to eat a lot to replenish the lost energy during moulting. Feed them on a balanced diet and clean water to aid in the process of replenishment.

1.4.3 Mating in Crickets

Once they reach reproductive age, female crickets are able to mate with more than one male during their lifecycle. This habit of mating with more than one male is termed as polyandry. Polyandry has both material and genetic benefits to the cricket. Material benefits such as replenishment of sperm supplies, reduced sexual harassment and acquisition of resources from males (nuptial gifts) directly enhance female fitness while genetic benefits such as production of genetically diverse, high quality off-springs with higher viability and sexual attractiveness, indirectly enhance fitness through the cricket's generations.

Mate selection depends on the male size and chirping type. Female crickets prefer bigger males because they produce larger spermatophore which increases fecundity.

The process of mating starts with the male calling for the females. After the female has located the male, she turns and faces the male and the process of courtship starts which ends with mating. Courting males produce pheromones and vibrations. The males raise their front wings above the abdomen and burst into courtship chirps. The male then turns away from the female and backs up, pushing his body beneath hers. Mating process consist of the female mounting the male (Fig. 6).

Figure 5: A female cricket mounting a male cricket

Source: https://www.flickr.com

Females typically approach males from the rear. The most receptive females mount quickly and begin feeding on secretions from a metathoracic gland near the top of the male's thorax. If the female does not mount, males continue periodic courtship song and vibrations, occasionally turning to face the female, and again facing away and pushing back.

Copulation occurs when the male reaches back with his abdomen and the female bends her abdomen downward to link the genitalia. Copulation lasts only a few seconds, during which the male threads the tube of a small spermatophore into the female's genitalia (Fig.7). The spermatophore contains spermatophylax which surrounds the ampulla containing sperms.

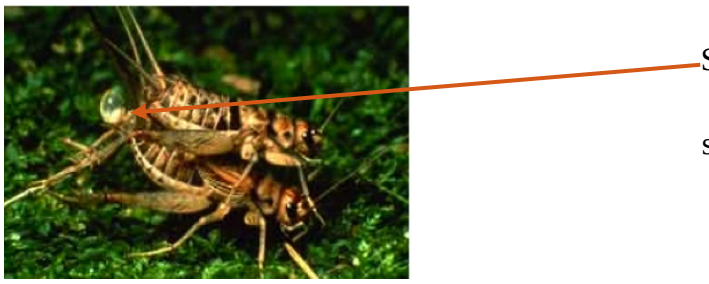


Figure 6:A male cricket inserting the spermatophore into the female genitalia

Source: https://www.flickr.com

Immediately the female dismounts the male, she separates the spermatophylax from the sperm ampulla with the mandibles and consumes it (Fig.8). As the cricket eats the spermatophylax (nuptial gift), the sperms are ejaculated into her reproductive tract and then stored in the seminal receptacle. The period taken by the female to consume the spermatophylax depends on the size of the spermatophore. The bigger the spermatophore the better.

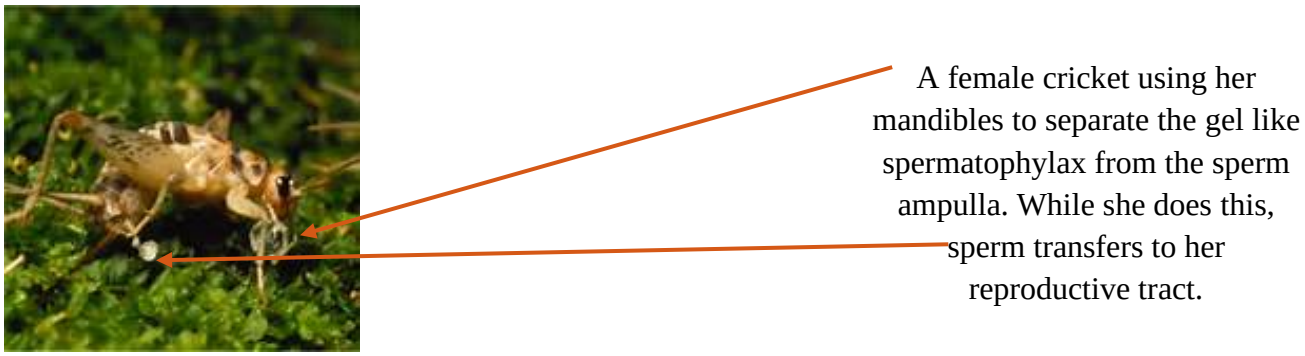


Figure 7: A female cricket eating the spermatophylax

Source: https://www.flickr.com

Did You Know?

- Mating activity begins within a day of maturation usually 24-72 hours after maturation.
- Larger males are preferred by females because size is associated with fecundity, genetic quality (superiority) and sexual attractiveness due to competitive ability.
- Male crickets use pheromones to locate female crickets.
- Males fight over calling sites so provide enough hideouts for territorial marking and mating.
- Males give nuptial gifts during mating to ensure complete transfer once copulation has commenced.
- Mating is an energy and nutrient costing process. A male can lose up to 22% of his body weight through the nuptial gift. Feed the crickets on a balanced diet.
- Females exert control over sperm transfer and usage.
- Female crickets can still discard spermatophylax even after ejaculation if the amino acid composition is not balanced.
- The spermatophore provides the female with the ejaculate and food source.

1.4.4 Fighting in Crickets

This is an aggressive conflict between crickets over resources. These fights usually occur between male crickets and is more pronounced in the presence of female crickets which is a valuable resource. Though, female crickets do fight occasionally over food, only when scarce, this rare occurrence is less aggressive and hardly proceeds to head butting stage. Most male crickets fight over:

- Sex mates to enhance reproductive success of their species or generation. The higher the number of copulations, the higher the chances of one's sperms being chosen for egg fertilization.
- Territories and space: male crickets have territories from which they call or attract females. Due to this, they will always be aggressive and defensive of these hiding spaces or territories against intruding males.
- Food: crickets grapple less with each other and rely more heavily on behaviour such as kicking and biting, which allow them to repel competitors and still remain close to the contested food.

Fighting in crickets follows a process and depends on the level of aggression. This can be briefly explained as:

- Antennation: This is the first stage in fighting whereby the crickets lash out at each other using their antennae and then raise their bodies off the ground. This is used in sex and species recognition.
- Juddering: This involves a rapid rocking back and forth of the body kicking with the hind legs, and shaking of the body.
- Aggressive stridulation: Chirping to inhibit more attacks.
- Flaring of the mandibles and biting.
- Wrestling which involves rushing forward, scuffling with forelegs and butting with the heads. A weaker male is sometimes flipped back or thrown sideways. This continues until one male finally retreats.

These fights are energetically costly and as such a farmer should ensure that there are enough territories and food for the crickets.

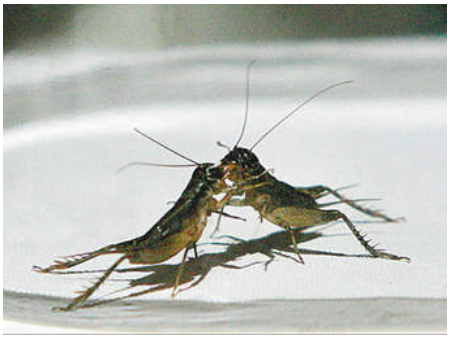


Figure 8: Male crickets fighting

Source: http://www.vocativ.com/world/china/photos-cricket-fighting-ufc-insect-world/

Did You Know?

- Fighting is costly in terms of energy consumption thus should be minimized as much as possible.
- Provide enough hide outs to reduce territorial fights.
- Broken and or bent antennae and wings are some of the signs of frequent fights.

CHAPTER TWO

2.1.Getting Started: Input/Materials needed

2.2.Rearing House

Housing is one of the important components of sustainable cricket production. A suitable house should address critical issues like favourable temperature and humidity to ensure reliability and cost-effectiveness of production. Examples of housing types that a farmer can use are many and not limited to mud house, brick house tunnel unit, wooden house and iron sheet house, *mabati*, that are listed in Table 5.

The choice of type of housing depends on:

- **Affordability** in terms of the cost of materials.
- **Space availability** which influences the choice of the caging system to use. A good house should have enough space to enable the farmer move freely while working and also house the rearing containers.
- Maintenance of **favourable conditions** in terms of temperature & relative humidity (RH%). A good house should be able to maintain temperature range of between 28-35°C and relative humidity of 60-65%.
- **Safety and security:** The house should be away from insecticide sprayed fields, free from predators and away from flood prone areas.
- **Convenience** in terms of accessibility by the farmer and proximity to source of feed such as vegetable fields.

NB: A farmer should strive to use locally available materials in constructing a cricket house to cut down on cost.

Table 5: Different types of cricket Houses

Housing Type	Applicability/Suitability
1. Wooden House 	**Advantages** • Can keep warmth. • Relatively affordable. • Easy to maintain. • Suitable for small scale faming of crickets. **Disadvantages** • The spaces between the jointed woods can hide vermins like spiders, geckos, lizards and snakes. Inside walls can be lined with cardboard or plywood. • Prone to termite attacks. • Easily affected by weather conditions (rot easily) • Wood deteriorates with time. • Wall and roof need regular cleaning to keep away predators like spiders. • Wood is an expensive building material • Cutting down trees for building leads to environmental degradation unless you use certified wood.
2. Iron sheet house 	**Advantages** • Relatively affordable. • Fairly durable. • Easy to maintain. • Easy to clean **Disadvantages** • Can hide predators. • Can get very hot during the day and very cold at night. A farmer may lose a lot of pinheads during the dry season when

	temperatures are high. Use hardboard, cartons and egg trays on the roof to act as a ceiling. These will absorb heat during the day which will be required at night when it is very cold. • Farmers in cold regions run loses on maintenance and heating costs as crickets grow slowly. • Wall and roof need regular cleaning to keep away predators like spiders. • Iron sheets can cut the farmer during cleaning and care must be taken.
3. Mud house 	**Advantages** • Retains warmth. • Affordable. • Mud mixed with cow-dung act as snake repellant. • Suitable for small scale faming of crickets. • Easy to maintain. **Disadvantages** • Less durable-mud deteriorates. • Can harbour vermins that attack crickets. • Are labourious since wall and roof need regular cleaning to keep away predators like spiders. • Easily affected by too much rains especially in waterlogged areas.

4. Tunnel house 	Roofing is made of polythene material while the sides is made of insect net. **Advantages** • Relatively durable • Relatively secure • Wall and roof do not need regular cleaning. • Are good in keeping off vermins that attack crickets e.g. spiders, snakes, flies, lizards and geckos • Is suitable for large scale farming of crickets. • Economy of scale is relatively high. • Requires less labour in cleaning it. **Disadvantages** • Can get very hot during the day and very cold at night. • Expensive. • Requires large space.
5. Prefabricated house 	The house is made of iron sheets and netting materials on the sides. **Advantages** • Relatively affordable. • Relatively durable. • It is well aerated. • Suitable for small to medium scale faming of crickets

	Disadvantages • Can harbour predators. • The netting material wears off with time. • The netting can be destroyed easily by the rat
6. Permanent house 	The house is made of bricks, sand and cement and glass walls **Advantages** • It is durable. • Suitable for large scale farming of crickets. • Economy of scale is high. • It is well aerated. **Disadvantages** • Starting capital is high. • Can harbour predators/vermins. • The flour can be too cold • It is labour intensive • Requires large space

2.2.1 General Management Practices in the Cricket House

A farmer should at all time:

- Keep predators away.
- Cover all openings with a netting material or wire mesh where applicable.
- Keep the cricket house clean.
- Don’t leave leftover feed or dead crickets lying around as they attract predators.
- Ensure the house is well ventilated.

