BIOLOGY AND ECOLOGY OF *Ceratitis capitata* (WIED.), *C. rosa* (KARSCH) AND *C.* (= *trirhithrum*) *coffeae* (BEZZI) AND THEIR ECONOMIC IMPORTANCE TO COFFEE INDUSTRY IN KENYA.

by

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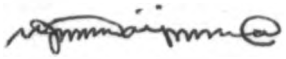
DECLARATIONS

I, JAMES WACHIRA WAIKWA, declare that this thesis is my original work and has not been presented for a degree in any other University.



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SUMMARY

Three species of fruitflies of the Family Trypetidae occur in Kenya breeding in ripe coffee berries. They are Ceratitis capitata Wied., Ceratitis rosa Karsch, and Ceratitis (Trirhithrum) coffeae Bezzi. The life cycle of C. capitata is well documented (Back and Pemberton, 1918; Christenson and Foote, 1960; Carnegie, 1962) but has been included here together with the life cycles of the other two species for comparative purposes. In this study the life history of C. capitata took 25 to 40 days at 23.8 ± 2°C. The egg took 2 to 5 days to hatch, the larval stage 6 to 12 days, the pre-pupal and pupal periods 12 to 16 days and the pre-oviposition period 5 to 7 days.

Under the same laboratory temperature conditions, the life cycle of C. rosa took 26 to 41 days. The incubation period was 3 to 5 days, the larval period 6 to 12 days, the pre-pupal and pupal duration 12 to 15 days and the pre-oviposition period 5 to 9 days. C. (Trirhithrum) coffeae took 34 to 50 days to complete its life cycle. The incubation period was 3 to 5 days, the larval period 8 to 14 days, the pre-pupal and pupal periods 14 to 19 days and the pre-oviposition period was 9 to 12 days. Both C. capitata and C. rosa can easily be confused because of their similarity in general appearance. Although C. rosa is generally a

bigger insect than C. capitata, the main distinguishing features are found in the colour of the thorax, wings, eyes and abdomen and in the possession of two clubbed "horn-like" hairs found on the head of the male C. capitata. T. coffeae is easily distinguished because it is black in colour whereas the other two species have hyaline wings spotted with yellow and black markings.

The larvae and adults of the three fruitflies exhibited diurnal periocidity in their emergence from coffee berries and pupation sites respectively. The larval periocidity appeared to be temperature dependent while that of the adults appeared to be temperature-independent. Records on seasonal history of the three species showed that breeding was continuous in coffee as long as ripening or ripe coffee berries were available.

Studies on ovipositional behaviour of C. capitata with respect to coffee berry age revealed preference to ripening coffee berries. Immature and mature green berries as well as completely mature-red berries did not seem to be favoured for oviposition by gravid females. This selectivity was attributed both to visual and olfactory responses.

The main factor responsible for fluctuation of population numbers in the field was the availability and abundance of ripening or ripe coffee berries. The peak

of the fruitflies was observed to extend for at least one month after the peak of the ripe crop due to a late population emerging from pupae in the soil after the crop was harvested. Temperature and rainfall did not appear to influence the abundance of fruitflies. The abundance of fruitflies was studied using four methods whose efficiencies were finally calculated. Trimedlure-baited traps had 81.82% efficiency for C. capitata, 18.0% for C. rosa and 0.18% for T. coffeae. Medlure-baited traps had 94.05% efficiency for C. capitata, 5.90% for C. rosa and 0.05% for T. coffeae. The suction trap had 50.55% efficiency for C. capitata, 5.83% for C. rosa and 43.62% for T. coffeae. The efficiency of the emergence traps was 9.93% for C. capitata, 39.01% for C. rosa and 55.06% for T. coffeae. From these studies trimedlure was the most effective bait.

Experiments with C. capitata revealed that 40.4% of the ovipunctured berries at the expanding stage dropped off the trees prematurely. This could result into a heavy economic loss to the farmers. No stinker beans or microorganism that may cause off-flavours of coffee liquor were, however, found from the ovipunctured coffee berries or ripe berries infected with fruitfly larvae or eggs.

(i) GENERAL INTRODUCTION

Three species of fruitflies of the Family Trypetidae (Diptera) commonly breed in mature ripening coffee berries in Kenya. They are Ceratitis capitata Wied., Ceratitis rosa Karsch and Ceratitis (Trirhithrum) coffeae Bezzi. Their larvae live in the coffee berry feeding on the fleshy pulp or mucilage. T. inscriptum Grah. is another coffee fruitfly closely related to T. coffeae but does not occur in Kenya. In Zaire, Stolp (1960) showed that this species was the vector of a Xanthomonas type of bacterium which was responsible for causing potato flavour in coffee liquor. The Kenyan coffee fruitflies have been suspected by Gibson (1970) to be the cause of "stinker" beans which lower the quality of coffee liquor.

Prematurely dropped coffee berries have been found bearing punctures caused by fruitflies (McCrae, 1965; Le Pelley, 1968). Extensive premature drop of coffee berries can considerably lower the yields. Investigations were, therefore, made to determine (i) the life cycle of the three species of fruitflies associated with coffee in Kenya, (ii) the timing of the emergence activities both of larvae and adults, (iii) breeding seasons of the fruitflies, (iv) ovipositional behaviour of C. capitata with reference to coffee berry age, (v) a comparison of sampling methods in the estimation of coffee fruitfly populations in the field,

and (vi) determination of economic importance of the fruitflies in Kenya. Knowledge on these aspects was seen as a necessary prelude to future development of fruitfly control programmes. The studies recorded here were done from July, 1973 to December, 1974.

(ii) LITERATURE REVIEW

The life history of C. capitata is well documented (Christenson and Foote, 1960). However, it has been included in these studies for comparative purposes with C. rosa and T. coffeae. Working in Hawaii and Rhodesia respectively, Back and Pemberton (1918) and Carnegie (1962) have recorded the incubation period of the egg of C. capitata as 2 to 4 days. Previously, Severin (1913) had shown that the period was as long as 18 days under cool weather and also in green fruits. Carnegie (1962) also observed that under the same conditions as those stated by Severin (1913), eggs may fail to hatch altogether. Between 14 and 28°C, Back and Pemberton (1918) found the larval period to last 6 to 11 days with an average of 2 days between the instars. A total of 4 instars preceeded the pupal stage. According to Severin (1913), the larvae reared on green fruits took longer periods to develop than those reared on ripe ones. Christenson and Foote (1960) noticed that the larvae pupated in the soil, and the pupal period was 12 to 15

days between 11 and 24°C. Working at Ruiru, Kenya, Ongute (1970) showed that the larval stage took 9 to 15 days under unspecified temperature and humidity conditions. He also observed that moisture did not prolong the pupal duration although it affected the survival of the pupae.

In Brazil, Bondar (1926) found that adult populations of C. capitata were present in every fruiting season of coffee. But in Kenya, Graham (1959) noted that large populations of C. capitata and C. rosa were present in coffee and peach plantations throughout the year. Working in Argentina, South America, McBride (1935) showed that coffee fruitfly population build-up in any one season was not dependent on temperature, humidity or rainfall. Ritchie (1928) was the first person to suggest that the larvae of the fruitflies fed on the stalk of the coffee berry causing a secondary rot which affected the stalk and caused the berry to drop. This may be the reason why McCrae (1956) attributed premature coffee berry drop in Kenya to fruitfly larvae which caused an abscission layer on the stalk.

(iii) SITES OF THE STUDY

This study was conducted mainly on the Ruiru Coffee Research Station Farm and the experiments were set up on plots at Jacaranda and Rukera Estates.