- Ensure the temperature is maitained 30°C by supplying a heater for faster growth and high survivorship of crickets.
- Ensure the crickets are not overcrowded to avoid cannibalism and egg eating.
- Do the cleaning in the morning when crickets are less agile.
- Keep a foot bath on the door way to deter introduction of germs and disease causing bacteria.
- Provide the crickets with food and water *adlibitum.*
- Change the food after two days to prevent the crickets from being poisoned by rotten food.
- Incase crickets are supplied with water in cottonwool balls, the balls must be changed after two days to prevent mites from hatching in these balls which may attack cricket eggs.
- The farmers should avoid spraying themselves with perfumes when getting into the cricket house. Perfumes kill crickets.Avoid sugar and coffee beverages in the cricket room as they will attract sugar ants which can in return feed on crickets.
- Avoid soapy water in cricket. The soapy water kills the crickets.
- While in the handling the crickets, the farmer must wear protective clothing.

2.2.2 Siting of a cricket house

A cricket house should:

- Be a safe distance from the main house due to the (noise) chirping of the cricket and for security purposes.
- Be on well drained ground and or a raised ground, away from flood prone areas.
- Not be in a bushy area because of predators.
- Doors and windows should face East-West direction to raise the needed temperature in cooler areas but in hotter areas these windows and doors should face away from direct sunlight.
- Ventilation should not face the wind directly.

2.3.Materials and Equipment

Basic equipment required in a cricket house are shown in Table 5.

Table 6: Materials and Equipment in a Cricket Rearing house

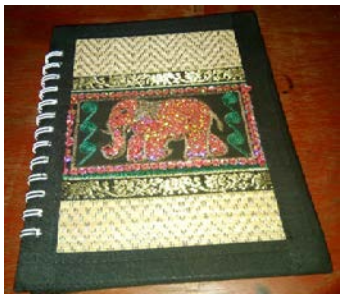
<table>
<tr>
<td>1. Hand Sprayer

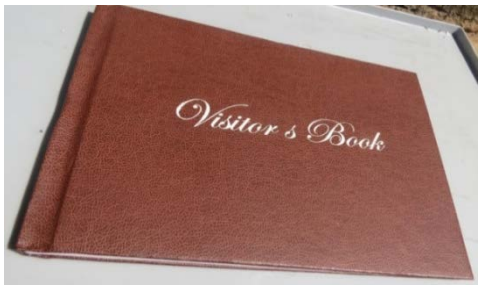
  It is useful in controlling the amount of water sprayed on the laying and drinking substrates. Spraying using a hand sprayer ensures that just the right amount of water goes into moistening the substrate.</td>
<td>2. Petri-dishes & Plates

  
They are useful as flat holding trays for feed and water inside the rearing container.</td>
</tr>
<tr>
<td>3. Masking and Cello tapes

  
They are used for labelling purposes.</td>
<td>4. Broom

 
For daily cleaning of the floor and walls of the cricket house.</td>
</tr>
<tr>
<td>5. Note Book

 
For recording all the observations and activities in the farm, purchase and usage of inputs.</td>
<td>6. Visitor’s Book

For recording the contact addresses of people visiting the farm. Remarks and reason for visiting</td>
</tr>
</table>

	the farm is very important as these might be source of new ideas, markets and inspiration.
7. Thermometer & Data logger   They used to record daily temperature & relative humidity readings.	8. Marker and Biro pens  They are for writing down all the activities and observations in the farm. Marker pens help in recording egg collection, hatching and laying dates.
10. Dust coats  Used as a protective cloth while working in the cricket house.	11. Drinking & Laying Substrate   Cotton wool Sterilised forest soil Cotton wool can be used as a laying and or drinking substrate.
12. A jiko/ Automatic heater  	13. Fan 

Used to warm the cricket house when temperature is low.	Used to cool the cricket house when temperatures are too high.

Did You Know?

- The materials that are used to build the cricket house have an influence on the climate in the house.
- A mud house or a brick house will warm up less faster but will keep the temperature longer.
- The type of material used depends on the financial capability of the farmer.
- A suitable house should maintain temperature for cricket rearing between 30- 35°C and humidity at 60- 65%.
- A farmer should record temperature levels in the morning, afternoon and evening to help them monitor temperature changes. Further still, a farmer can use data logger to monitor both the temperature and humidity profiles.
- When modifying an existing house to fit the climatic conditions and provide the needed temperatures; use old cartons, egg trays or unused hardboards as ceiling on the roof if you live in cold regions.
- A thick plastic sheet placed on the roof and walls may also bring the temperature to the optimum level required.
- In cold regions, a mud house with iron sheet roof is preferable. Mud acts as insulation that retains the warmth in the house.

CHAPTER THREE

3.1. Starting up a colony

Before a farmer can embark on cricket farming there are myriad of factors and variables that should be taken into account. Amongst the most important issues are type of cricket species to be reared, their social acceptability, behaviour and marketability, where to source clean eggs or starter colony and rearing materials and their suitability, feeds, production systems and methods and what cost implications he has to incur.

3.2. Species Selection

To ensure optimum and efficient production, a farmer must take into account the following characteristics of the cricket species.

- Ease of mass rearing in terms of adaptability to the local climatic conditions.
- Availability and ease of colony formation. This is very important especially in a case where a farmer wants to neutralize inbreeding.
- Produces faster i.e. shorter life cycles ensuring high production turn over/cycles. This also ensures quick or faster return on cricket investment.
- High fecundity i.e. the chosen species should be able to lay many eggs thus forming big colonies within a short duration.
- Larger biomass with high nutritional value.
- Marketability i.e. readily acceptable to consumers or palatable.
- Resilience: Less susceptible to pests and diseases.

3.3. Eggs

A prospective farmer can start a colony with eggs or mother stock. These can be obtained through:

- Getting mother stock from the wild or from a well-established farmer to lay eggs. The advantage of getting a mother stock from a well - established farmer ensures that a prospective farmer gets crickets of superior genes and disease free. However, a farmer should be careful while sourcing mother stock from the wild because the adult cricket maybe past peak laying age and carrier of diseases. It might also be very difficult to capture enough crickets to start a colony.
- Buying eggs from a well-established farmer which is the easiest way to start a colony.

When buying eggs ensure that:

- They are cream-yellow and not milkish white or black in colour. Milkish white is a sign that the eggs are rotten or not fertilized while black colour is a sign that the eggs are denatured.
- They are not flaccid.
- They are well packed in a moist medium to prevent desiccation.
- The farm does not have pests such as spider and mites or disease infestation

Figure 9: Freshly laid eggs on sterilised forest soil

3.4. Laying substrate

An egg laying medium is required for adult crickets. Female crickets lay their eggs in a moist medium 24-48 hours after mating. A farmer can use sterilised moistened forest soil, moistened fine sand, autoclaved and moistened wood shaving or cotton wool as a laying substrate.

Important considerations that a farmer should note are:

- One week after the start of chirping of crickets, a farmer is supposed to provide a laying substrate.
- The laying substrate should be moist and soft all the time to enable the cricket insert the ovipositor and also to protect the eggs from desiccation.
- Do not over water the laying medium as this will deter crickets from laying because of the fear of eggs drowning and at the same time facilitate rotting of the eggs.
- The laying substrate should be well aerated.
- The laying substrate should be able to maintain moisture.
- Sterilised laying substrate should be kept in air tight container.
- If a farmer chooses to use sand, wood shavings or soil, the substrate should be covered with a thin netting material or mesh to keep away droppings and prevent the males from eating the eggs (Fig.10).

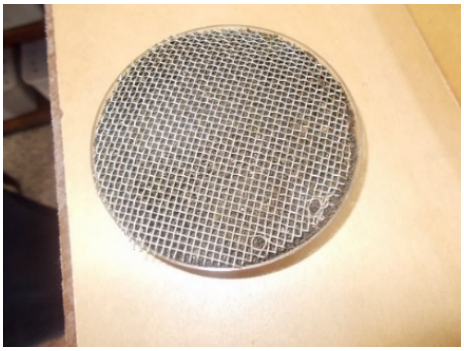


Figure 10: A covered laying substrate

3.4.1 Forest Soil as a laying substrate

Forest soil is suitable substrate for egg laying because it is easily available and holds in moisture necessary for hatching of eggs.

- Identify an area where the soil has been lying fallow for a long period of time without any agricultural activities. Preferably forests or along a live fence. Fallow land is recommended because it is free from chemicals like fertilizers and pesticides used in the agricultural land.
- Remove a small top layer, any rocks, plastic and organic matter like branches and leaves.
- Gather the soil up to 15cm (6 inches) deep and sieve to remove any stones or tree parts that might have been carried with the soil from the forest.
- Sterilize by heating the soil. Forest soil must be sterilised to:
    - Kill harmful microorganisms that might harm eggs and pinheads;
    - Kill weed and tree seeds that might germinate and;
    - Loosen the soil structure for ease of ovipositor insertion.

Sterilization is done by subjecting it to high heat in a heavy cooking pot or *sufuria* for 15 minutes while stirring continuously. Let the sterilised soil cool before it is used as an egg laying substrate.

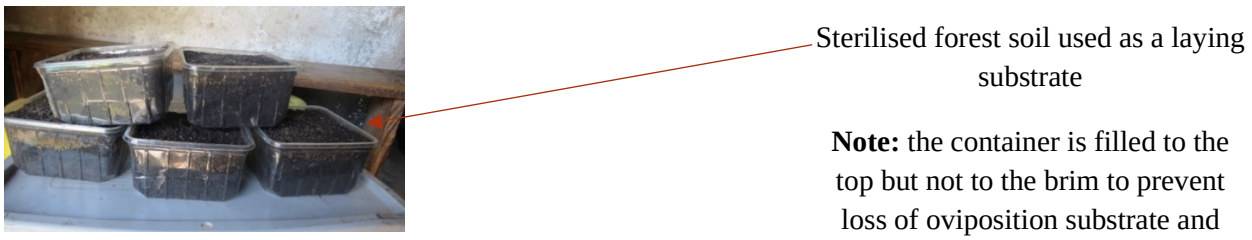


Figure 11: How to fill a laying container with sterilised forest soil.

3.4.2 River bed sand/silt as a laying substrate

These are the river deposits. When collecting sand for use as a laying substrate, ensure you collect the soft and not the coarse structured. Its suitability as a laying substrate is in its structure. The loose structure is advantageous because:

- It allows water to pass through easily.
- It makes it easy for the cricket to insert the ovipositor into the laying medium.
- It is readily available and less costly.

However, the loose structure means that it dries up very quickly posing threat to the eggs. Just like the forest soil, it should be sterilised before use.

3.4.3 Cotton wool as a laying substrate

Cotton wool as a laying medium is quite absorbent and retains moisture. However, it is expensive and might encourage bacterial and fungi growth if it is not well aerated.

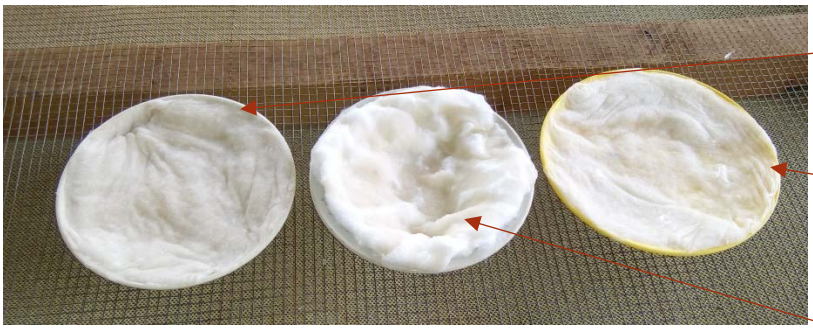


Figure 12: How to place cotton wool for laying

3.4.4 Autoclaved and moistened wood shavings

Autoclaved and Moistened wood shavings as a laying medium is quite absorbent and retains moisture. The wood shavings can be obtained from carpentry workshops. The wood shavings must be well sun dried or autoclaved to kill the mites that may attack the eggs.

3.5. Egg laying Container

An egg laying container should be dip enough to enable the crickets insert their ovipositor and lay their eggs but shallow enough to enable crickets access it. A farmer need not use costly containers. Plastic bowls and fruit packaging materials can serve as laying containers (Fig.13).


Figure 13: Examples of egg laying containers

The egg laying container should be filled with the moist laying substrate. A farmer should provide a climber to enable crickets reach the laying substrate. While moisturizing the laying substrate a farmer should note the following:

- While moistening cotton wool, no water should drip even when squeezed.
- The moistened soil should not stick together.
- The cotton wool should be 1cm thick and fluffy (Fig 12). This is to ensure that the pinheads can wriggle out as they hatch.

All the egg laying containers should be labelled (Fig. 14). Important dates that a farmer should record include:

- Date of egg laying
- Expected date of hatching
- Expected date of laying

Figure 14: Well labelled egg collection containers

Adequate laying substrate should be provided to prevent loss of both oviposition substrate and previously laid eggs by adults kicking substrate out of the container as they scramble for the laying space.

3.6. Egg Collection

This should be done as often as possible. Daily collection of eggs is advisable if uniformity in size and age is to be achieved. If a farmer has few mother stocks then, collection can be done after every three days. The collected eggs should be put separately from the mother stock and labelled accordingly. Egg collection should be done for a maximum of two weeks after which the laying stock is harvested. Uniformity in age sets is important because:

- Bigger crickets sometimes cannibalise younger ones.
- Ease of collection during harvesting as the farmer does not have to separate the adult from young ones which is quite tedious.
- There is reduced competitiveness in laying. In the presence of younger female crickets in a mixed colony, older females spend less time on the laying substrates and move to the hide-outs.

NB: The older females have dark rough, dirty wings while young females have lighter, shiny and cleaner wings.

3.7 Egg incubation

The collected eggs can be placed into incubation cages to hatch. The eggs can be incubated under same temperature under which a mother colony is being reared or placed in the incubator machines. The relative humidity recommended for high egg hatchability must maintained between 90-100%. Depending on the species of the cricket, humidity and the temperature the eggs are subjected to, the eggs will hatch from the 6^{th} -14^{th} day. For faster egg hatching, the temperature must be maintained between 30-35°C.

3.8 Water

Water is very important to caged crickets especially if they are being fed on dry food. Crickets frequently drink water but prefer to stay, under normal conditions, in a dry place. Moist cages are not only readily infested by mites and micro-organism, but also adversely affect oviposition and feeding, and generally reduce the activities of nymphs and adult crickets. The arrangement for constant water supply, therefore needs special attention.

Crickets should be provided with clean water free from chlorine and organic impurities. A watering medium should:

- Be absorbent to prevent drowning the crickets especially the pinheads.
- Not encourage bacterial and fungal growth

A farmer can use a damp blanket, mattress, hydration crystals used in tree nurseries or cotton wool placed on a petri dish or flat board for pinheads to avoid drowning (Fig.19), however, the usage of this is likely to lead to moulding. It is advisable to change the material frequently. Hydration crystals float on water preventing crickets from drowning, however, they shrink in size and require regular top up else they will stick to the container making them hard to clean.

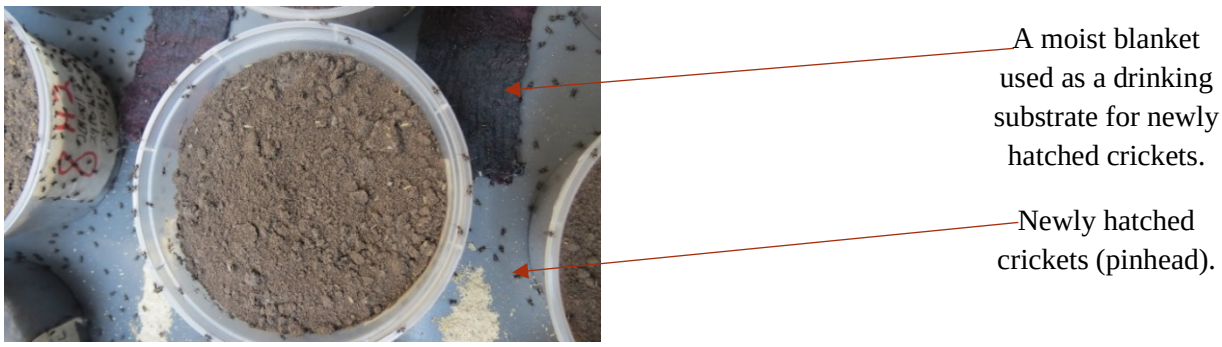


Figure 15: A moist blanket used as drinking substrate for pinheads

For adult crickets, provide water in a shallow bowl or petri dish with immersed gravel (Fig.16). This is to deter female crickets from laying on the drinking medium. The gravels provide a perching medium preventing the crickets from drowning.

Figure 16: Waterer for adult crickets

Drinking substrate should be changed more often because of the possibility of bacterial and fungal growth. The bacterial growth is further accelerated by the cricket droppings or faecal matter which get mixed with the moist medium.

When refilling the waterer, discard the old water and wash the pebbles/ gravel before reusing them.

3.9 Feeds

Crickets need to be fed on balanced diet for optimum growth. A balanced cricket diet should contain both macro nutrients (protein, lipids and carbohydrates) and micronutrients (vitamins and minerals). The feed should ensure:

- High survivability and longer lifespan i.e less mortality due to quality of the diet. Low quality diet increases crickets' vulnerability to diseases and parasites.
- High fecundity (fertility) to cater for the subsequent generations for continual production.
- Shorter development period i.e the time it takes for the crickets to reach maturity.
- Crickets of high nutritional value and larger biomass.
- Less or reduced cannibalism. Crickets fed on low quality diet will cannibalise on others to compensate for the missing nutrients.

Balanced diet is paramount because dietary composition has effects on the nutrient composition of the crickets as can be seen in Table 7. There are large variations in crude protein and fat contents across the four diets.

Table 7 : Nutritional composition of crickets fed on different feed types

Cricket Species	DM%	ASH%	FAT%	CP%	P%
Gryllus bimaculatus					
Poultry Growers' Mash	95.18	3.27	27.46	61.68	1.09
Rice bran + Spent brewer's yeast	92	4.57	14.93	70.1	1.23
Rice bran + Bloodmeal	95.99	3.5	33.44	57.49	1.26
Rice bran + Spent brewer's grain	94.59	4.43	27.4	62.11	1.36
Acheta domesticus					
Poultry Growers' Mash	94.35	3.66	29.58	62.41	1.32
Rice bran + Spent brewer's yeast	94.85	4.74	19.2	71.09	1.31
Rice bran + Bloodmeal	95.34	3.58	25.61	66.26	1.33
Rice bran + Spent brewer's grain	95.01	4.36	24.33	66.63	1.41

* DM -Dry Matter, CP – Crude Protein, P- Phosphorous

Orinda et al., 2017

Crickets are omnivorous meaning they eat both animal and plant matter indicating a wider nutritional spectrum. This makes them easy to rear in large scale since they can be fed on variety of feed types.

They respond to feed through biting. Texture of the feed is important because these are biting insects. Pinheads can be given softer feed but the texture can be made coarser as they approach adults otherwise the adult crickets will start nibbling the hideouts. The feed can be made into smaller pellets or crumbles.

Crickets are generally fed on poultry growers' mash or chick mash but a farmer can substitute with *kienyeji* mash. During the first 3-4 weeks of the cricket life, feed a 20% protein feed after which a 15% protein feed should be given until maturity. While both carbohydrates and proteins are equally important, they are both utilized differently. Carbohydrates serve as an energy source and proteins provide amino acids that are assembled into structural tissues and enzymes. The cricket feed should contain the essential amino acids since the insect cannot synthesize them. Water and food consumption peaks when crickets reach medium size but optimal requirements depend on life stage of the cricket, sex and species.

Two weeks before harvesting a farmer can provide fresh edible vegetables and fruits (Fig.23). This helps in:

- Cutting down cost of feed.
- Cleaning the crickets' gut before harvesting.
- Improving the taste of the crickets.

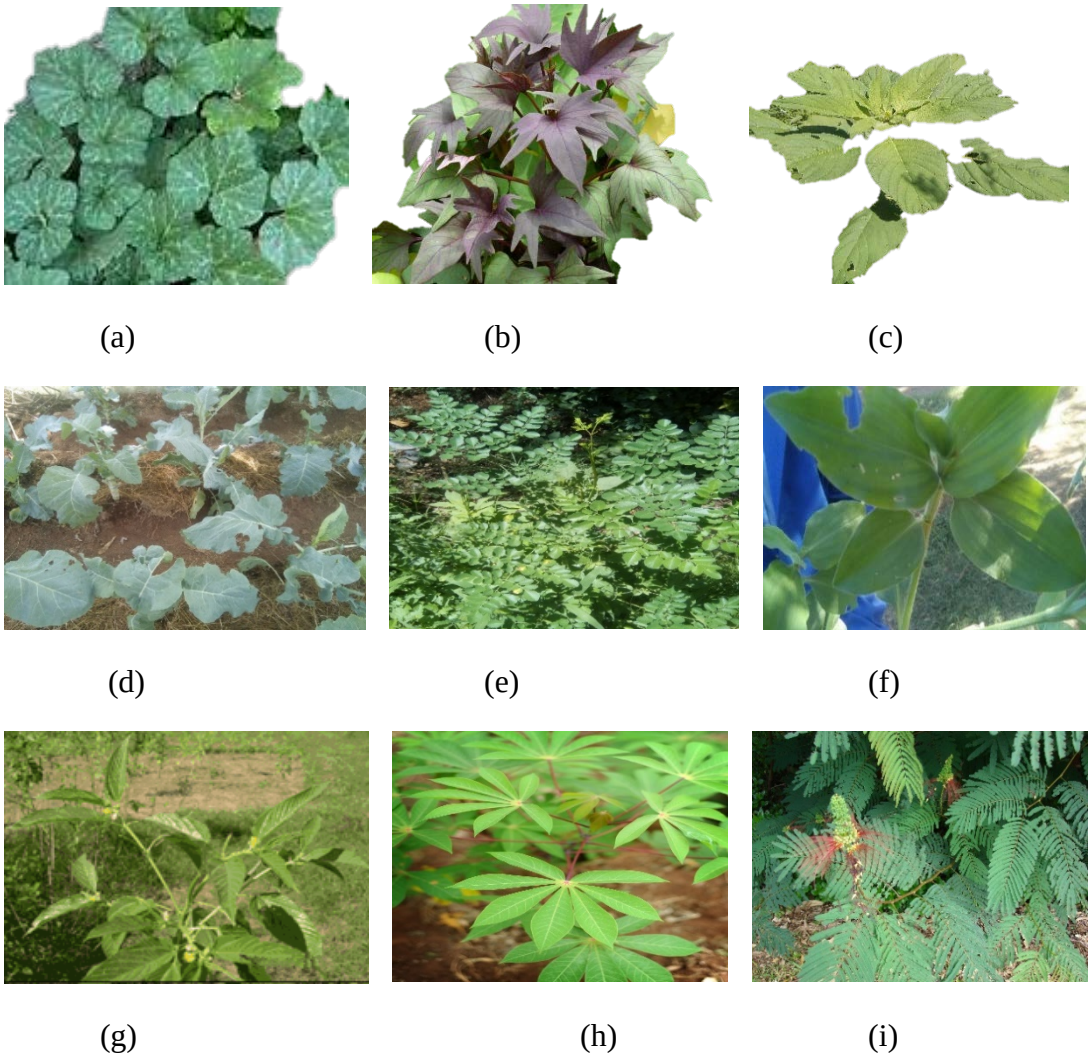
The juicy vegetables also provide water to the crickets. Before feeding the fresh vegetables and fruits, make sure that they are free from;