Observations on the influence of seasons on the breeding history of the fruitflies were done both at the Coffee Research Station Farm and on the University of Nairobi Farm at Kabete. Ruiru Coffee Research Station lies on latitude 1^{o} 00' S and longitude 36^{o} 55' E at an altitude of 1659 m. The University farm at Kabete lies on latitude 1^{o} 15' S and longitude 36^{o} 44^{o} E at an altitude of 1960 m. The rainfall pattern at Ruiru shows a bimodal distribution with the long rains occurring from late March to mid-June and the short rains from October to December. The mean annual rainfall taken over 37 years is 87.3 mm and this is not adequate for coffee production. Irrigation is therefore practised on coffee throughout the year to supplement the water requirement. The mean maximum annual temperature is 24^{o}C and the mean minimum annual temperature is 12.9^{o}C. The mean relative humidity is 79%.

CHAPTER I

THE LIFE CYCLES OF THE COFFEE FRUITFLIES

INTRODUCTION

The development of an insect from egg to adult and again to egg represents its life cycle. Some insects, for example, the coffee fruitflies, complete more than one life cycle in a year and are known to be multivoltine. Some other insects complete one life cycle or one generation each year and are known as univoltine. Insects that complete one life cycle in a period longer than one year are said to be perennial. Knowledge of the life cycle of an insect pest assists in knowing the harmful stages, and thus enables planning effective contol measures against the pest.

MATERIALS AND METHODS

Materials for studying the life cycles of C. capitata, C. rosa and T. coffeae were obtained as larvae in ripe coffee berries from the field. Five hundred ripe coffee berries from different trees were placed in a breeding cage constructed from a 4-gallon tin (Plate 1). The cage was placed horizontally on a bench in the insectary and a layer of previously sterilized sand was spread on the base of the tin to a depth of 2 cm to act as a medium in which the larvae pupated. The coffee berries were evenly spread on the

sand before the open end of the tin was sealed. A 2 cm hole was cut in the centre at one end of the cage and fitted with a 2 x 15 cm glass tube that was open at both ends. The external opening of the tube was covered with a nylon mesh held in position by rubber bands to prevent the emerged flies, which were attracted by the light to the tube, from escaping. Three such cages were set up in the insectary at a temperature of 24 ± 2°C and relative humidity of 50 - 80%. Emerged fruitflies were removed from the tube every morning, counted and identified. Different species were confined in separate rearing cages (Plate 2). This method yielded enough flies for all the life cycle experiments.

A total of 40 adult flies comprising of equal number of females and males of each species were kept in a rearing cage. The rearing cage was constructed from perspex material and measured 27 x 26 x 25 cm. The flies were fed on a solution of 10 parts honey, and 10 parts hydrolysed protein (buminal), and 80 parts water by volume. Most females became gravid after ten days and were thereafter presented every day with 20 clean berries to serve as ovipositional media. These berries had developed under fly-proof cages (Plate 3). The 20 berries were examined every morning for ovipositional punctures and the punctured ones were kept in kilner jars covered with wet blotting papers to minimise

evaporation and increase humidity. The flies were presented with a fresh lot of 20 clean berries every time the old lot of berries was removed from the cage. The berries in the kilner jars were held in the laboratory under room temperature (min. mean 21.6°C; max. mean 26°C) and relative humidity ranging from 50% to 80%. The hatched eggs were determined by dissecting 5 berries from each kilner jar every day starting on the second day after oviposition.

The larval developmental period was determined by rearing single larvae on a small quantity of ripe pawpaw tissue in individual glass vials in which their development could be observed. This method was resorted to because, under normal conditions, the larvae develop within the coffee berries making it difficult for their developmental stages to be observed. Fruitfly eggs laid in clean coffee berries were therefore transferred to the pawpaw slices immediately after they were oviposited. The first instar larvae were then transferred from the pawpaw slices to individual vials containing a small amount of the pawpaw tissue.