- insecticide.
- pests and their eggs

Crickets show the best performance when fed on feeds with high moisture and nitrogen levels. This means that the farmer should feed young fresh leaves.

Wash the fruits and vegetables before feeding. Leaves such as cassava, *Calliandra calothyrsus* and *Moringa oleifera* need to be withered before feeding due to toxins and anti-nutritional factors. These factors alter the nutritional value of the feeds and at the same time, may affect the health of crickets. They may also prevent easy digestion of protein in the feed. The best

way to destroy anti-nutritional factors is to wither the leaves or dry them and feed them in powdery form or in combination with other feedstuffs.



(a) (b) (c)

(d) (e) (f)

(g) (h) (i)

Figure 17: Leaves that can be fed to crickets; (a) Pumpkin leaves, (b) Sweet potato leaves, (c) Amaranth leaves, (d) Kales (e) *Moringa oleifera* leaves, (f) Wandering jew (*Commelina bangelensis*), (g) Jute (*Corchorus olitorius*), (h) Cassava leaves (i) *Calliandra calothyrsus*

Feeding Rates

Feeding rates may be adjusted with the growth rate or biomass of the crickets. This is because of the physiological requirements by the body of the cricket as they go through different life stages. Foraging crickets need more feed as they use a lot energy moving around looking for feed unlike the confined crickets. Feeding rates depend on:

- Stocking rate/ number of crickets in a cage
- Age of the cricket
- Body weight

After the last instar, growth stops and the cricket only needs feed for daily maintenance. A farmer can calculate the quantity of feed as per the cohorts as the crickets grow into adulthood.

3.10 Provision for Hide-outs

Crickets are nocturnal insects that like hiding that should be provided with hide-outs in order to;

- prevent stress and anxiety.
- provide a hiding place from predators.
- provide a dark environment that is essential for production of melatonin, a critical hormone for growth and immune system.

Bent ovipositor, broken antennae and wings, cannibalism are signs of distress. Limited hideouts may also encourage cannibalism and fighting. Consequently, it is imperative to provide enough hideouts as their territories. Various materials can be improvised as hideouts, among them include use of egg-trays, inside of tissue paper rolls, or cartons (Fig.21). If a farmer chooses to improvise, then he should ensure that the individual hiding spaces are several but smaller to reduce male fighting for calling sites and territories. The more space there is in a cage, the smaller the population of crickets in each territory, the higher the quality of eggs produced from reproduction.

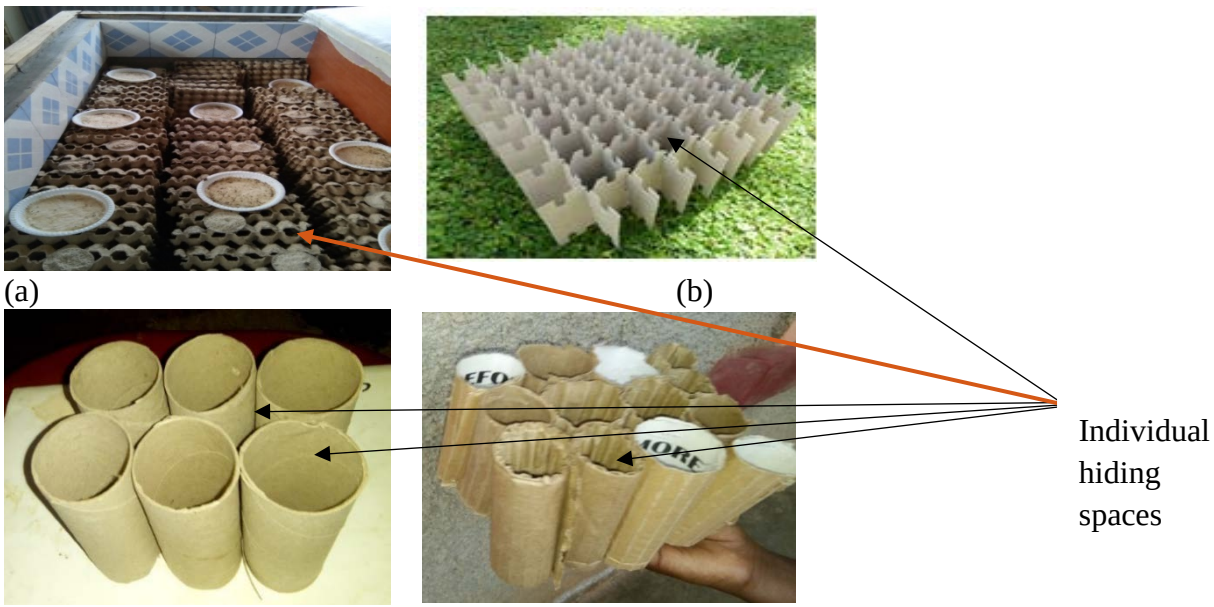


Figure 18: Examples of hide-outs that a farmer can use; (a) egg trays, (b) custom made hide out, (c) inside of tissue rolls and (d) improvised carton made hide-outs.

Hiding places should be placed vertically:

- So that the cricket droppings and dead crickets will not collect in the hiding place.
- The hiding places stays clean.
- For ease of crickets' movement - crickets like moving up and down.

Regularly inspect the hide-outs for presence of predators like spiders (Fig.22).

Figure 19: Spider invasion

Did You Know?

- Physical qualities of feed such as hardness, shape, smell, taste and anti-nutritional components influences the crickets' capacity to consume and digest the feed.
- It is advisable to feed crickets on leaves which are not normally consumed by humans to minimize on the possible competition between use as food and feed.
- Feed forms the largest part of the variable costs but this can be reduced by feeding safe agricultural by products.
- Never feed rotten fruits or vegetables to cricket because:
    - There is possibility of adult crickets laying eggs on them.
    - There is possibility of fungal and bacterial growth.
    - They attract micro flies.
- Young crickets have the tendency of choosing suitable feed to consume in balanced proportion BUT a farmer is still advised to feed a balanced diet.

CHAPTER FOUR

4.1.Rearing Systems

Domesticated crickets are confined in an enclosed container or cage where they cannot jump out. These containers can be of various types such as glass cages, wooden boxes, concrete blocks or cylinders, and plastic drawers or crates. The size and number of such containers depends on the availability of space, affordability as well as the scale of production. The cages/containers are kept within the cricket house. A rearing container should:

- Be high enough (about 80-100cm) to deter cricket from jumping out of the container.
- Be smooth to prevent crickets from crawling out and for ease of cleaning.
- Provide enough space for ease of cricket movement. An individual cricket needs an area of 2.5cm^2 for ease of movement.

4.1.1 Pen System

The pens can be constructed using bricks and cement or compacted mud. When constructing a pen, ensure the following:

- The height should be 0.6m for ease of reaching the hideouts without straining and to deter crickets from jumping out. The width should be 2m but the length will depend with the available space. A pen of 1.5m by1.5m by 0.6m can carry up to 10 kg of crickets per cycle (approximately 10,000 crickets).
- 30cm of the upper part of the inside wall should be smooth/slippery to prevent crickets from crawling out. A farmer can use wall tiles. The lower part should have grip to enable crickets to crawl on (Fig. 20).
- The hide-outs should be raised not be placed directly on the floor as shown in the fig. 20. This ensures that the crickets are not in contact with their droppings. It also helps with the insulation as it can be very cold at night.

1. Use of slippery wall tiles to deter crickets from crawling out.
2. The lower rough part of the pen to enable crickets crawl or move easily within the pen.
3. Vertical placing of hide-outs on a raised platform.

Figure 20: Pictorial representation of the inside of a pen

- The lid should be covered with a netting material to keep predators away and to help with ventilation. See fig. 21 below.

1. Netting lid for the pens (make sure that the lid is tightly fitting). It is recommended to use insect net.
2. Use stoppers to help in pressing the lid down preventing entry of predators.

Figure 21: A closed pen

1. Cricket feed
2. Drinking substrate

Figure 21: A fully arranged pen

Advantages of Pen System

- It is durable i.e. minimal maintenance cost
- Appropriate for large scale cricket production.
- Crickets have enough space for movement and reduced contact with faeces.
- Efficient utilization of space in pens.
- Fully enclosed system that protects the crickets from crawling predators.
- Mimics the natural environment suitable for crickets' growth.
- Provides better results in terms of faster growth and maturity of crickets
- Large carrying capacity and therefore quick returns on investment

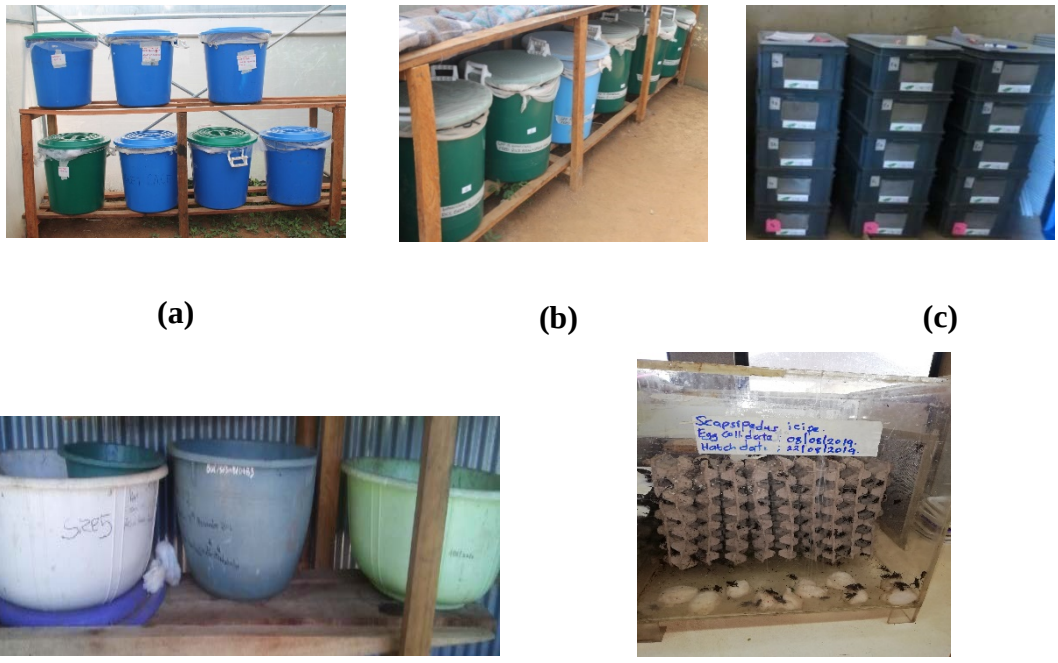
Disadvantages of Pen system

- Requires relatively large space for construction.
- High initial cost of construction which might deter some rural farmers from adopting it.

- Cleaning and disinfecting the units is time consuming and tiresome as it requires movement of entire cricket stock.
- Easy spread of diseases and pests in case of attack.
- Does not make use of vertical space when land availability is a limiting factor.

4.1.2 Plastic Containers and Perspex cages

These include 100 litre plastic buckets and basins, 80 litre plastic buckets and basin, 80 litre laundry boxes or kids toy boxes and crates and Perspex cages measuring (60X60X60) cm.



(a) **(b)** **(c)**

(d) **(e)**

Figure 22: Examples of plastic rearing containers. (a) A 100L buckets with perforated lids on, (b) A 100L buckets without lids, (c) Crates stacked upwards, (d) Large basins, (e) Perspex box.

During cold season, a farmer may wish to place the lids on bucket but should ensure that holes are drilled on them for ventilation (Fig. 23a). A netting material is used for covering the rearing container to:

- Keep away predators.
- Help in ventilation.
- Prevent crickets from crawling out.

The netting material should be tightly secured (using a *bladder* or elastic band) on the bucket (Fig.23b). A farmer can harvest up to 3 kg per bucket per cycle.

Advantages

- Most suitable for small -scale cricket production.
- Relatively affordable compared to pen system.
- Fully enclosed system that protects the crickets from predators.
- Lower risk of losing an entire colony in the case of disease outbreak.
- Retains warmth that is much needed thus boosting cricket growth during the wet season.
- Easy to transfer crickets in buckets from one place to another when selling, harvesting or disinfecting the production unit.
- The system can make good use of vertical space in the case of stacking.

Disadvantages

- Plastic buckets need replacement with time as they depreciate.
- Higher possibility of overheating in the case of stacking.
- Crickets have increased contact with faeces and are allowed less freedom of movement.
- Humidity during the wet season can cause losses among smaller crickets, due to lower temperatures in the buckets.
- Difficult to maintain cleanliness when too many crickets are raised in the same bucket.

4.2. Production Methods

4.2.1. Continuous Production Method

A layer of substrate (soil) is placed on the whole bottom of a cricket breeding container. Food and water bowls are placed on top of the soil along with cartons.

Advantages

- It is suitable for small scale production.
- It requires low maintenance. As large crickets are harvested, they are replaced with pinheads hatched from the substrate placed at the bottom of the container.
- It is less costly as it does not require as many containers or components as required by the batch system.
- Provides a range of cricket sizes within a single container.
- Micro flies are not usually a problem as the large crickets eat the maggots that lay their eggs in soil substrate.

- It is less laborious as there is limited cleaning procedures and movement of hide outs.

Disadvantages

- It is time consuming to sort out adult crickets during harvesting. It yields less crickets per container compared to batch system
- There is possibility of fungal growth and bad odour due to mixing of cricket droppings and moist soil.
- The mixture of cricket droppings and moist soil creates a hard pan over time thus making it hard for pinheads to wriggle out after hatching. This lowers productivity over time.

4.2.2. Batch Production Method

Laying substrates are placed in a breeding container where the females lay their eggs and occasionally removed and placed in another empty container termed as incubation chamber. After hatching, the crickets can be moved to a rearing container if it is small otherwise it can serve as the rearing container. No substrate is placed on the floor of the breeding container. This method is the popular method used however it requires a great deal of maintenance.

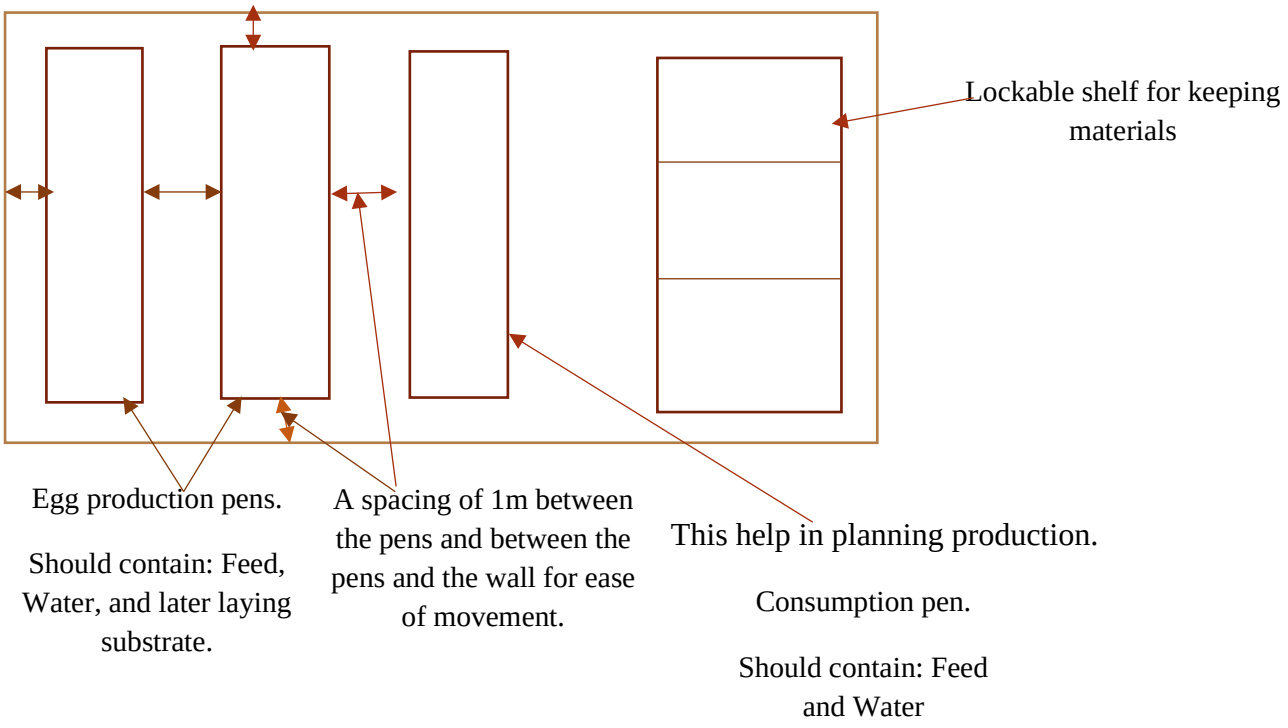
Advantages

- It ensures uniformity in production as each batch contains crickets of the same age group.
- It is easier to clean by shaking the droppings to one end for removal.
- It is easier to plan smooth and sustainable production because of use of batches.
- It is not time consuming as there is no need of sorting out crickets during harvesting due to uniformity in age.
- Suitable for commercial production.

Disadvantages

- Requires more maintenance and time to manage than a substrate system. The breeder containers need to be sprayed every second day and new breeding containers need to be prepared once per week.
- Special care must be taken to ensure that the incubation chamber is not infected with micro flies and maggots which will quickly destroy the breeding colony.
- Requires more containers and components than a substrate system.

4.3. Production Schedules and Rearing house Set-up



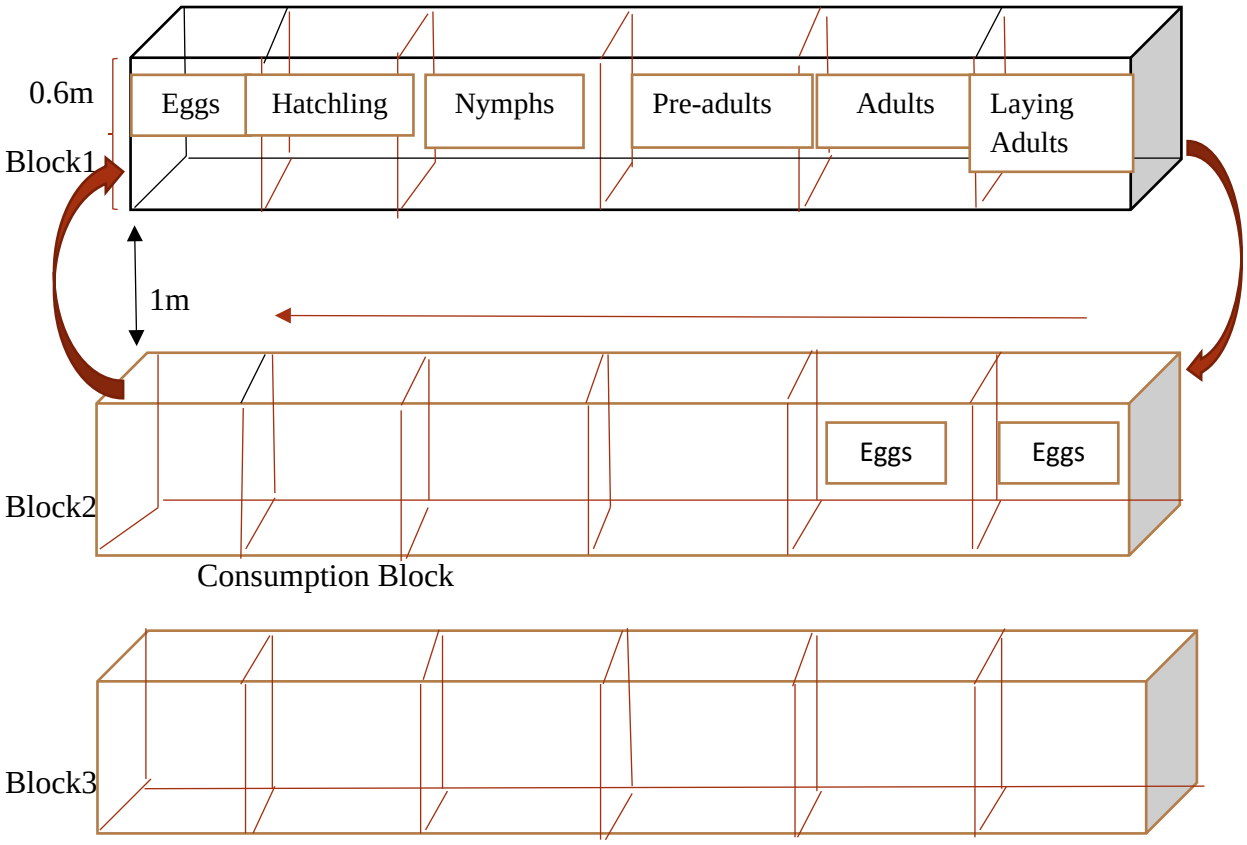


Figure 24: A pictorial arrangement of a pen system in a cricket house

Block 1 & 2 (Fig. 24) are dedicated to egg production while block 3 (Fig.24) is entirely for consumption. Block 3 is harvested just when they have just emerged into adult when the chitin is still soft. The culled mother stock from blocks 1 & 2 can also be consumed or sold. The only disadvantage is that they have hardened chitin. In between the blocks, leave a space of 1m for ease of movement. When production is well planned, a farmer can harvest 10kgs of crickets after every two weeks. A pen of 1.5m x 1.5m x 0.6m can produce approximately 10kgs of fresh weight.