The larvae emerging from the coffee berries in the kilner jars (some ovipunctured berries were not dissected to determine the incubation of the egg) were allowed to pupate in sterilized sand which was kept slightly moist by sprinkling water frequently.

The kilner jars were covered with nylon mesh held in position by rubber bands to prevent emerged adults from escaping. There was a separate kilner jar for each species. The pre-oviposition period of each species was determined by confining some females and males together immediately after their emergence and supplying them with 20 clean ripe coffee berries starting on the first day after emergence.

RESULTS

Descriptions of the developmental stages and their duration.

(i) Ceratitis capitata: The Mediterranean Fruitfly.

This species is an average sized fly with iridescent wine coloured eyes, grey thorax with black spots, hyaline wings which have black, brown and ochraceous markings (Plate 4). The male is easily distinguished by the two horn-like hairs ending in clubs located near the antennae. The ovipositor of the female is about half as long as the rest of the abdomen. The length of 10 females measured from the head vertex to the abdomen tip varied from 5 to 6 mm, while the length of the same number of males varied from 4.5 to 5 mm. The antennae are aristate with individual aristas longer than the main

stem. The thorax dorsum has black bristles whereas the abdomen is characterised by yellow and black crossbands, the former being broader and more conspicuous. The ovipositor is horny and is usually enclosed in a sheath bearing small bristles. The fly sticks its wings when at rest or walking.

The egg: The egg is small and spindle-shaped, 1.00 mm in length and 0.4 mm in diameter. It is white in colour. The surface is smooth and shiny when viewed under a microscope. Eggs are laid under the skin in a ripening coffee berry in punctures made with the female's ovipositor. The number of eggs range from 1 to 9 per puncture, but 2 and 3 are more common.

The larva: The larva is cylindrical in shape, tapering anteriorly and without locomotive appendages (Plate 6). The length of 10 third larval instars ranged from 6 to 8.5 mm. The first and second instars are white but the third instar can be either white, yellow or brown. Outside the berry, the larva moves using body muscles and a pair of hooks at the mouth. It loops and moves in sudden jumps. The third instar larva has an amphipneustic tracheal system and a pair of posterior spiracles each containing three simple slits. It has 12 apparent segments and a reduced head which is incomplete posteriorly and can be withdrawn into the thorax. The mean widths of head

capsules of 10 larvae of each instar were as follows:-

First instar	0.19 mm
Second instar	0.31 mm
Third instar	0.51 mm

The pupa: The pupa is whitish to brownish in colour and generally resembles that of the species of Cyclorrhapha (Plate 5). It is enclosed in a larval skin which hardens forming an outer shell or puparium. The puparium has 12 apparent segments. The length of 10 measured puparia ranged from 5 to 7 mm.

Incubation period

Out of 103 eggs that were observed at a mean temperature of 23.8 $\pm$ 2^{o}C, 68 hatched and 35 failed to hatch. The incubation period ranged from 2 to 5 days. Of these, 15 hatched after 2 days, 9 after 3 days, 33 after 4 days and 11 after 5 days. Table 1 shows the number and percentage of eggs which hatched or failed to hatch after a specified number of days.

The larval period

The larval period of 79 specimens reared in the laboratory at a mean temperature of 23.8 $\pm$ 2^{o}C (relative humidity 50 - 80%) on pawpaw tissue ranged from 6 to 12 days. Most completed

their larval development between 10 and 12 days. Table 2 shows the variations in the durations of larvae maintained under similar conditions.

The pre-pupal and pupal durations

Of the 79 larvae that entered pre-pupal and pupal stages at a mean temperature of 23.8 $\pm$ 2°C and a relative humidity ranging from 50 - 80%, only 47 completed their development. Only one fly emerged from a pupa 12 days after pupation. Most flies emerged on the 14th and 15th day. Table 3 shows the variations in the durations of the pupae maintained under the same conditions.