The set- up is also applicable to plastic containers such as bucket system. A small-scale farmer can start with six buckets and harvest up to 3kgs per bucket and approximately 5kgs of cricket after every two weeks. It is advisable to start small and expand with time.

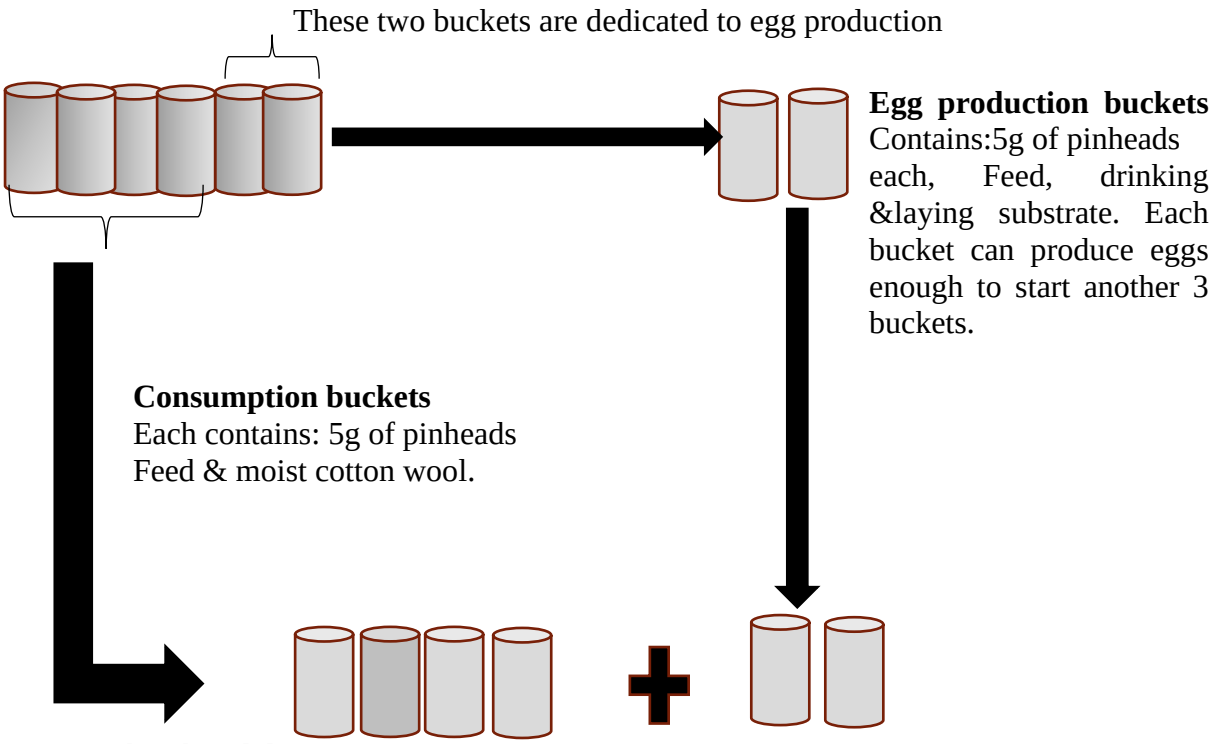


Figure 26: Pictorial presentation of bucket system

Did You Know?

- Egg production colony is also known as mating colony.
- Mating colony is maintained at 30-35% of the whole colony.
- Consumption colony is harvested at penultimate stage when the whole colony is 80-85% winged.

4.4.Harvesting

This should be done at the right time before natural attrition sets in. Harvest to dispose old stock after laying for two weeks. The harvested crickets can be consumed or sold off to processors. A farmer can harvest some crickets when they are about to emerge into adults when the chitin is still soft to cut down on cost of feed (efficiency of feed conversion starts to decline after this stage) and labour, however, he must maintain a small population called mating or breeding colony to sustain the colony. In this case, the harvesting should be done when approximately 80-85% of the whole colony is winged. The mating stock should be maintained at approximately 30-35% of the total population because of the possibility of mortality and natural variances due to environmental factors and fecundity.

Harvesting Process

i. Harvesting should be done in the morning when the crickets are less agile. Crickets are cold blooded which means their body temperatures depends on the temperature of the surrounding. In the morning when it is still chilly, they would prefer hiding in the hideouts. This makes collection easier.
ii. To easily collect the crickets, gently lift the hideouts from the rearing containers and then shake them gently in another clean bucket with a lid.
iii. After collecting all the crickets, transfer them into a clean plastic or zip lock paper.
iv. Put the plastic paper containing crickets in a deep freezer for 30 minutes or until the crickets become immobile or frozen. This is a humane and food-safe way of immobilizing the crickets and does not interfere with their physical and nutritional composition. Since the house crickets are ectotherm, sub-zero temperature leads to *torpor*, a naturally occurring state of low-activity until the temperature rises. Blanch the crickets (Fig. 27). Blanching is the process whereby the crickets are put in a boiled water for three minutes and then removed and immediately plunged into cold water for one minute to halt the cooking process.
v. The blanched crickets can further be frozen, dried or roasted.

(a) (b)

Figure 27: (a) Blanching crickets, (b) Already blanched cricket ready for packaging

Did You Know?

- After harvesting, clean and disinfect the rearing containers.
- Leave the rearing container to rest for two weeks before introducing another colony.
- Farmers are advised to use agricultural lime while disinfecting the containers and not chemicals.

CHAPTER FIVE

5.1 Threats to cricket farming

These varies from parasites, predators, pathogens to inherent and biological threats like inbreeding. Parasites live on the cricket since this provides them with suitable condition to reproduce. They can live within or on the crickets which eventually die at the end of their life cycle.

Predators feed directly on the crickets. They do so by killing the crickets or using chemical stimuli to locate the crickets and trap or attack in groups especially for smaller predators like black ants.

Pathogens are the microparasites and includes viruses, fungi, nematodes and bacteria. Some pathogens will depend entirely on the host cricket to complete their life cycle while others will not.

These threats can be spread or transmitted through air, soil, food substrate and cuticle of the cricket. It is important to note that microbial prevalence and populations associated with wild insects and those with cultivated insects may differ. These differences are largely determined from the source of food the insects are eating and production environment. Therefore, proper farming techniques should be adapted for control of pathogens that might harm humans.

5.1.1 In-breeding

This is mating of close relatives. Although crickets are known to be polyandrous in the wild, confinement increases their chances of inbreeding.

Symptoms of In-breeding

- Less active and slow-maturing crickets.
- Reduced body size and weight.
- Body deformity.
- Reduced resistance to diseases (low immunity).

Management

- Colony size is important in inbreeding management. A farmer is advised to keep a large population within a rearing unit to increase the chances of outbreeding. This further provides an environment for fair and natural male to male competition and female response to male courtship ensuring that only superior and fittest genes are selected for procreation.
- Bring in new stock from outside the farm after the third generation to neutralize inbreeding.

5.1.2 Cannibalism

This occurs when crickets eat or prey on each other. It can be due to overcrowding or imbalanced feed.

Management

- Ensure the crickets are provided with diets with right amount of protein and water *adlibitum*
- Ensure there is no overcrowding in the cages or in any production system

5.1.3 Parasites

These include mites, parasitic wasps and flies amongst others.

a) **Emerald wasp:** Emerald or Jewel wasp (*Ampulex compressa*) is a solitary wasp of the family *Ampulicidae*. The wasp has a metallic blue-green body. It immobilizes the cricket with its venom and then lays its eggs on the cricket's body. The eggs hatch after around 3 days. The hatchlings feed on the immobilized cricket for the first few days of their life. Cover the cages to prevent entry of the wasp.

Figure 28: An emerald wasp **Figure 29: An emerald wasp-laying eggs on another insect.** Source: https://www.flickr.com

b) **Phonotactic fly**: It is called phonotactic because it is attracted by the cricket chirps. The most notorious phonotactic fly is the female tachinids, *Ormia ochracea*. It uses the chirps to locate the male crickets and deposit their larvae on them. The larvae attach themselves on the cricket and develop endoparasitically. The larvae attach themselves on the flight muscles in the thorax of the cricket. They then migrate to the abdomen; here they grow and feed on the cricket's fat body, abdominal and thoracic muscles. The host cricket dies after

around 7-10 days when the larvae mature and emerge to pupate. A farmer should cover the cages to prevent entry of the fly.

(a) **(b)**

Figure 30: (a) A tachinid fly (b) A mature tachinid fly larvae coming out of a host cricket

Source: **http://junglekey.fr/wiki/definition.php**

c) **Micro-Flies**: These are very small flies, the size of the fruit flies. They are mostly attracted to wet food and dead crickets in the cricket cage. They lay their eggs on the egg laying substrate which hatch after a few days. Their freshly laid eggs are white and smaller than cricket eggs. They turn brown when they are about to hatch. The hatched maggots feed on the cricket eggs as they hatch earlier than crickets. Maintain cleanliness in the cage all the time. Change unconsumed vegetables and fruits every day. Ensure the cage is dry all the time. If possible, install midge fly screen on all external openings of the container.

d) **Mites:** large red mites occasionally invade the cricket rearing places. They mostly attach themselves on the dorsal part of the crickets beneath the wings. The crickets become weakened and movement is impaired.

5.1.4 Pathogens

Gregarine sporozoans have been reported to occur in the midguts of *Gryllus spp*. They occur as parasites in the body cavities and the digestive systems of crickets. They can also be transmitted through the semen. The effects of their occurrence include slower development and reduced spermatophore which eventually reduces reproduction.

Management

- Remove all the dead crickets as feeding on these dead crickets' aid in spread of the pathogen.

- Maintain cleanliness all the time and ensure the pens are well aerated to prevent moulding.

5.1.5 Diseases

5.1.5.1. Cricket Paralysis Virus (CPV)

The Cricket Paralysis virus has been reported to attack only *A. domesticus, T. oceanicus and T. commodus* in America and parts of Europe. It mostly affects the early to mid- instar nymphs. The virus does not affect human beings. In Kenya, there have been no reported cases of any diseases but with the increased intensive production and high stress factors, there are high chances of diseases outbreak.

Symptoms of Cricket Paralysis Virus

- The crickets flip over on their backs due to immobilization of hind legs.
- They become paralyzed and eventually die.

Management

- In case of outbreak, it is advisable to burn the whole colony and bury the remains six feet under.
- Since this virus only attacks *A. domesticus* species, a farmer can diversify into other resilient species such as *G. bimaculatus.*

5.1.5.2. *Acheta domesticus* densovirus (*Orthopteran ambidensovirus*1)

It was first reported by researchers in France in 1977 but has since been reported in Europe, USA and Canada. It has been found to be highly contagious in *Acheta domesticus* species only. It is lethal and can wipe up to 80% of the colony in a short time. It is very lethal in the last three stages of nymphal instars as well as in adult stage. The virus is potentially airborne and can as well survive in the soil and the cricket cuticles or epidermis for a substantial duration of time.

Symptoms of Adensovirus

- Reduced feed intake (anorexia) and lethargy or tiredness
- Reduced body mass and flaccidity
- Retarded growth

- Partial or complete paralysis and eventual death

Management

- Diversify into other species such *Gryllus* s*pp.*
- Destroy the whole infected colony and sanitize the rearing units.

5.1.5.3. *Gryllus bimaculatus* nudivirus

It has been reported in a laboratory in southern Germany and can lead to 100% mortality. It is more lethal in the nymphal stages but chronic in the adult phase. It can be transmitted through foods at mating or nesting places which are contaminated with the faecal matter.

Symptoms

- Reduced size
- Swollen abdomen that contains a viscous and milky haemolymph
- Sluggishness

Management

- Maintaining high standards of hygiene within the rearing facility.
- Remove dead crickets in the colony as cannibalistic feeding might aid in transmission.
- Destroying the infected colony if the infection is large scale.
- Switching to new breeding stock or even new cricket species.

5.1.5.4 Cricket iridovirus

It was first detected in mass cricket rearing colonies in 1996 in Netherlands and Germany. It majorly affects *A. domesticus, G. bimaculatus* and *G. campestris.* It can be transmitted through predation or cannibalism, parasitic wasps such as emerald wasp or during mating.

Symptoms

- Reduced fecundity and life span in both nymphs and adults.
- Lethargy and disorientation.
- Eventual death.

5.1.5.5 Rickettsia

It has been reported in farms in Kenya and Uganda. It grows in the cell vacuoles of the fat body.

Symptoms

- Swollen abdomen that turns yellowish/whitish.
- The swollen abdomen produces viscous liquid.
- Reduced fecundity i.e the cricket lays few eggs.

Figure 31: A cricket infected by rickettsia spp.

Vergara et al., 2018

Management

- Maintaining high standards of hygiene within the rearing facility.
- Sterilize the laying substrate.
- Rearing materials that can be re-used such as hide outs and rearing containers, should be aired more often or dried in direct sunlight.
- Destroying the infected colony if the infection is large scale.
- Disinfect the whole rearing unit.

5.1.6 Predators

Characteristics, Behaviour & Prevention

1. **Lizards & Geckos**

   They like hiding in the crevices and sometimes burrow themselves in the ground. They lay eggs on the small burrows or crevices. They feed on pinheads and can eat a whole colony within a short time.

Management

- Occasionally inspect the hideouts
- Keep the cages covered all the time.

Figure 32: A Lizard **Figure 33: A gecko**

Source: http://malcolmtattersall.com.

2. Spiders

They like hiding in the crevices. There are types of spiders that feed on the crickets and those that spin their web restricting crickets' movement. They trap the crickets in their web and then suck them dry. They multiply very quickly.

Management

- Occasionally inspect the hideouts before and during use.
- Keep the cages covered with the netting material all the time.

NB: They are very dangerous because they are capable of hiding even in tiny spaces, underneath the cages or in unused hideouts meant for crickets.

Figure34: Examples of spiders

Source: https://uspest.com/

3. Snakes

They are usually attracted by the chirping of the crickets. They like hiding in dark places within the rearing house such as corners, crevices and roofs. During dry and hot season, snakes are more likely to look for cool places within the rearing house. A part from feeding on the crickets, they can also bite the farmer.

Management

- Maintain cleanliness within and outside the rearing house.
- Clear bushes and long grass around the rearing house.
- Cover all the openings, crevices to prevent entry of predators.
- Sprinkle snake repellent around the house.
- Plant snake repellant shrubs around the cricket house like lemon grass, variegated snake plant (mother in-law's tongue) and marigolds.

4. Rats and mice

They like hiding in dark places within the rearing house such as corners, crevices and roofs. They feed on both the crickets and crickets' dry feed. They can chew their way into the cage.

Management

- Maintain cleanliness within and outside the rearing house.
- Clear bushes and long grass around the rearing house.
- Cover all the openings, crevices to prevent entry of predators.

Figure 23: A rodent

Source: **https://images.search.yahoo.com**

5. Black Ants and Sugar ants

They are of different types. They are a menace to eggs and pinheads and can wipe out a colony due to their coordinated attack. They carry the pinheads and eggs away. They are mostly attracted by dead crickets. During dry periods, they go about looking for water so they may be attracted by the drinking medium in the cage.

Management

- Make sure there are no dead crickets in the cage.
- Sprinkle agricultural lime around the house to keep away ants.
- Dig a trench of 10cm filled with water around the cricket house.
- Smear the stands of cages with grease or old engine oil to trap the ants.
- Make sure there is no sugar or coffee in the cricket rearing room to avoid attracting sugar ants.

Figure 24: Examples of black ants

Source: https://images.search.yahoo.com/images/view

6. Birds

They feed on both the pinheads and adult crickets. Keep the rearing house locked but well ventilated. Rearing house should not be near the trees that can harbour the birds.

Did You Know?

- The list of predators is not exhaustive even frogs, chameleons and domesticated chicken, can be predators. A farmer should be very observant.
- Crickets employ different defensive strategies to predators and parasites. These can be hiding, burrowing, camouflaging, fleeing, threatening and attacking.

- General cleanliness, in and around the house is the key to deterring predators.
- Do not use insecticide to kill other insect predators.
- Regularly inspect the cricket colony for any sign of predators.

CHAPTER SIX

6.1 Cricket Products and Possible Business Enterprises

There are two major products from rearing crickets; crickets and their manure (biofertilizer). A part from earning income from cricket sale, a farmer can also benefit from the cricket droppings which is very rich organic manure. It is always advisable to have a small vegetable garden next to the cricket farm to benefit from the nitrogen rich droppings while at the same time supplying safe and fresh vegetables for them. The value chain analysis of cricket rearing could lead to different enterprises (Fig.34).

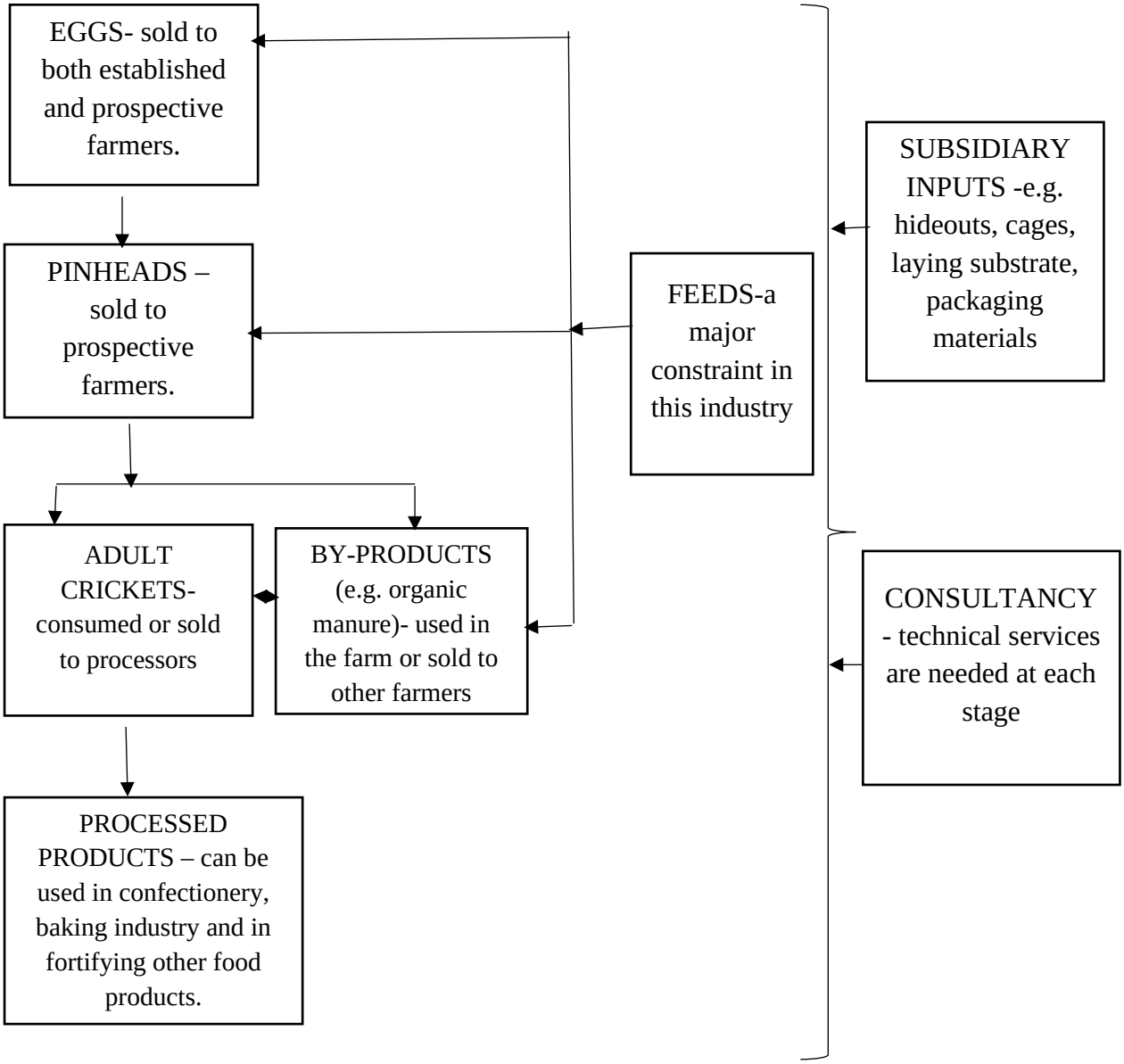


Figure 25: The probable cricket value chain

1. **Cricket feed enterprise**: This a potential area. Feed is a major constraint in this new industry.
2. **Egg enterprise**: A farmer can specialize in egg production. These can be sold to both prospective new farmers and established ones to control in breeding.
3. **Adult cricket enterprise**: These can be eaten as food or sold to those who want to process to other products (Fig.36).

Figure 26: A plate of fried cricket

Figure 39: (a) Cookies **(b) Cupcakes**

4. **Processed Cricket products**: There are arrays of products that can be processed from cricket. One is only limited by his/her imagination (Fig.37).

6.2 Gross Margin Analysis and Projected Income

The rates used here are from Flying Food project for the year 2016-2017.