The callow adult

The wings of the newly emerged fly were colourless and remained folded above the abdomen for about 30 minutes. In an hour's time the wing colour pattern began to show. The fly then started to walk with the wings stuck out to the sides of the body. Pre-oviposition period of 10 females ranged from 5 to 7 days.

(ii) Ceratitis rosa: Natal Fruitfly

The adult: Adults of this fruitfly closely resemble C. capitata (Plate 7). The length of 10 females from head vertex to abdomen tip ranged from 5 to 6.5 mm and the length of the same number of males ranged from 4.5 to 5.5 mm. Eyes are iridescent and greenish in

colour. The antennae are aristate with individual aristas longer than the main stem of the antenna. The thorax is greyish with black spots on the metanotum. Thoracic bristles are very conspicuous and the wings are hyaline with black and grey bands. The abdomen is hairy characterised by black and white circular bands. When fully extended the ovipositor is half as long as the rest of the body and short bristles are found on the horny sheath which encloses the ovipositor.

The egg: The egg is small and spindle-shaped, 1.00 mm long and 0.4 mm in diameter at the thickest spot. It is usually creamy white in colour with a smooth and shiny surface when viewed under a microscope. Eggs are laid in batches in cavities beneath the skin of ripe coffee berries made with the aid of the ovipositor. There are usually 2 to 7 eggs per batch.

The larva: The larva is cylindrical in shape tapering anteriorly and legless (Plate 9). Third instar larvae range from 6 to 8.5 mm in length at maturity. First and second instar larvae are white, but the third is either white or yellowish-brown and has 12 apparent segments. Outside the berry, its movement is as described for C. capitata. Each of the two posterior spiracles contain three simple slits and the tracheal system is amphineustic. The mean widths of 10 head capsules of each instar were as follows:

First instar	0.19 mm
Second instar	0.32 mm
Third instar	0.51 mm

The larva's head is incomplete posteriorly and can be withdrawn into the thorax.

The pupa: It is brownish to red-brown in colour and generally resembles the pupa of the species of Cyclorrhapha (Plate 8). The length of 10 pupae ranged from 5.5 to 7 mm. The pupa has 12 apparent segments.

Incubation period:

A total of 55 eggs of C. rosa were observed at a mean temperature of 23.8 $\pm$ 2°C and a relative humidity ranging from 50 - 80%. Of these, 29 eggs hatched, 6 after 3 days, 13 after 4 days and 10 after 5 days. Table 4 shows the variations in incubation period of eggs maintained under the same temperature and humidity conditions.

The larval period:

The feeding period of 63 larvae reared on ripe pawpaw at a mean temperature of 23.8 $\pm$ 2°C and 50 - 80% relative humidity ranged from 6 to 12 days. Only 2 larvae completed their development in 6 days. Most of the larvae took more than 10 days to complete their development as shown in Table 5.

The pre-pupal and pupal period

The combined pre-pupal and pupal durations of 70 pupae ranged from 12 to 15 days. Five adults emerged after 12 days, 8 after 13 days, 30 after 14 days and 27 after 15 days.

The callow adult

Wings of newly emerged adults were colourless but colour pattern started to appear after an hour. Wings remained folded above the abdomen for about 30 minutes but the fly could walk from place to place. Pre-oviposition period of 10 females reared in the laboratory ranged from 5 to 9 days.

(iii) Trirhithrum coffeae

The adult: This species was first described by Bezzi as Trirhithrum coffeae. It is smaller than C. capitata and C. rosa. It is black with light green, iridescent eyes. The length of 10 female flies varied from 4.5 to 5 mm measured from head vertex to abdomen tip. Wings are mottled but thorax and abdomen are black. Legs are also black with white tarsi. Each sex may be distinguished by its wing pattern. The male has a peculiar diffuse pale wing, whereas female wings have sinuous marginal bands.

Both sexes have a trace of narrow yellow notopleural stripe which is usually stronger in the male. In the female, the hyaline division between the marginal and the cubital bands end squarely on the upper cross-vein. The adult fly is shown in Plate 10.

The egg: The egg is white, spindle shaped and microscopic. The mean measurements for 10 eggs were 0.8 mm in length and 0.3 mm in diameter. It is smooth and shiny when viewed under a microscope. Eggs are laid singly in batches of 2-3 in punctures made with the aid of the ovipositor under the skin of ripening coffee berry.

The larva: The length of 10 larvae varied from 5 to 7 mm. The larva is cylindrical in shape, tapers anteriorly and has no locomotive appendages (Plate 12). It moves in the same way described for the other two species. It is white in colour with 12 segments and two posterior spiracles each bearing three simple slits. The tracheal system of the third instar larva is amphipneustic. The head is reduced and incomplete posteriorly and can be withdrawn into the thorax. Mean widths of 10 head capsules of each instar were as follows:

First instar	0.14 mm
Second instar	0.24 mm
Third instar	0.38 mm

The pupa: The pupa is barrel-shaped, brownish in colour with a mean length 6 mm. Pupation takes place in the soil. Each pupa shows 12 distinct segments. The pupa of this fly is shown in Plate 11.

The incubation period

Incubation period of 45 eggs recorded at a mean temperature of 23.8 $\pm$ 2°C and a relative humidity of 50 - 80%, ranged from 3 to 5 days. Of the 45 eggs studied, 8 hatched after 3 days, 14 after 4 days and 13 after 5 days. Table 6 shows the number of eggs which hatched or failed to hatch after a specified duration in days.

The larval period

The feeding period of 52 larvae which were reared under similar conditions as the eggs and fed on pawpaw tissue ranged from 8 to 14 days. Most larvae completed their duration on the 11th day after hatching from the egg. Very few of them pupated on the 8th or 9th day. Table 7 shows the variations in the feeding period taken by the larvae reared under the same conditions.

The pre-pupal and pupal duration

Observations were made on 51 pupae under similar conditions as those of the larvae. The combined pre-pupal and pupal duration took 14 to

19 days. Most pupae, however, yielded adults on the 14th and 15th days of their duration (Table 8).

The callow adult

Wings of newly emerged adults were colourless at first. An hour later the colour pattern started to appear. The wings remained folded above the abdomen for about 30 minutes during which time the fly could not fly. On unfolding, the wings characteristically stuck out to the sides of the insect's body. Pre-oviposition period of 10 adult females reared in the laboratory ranged from 9 to 12 days.

DISCUSSION

C. capitata and *C. rosa* adults are generally similar in appearance. However, they are easily distinguished by a number of characteristics. Although *C. rosa* adults are bigger than *C. capitata* adults, the main distinguishing features occur on the abdomen and thorax. They are also different in eye colour and wing pattern. The abdomen of *C. capitata* is characterised by yellow and black cross bands whereas that of *C. rosa* is characterised by black and white cross bands. Wings of *C. capitata* have black, brown and ochraceous markings while those of *C. rosa* have grey bands. The eyes of *C. capitata* are wine coloured whereas the eyes of

C. rosa are green in colour. T. coffeae is quite distinct from the other two species in that it is the smallest of the species and has a black body. The immature stages of the three coffee fruitflies are closely similar except in size. The larvae of C. rosa are the biggest while those of T. coffeae are the smallest. Life history studies have also revealed that durations taken by developmental stages of the different species are more or less equal. Reared under similar conditions of 23.8 $\pm$ 2°C, C. capitata completed its life cycle in a minimum of 20 days and a maximum of 33 days. This life cycle duration of C. capitata is similar to that observed by Christenson and Foote (1960) at a lower temperature of 14 to 18°C. Also, it has been shown that cool weather and green fruits may extend the larval feeding period (Christenson and Foote, 1960; Carnegie, 1962) but, these factors were not tested in the present studies. Generally, durations of immature stages in the three species of fruitflies were also equal. The synchronisation of the life cycles in the three species may be of advantage to the farmer in the timing of application of control measures. Emerging larvae in search of suitable pupation sites or emerging adults from the soil may be easily dealt with by a selected control method. On the other hand, the occurrence of the three species at the same time

accounts for the large number of adult flies damaging the berries through oviposition and causing them to drop.