Table 8: Gross margin analysis of a pen system in the first year of investment

Pen System housed in a prefabricate house

S.NO.	**Item**	**Unit Price**	**Quantity**	**Total (KShs)**
1.	Construction of a prefabricated house measuring 7m x7m (done once). Labour and pen inclusive. Pen measuring 3m x3m x 0.6m	40,000	1	40,000
2.	Egg trays (a farmer can use tissue rolls or improvised carton hideouts to cut down on costs)	20	160	3200
3.	Feed (chicken mash). A farmer can supplement with fresh vegetables and fruits.	500	2bags each 10kgs	1000
4.	Labour (assumes that a farmer will use family labour)	Free	Free	Free
5.	Cotton wool 400g (a farmer can choose to use sterilised forest soil to cut down on cost)	250	8 pieces	2000
6.	Laying & drinking containers (assuming that a farmer can recycle used containers to cut down on costs) Petri dishes	18	40pieces	720
	Total Cost			**46,920**
7.	Sale of cricket. (40kg/cycle) 4cycles/year (40*4=160kgs)	350/kg (ADS & TNO rate)	160	56,000
GROSS MARGIN				9,080

Table 9: Gross margin analysis of bucket system per year

Bucket System housed in a mud house

S.NO.	**Item**	**Unit Price**	**Quantity**	**Total (KShs)**
1.	A 100litre bucket (once)	1200	6 pieces	7,200
2.	Construction of a mud house (done once)			
	Cedar posts 10ft	385	4 pieces	1,540
	Iron sheets 15	600	15 pieces	9,000
	Wire nails	140	9kgs	1,260
	Roofing nails	180	4kgs	720
	Compacted mud (free)	Free	Free	Free
3.	Egg trays (a farmer can use tissue rolls or improvised carton hideouts)	20	24	480
4.	Feed (chicken mash)	500	2bags each 10kgs	1000
5.	Labour (assumes that a farmer will use family labour)	Free	Free	Free
6.	Cotton wool 400g (a farmer can choose to use sterilised forest soil to cut down on cost)	250	4 pieces	1000
7.	Laying & drinking containers (assuming that a farmer can recycle used containers to cut down on costs) Petri dishes	18	24	432
	Total Cost			**22, 632**
6.	Sale of cricket			
	(3kg/bucket*6 =18kgs)/cycle 4cycles/year (18*4=72kgs)	350/kg (ADS & TNO rate)	72	25,200
GROSS MARGIN				2,568

Table 10: Projected income statement of a pen system in 4 years

	1st Year	2nd Year	3rd Year	4th Year
Total cost	46,920	3950 (2 rolls of cotton wool, hideouts & feed	3950 (2 rolls of cotton wool, hideouts & feed)	3950 (2 rolls of cotton wool, hideouts & feed
Total income (160kgs/year)	56,000	56,000	56,000	56,000
	9,080	**52,050**	**52,050**	**52,050**

Table 11: Projected income statement of bucket system per year

	1st Year	2nd Year	3rd Year	4th Year
Total cost	20,632	1,230 (2cotton wool rolls, hideouts & feed)	1,230 (2cotton wool rolls, hideouts & feed)	1,230 (2cotton wool rolls, hideouts & feed)
Total income (3kg/bucket*6)	25,200	25,200	25,200	25,200
	2568	**23,970**	**23,970**	**23,970**

BIBLIOGRAPHY

1. Ayieko M.A., Ogola H. J. and Ayieko A. I. (2016). Introducing rearing crickets (gryllids) at household levels: adoption, processing and nutritional values. *Journal of Insects as Food and Feed.* 2(3): 203-211 Wageningen Academic.
2. Clifford C.W. and Woodring J.P. (1990). Methods of rearing the house cricket, *Acheta domesticus* (L) along with base-line values for feeding rates, growth- rates, development times, and blood composition. *Journal of Applied Entomology*. 109, 1-14.
3. Cricket Rearing Manual (2013). Jaramogi Oginga Odinga University of Science & Technology (Flying Food Project).
4. FAO (2013). *Edible insects: Future Prospects for feed and food security*. FAO Publication.
5. Hallett Ian (1995). Breeding and housing cricket. Melissa Kaplan's Collection www.anapsid. Org/crickets.html.
6. Hanboonsong, Y., Tasanee J., Durst P.B. (2003). *Six-Legged Livestock: Edible insects farming, collecting and marketing in Thailand.* FAO Publication.
7. Klassey Glenn (2012). *The complete cricket breeding manual*. Zega Enterprises, Australia.
8. Magara, J.O.H., Tanga, C.M., Ayieko, M. A., Hugel, S., Samira A. M., Khamis, F.M., Daisy Salifu, D., Niassy, S., Subramanian S., Komi K. M. F, Nanna Roos, N. and Ekesi, S. (2019a). Performance of Newly Described Native Edible Cricket *Scapsipedus icipe* (Orthoptera: Gryllidae) on Various Diets of Relevance for Farming". Journal of Economic Entomology, XX(X), 2019, 1–12. doi: 10.1093/jee/toy397.
9. Magara, J.O.H., Ayieko, M. A., Niassy, S., Daisy Salifu, D., Azrag, G. A.A., Fathiya M. Khamis,F.M., Subramanian S., Komi K. M. F, Nanna Roos, N. Ekesi, S. and Tanga, C.M.,. Integrating temperature-dependent life table data into Insect Life Cycle Model for predicting the potential distribution of *Scapsipedus icipe* Hugel & Tanga". PLoS ONE 14(9):e0222941.DOI:10.1371/journal.pone.0222941
10. Nation J.L. (2002). *Insect Physiology and Biochemistry*. CRC Press. Boca Raton, Florida.
11. Patton R.L. (1967). Oligidic diets for *Acheta domesticus* (Orthoptera: Gryllidae). *Annals of the Entomological Society of America*. 60, 1238-1242.
12. Patton R.L. (1978). Growth and development parameters for *Acheta domesticus* (Orthoptera: Gryllidae). *Annals of the Entomological Society of America*. 71, 40-42.
13. Nakagaki B.J and Defoliart G.R. (1991). Comparison of diets for mass-rearing *Acheta domesticus* (Orthoptera, gryllidae) as a novelty food, and comparison of food conversion

efficiency with values reported for livestock. *Journal of Economic Entomology*. 84, 891-896.

14. Tanga, C.M., Magara, J.O.H., Ayieko, M.A., Coopeland, R.S., Hugel, S. Samira A. M., Khamis, F.M., Salifu, D., Niassy, S., Subramanian S., Komi K. M. F., Roos, N. and Ekesi, S. (2018). A new edible cricket species from Africa of the genus Scapsipedus. *Zootaxa* 4486 (3): 383–392. doi.org/10.11646/zootaxa.4486.3.9
15. Van Huis A. and Tomberlain J.K. (2017). Insects as food and feed: From production to consumption. Wageningen Academic Publishers.Netherlands.
16. Van Huis A., vanItterbeeck J., Klunder H., Mertens E., Halloran A., Muir G., et al. (2013). Edible insects: future prospects for food and feed security. No. 171. Food and Agriculture organization of the United Nations (FAO).
17. Orinda M.A., Mosi R.O., Ayieko M.A. and Amimo F.A. (2017). Growth performance of Common house cricket (*Acheta domesticus*) and field cricket (*Gryllus bimaculatus*) crickets fed on agro-byproducts. *Journal of Entomology and Zoology Studies*. 5(6): 1664-1668.
18. GREEiNSECT Project. (2017). Insect production systems for food and feed in Kenya. Technical brief #2. http://greeinsect.ku.dk/news/greeinsect-technical-brief-2-farming/
19. Payne, C.L.R., Scarborough, P., Rayner, M., Nonaka, K. (2016). Are edible insects more or less 'healthy' than commonly consumed meats? A comparison using two nutrient profiling models developed to combat over- and undernutrition, European Journal Clinical Nutrition. 70: 285–291.

This manual seeks to provide appropriate technology for sustainable cricket farming. It encourages farmers to utilize cheap, affordable and locally available materials. It is hoped that the manual will lead to a surge in cricket farming in Kenya and African region. It targets trainers, farmers, entrepreneurs and institutions interested in cricket farming.

About the Authors

Mary A. Orinda was a PhD student in the GREEiNSECT Project funded by DANIDA and currently a Lecturer in the School of Agricultural and Food Sciences of Jaramogi Oginga Odinga University of Science and Technology. She was formerly a field co-ordinator with European Committee for Training and Agriculture specializing in farmer's resource mobilization and capacity building.

Jackline A. Oloo is an MSc. Student in the School of Agricultural and Food Sciences of Jaramogi Oginga Odinga University of Science and Technology. She is also a specialised field extension officer and is currently engaged with Flying Food Project working on rural extension services.

Henlay Juma Otieno Magara a PhD student in the GREEiNSECT Project funded by DANIDA and a consultant in the technology transfer unit of International Centre of Insect Physiology and Ecology. He was formerly an extension officer in Kisii and Machakos counties, Kenya.

Prof. Monica A. Ayieko is a Professor of Consumer Sciences at the Jaramogi Oginga Odinga University of Science and Technology (JOOUST), in the School of Agricultural and Food Sciences. She has extensive knowledge in agricultural households and food production. She has worked in the field extension, currently a university lecturer cum researcher. She developed keen interest in the use edible insects for food security, particularly for households along the Lake Victoria region which normally have plenty of edible insects. She is currently working with farmers to promote commercialization of the same at the farm levels. Has successfully developed several processed products of edible insects and is attempting rearing insects as a pilot project for sustainability. Through the effort of Professor Ayieko, JOOUST is a proud recipient of the coveted ACE II World Bank funding to set up Africa Centre of Excellence in Sustainable Use of Insects for Food and Feed.

Dr.Sunday Ekesi is the Director of Research and Partnerships at International Centre of Insect Physiology and Ecology (ICIPE). He is an entomologist and integrated pest management (IPM) specialist with extensive knowledge and experience in sustainable agriculture and biodiversity in Africa and beyond.

Prof. Nanna Roos is an Associate Professor in human nutrition, with long-term research focus on the role of animal-source foods in diets in populations vulnerable to undernutrition in Asia and Africa. Since 2012, she has engaged in research in edible insects, in low-income settings as well as in a Western context. She is leading and involved in several research projects addressing the potentials of edible insects. Currently, she is leading a work package on insects for human consumption in the EU supported project SUSINCHAIN. Nanna Roos has been invited as an expert on the EFSA working group on insect production and consumption in 2015.

This manual provides a clear and elaborate guide on how to rear two species of crickets; Acheta domesticus and Gryllus bimaculatus. It focuses on modern rearing or domestication of crickets particularly for food and targets trainers, field workers and farmers. Further, it attempts to upgrade and refine the knowledge of trainers such that the appropriate know-how is transferred to farmers. It is our hope that the manual will improve cricket rearing and spur interest in its farming in Kenya. The organization of the material in this manual is in the chapter format. In chapter one, the view of a cricket as a delicacy and one with the potential to address the chronic food insecurity experienced in Kenya and beyond, is explored. Further, the chapter also highlights the behaviour and life cycle of crickets.

Chapter two and three give insights into cricket housing and rearing equipment. Different aspects of feeding and laying substrates are explored. Chapter four deals with farm set up, taking into account the rearing systems and production methods while chapter five focuses on crickets as a living organism that are prone to threats like diseases and predators. It also explores the possible management or prevention measures.

Chapter six explores the innovative edible cricket products and business enterprises that can be developed from the cricket value chain.

While implementing suggestions contained in this manual, we encourage trainers and farmers to also be creative and use locally available materials to cut down on rearing costs. We are also open to new ideas which can be used to improve the manual in future.

Mary A. Orinda, Jackline A. Oloo, Monica A. Ayieko
Jaramogi Oginga Odinga University of Science and Technology, Kenya

Henlay Juma Otieno Magara, Sunday Ekesi
International Centre of Insect Physiology and Ecology, Kenya

Nanna Roos
University of Copenhagen, Copenhagen

View publication stats