Table 1. Number of days required for hatching by the eggs of C. capitata at 23.8 ± 2°C

Duration in days	No. and % of eggs hatchings		No. and % of eggs failing to hatch		Total No. of eggs
	No.	%	No.	%	
2	15	75	5	25	20
3	9	36	16	64	25
4	33	75.3	12	26.3	45
5	11	84.6	2	15.4	13

Table 2. The number of days required to complete development by larvae of C. capitata at 23.8 ± 2°C

Duration in days	Number of larvae completing development	% of the total
6	2	2.53
7	3	3.80
8	7	8.86
9	11	13.92
10	17	21.52
12	19	24.05

Table 3. The number of days required by the pupae of *C. capitata* before adult emerged at 23.8 ± 2°C

Duration in days	No. of adults emerged	% of the total
12	1	2.13
13	5	10.64
14	20	42.55
15	18	38.30
16	3	6.38

Table 4. The number of days required for hatching by eggs of *C. rosa* at 23.8 ± 2°C

Duration in days	No. and % of eggs hatching		No. and % of eggs failing to hatch		Total No. eggs
	No.	%	No.	%	
3	6	30	14	70	20
4	13	65	7	35	20
5	10	66.3	5	33.3	15

Table 5. The number of days required by larvae of *C. rosa* to complete development at 23.8 ± 2°C

Duration in days	No. of larvae completing development	% of the larvae
6	2	3.17
7	2	3.17
8	4	6.35
9	6	9.52
10	15	23.81
11	20	31.75
12	14	22.22

Table 6. The number of days required for hatching of *T. coffeae* at 23.8 ± 2°C

Duration in days	No. and % of eggs hatching		No. and % of eggs failing to hatch		Total No. of eggs
	No.	%	No.	%	
3	8	80	2	20	10
4	14	73.7	5	26.3	19
5	13	81.3	3	18.7	16

Table 7. The number of days required by larvae of *T. coffeae* to complete development at 23.8 ± 2°C

Duration in days	No. of larvae completing development	% of larvae
8	2	3.85
9	3	5.77
10	10	19.32
11	15	28.85
12	10	19.32
13	5	9.62
14	7	13.46

Table 8. The number of days required by pupae of *T. coffeae* before adult emergence at 23.8 ± 2°C

Duration in days	No. of adults emerged	% emergence
14	22	43.14
15	15	25.50
16	5	9.80
17	7	13.73
18	2	3.92
19	2	3.92

Plate 1 Tin cage for rearing fruitfly larvae collected from field in infested coffee berries.

Plate 2 A cage for rearing adult fruitflies.

Plate 3 A fly-proof cage in which mature coffee trees were enclosed for infesting with fruitflies.

Plate 4 C. capitata adult

Plate 5 C. capitata pupae

Plate 6 C. capitata larvae

Plate 7 C. rosa adult

Plate 8 C. rosa pupae

Plate 9 C. rosa larvae

Plate 10 T. coffeae adult

Plate 11 T. coffeae pupae

Plate 12 T. coffeae larvae

CHAPTER II

STUDIES ON THE TIMING OF EMERGENCE ACTIVITIES

INTRODUCTION

A great deal of information on the determinants of fecundity and developmental rates of fruitflies is available (Bateman, 1972; Christenson and Foote, 1960). They include moisture, temperature, light, food and natural enemies. However, no work has been done on determining the factors involved in the timing of emergence activity by the mature third instar fruitfly larvae from inside the fruit in search of suitable sites for pupation. Such information would be useful in the timing of the application of suitable control measures which would reach the larvae. Chemical control measures while the larvae are still within the fruit tissues are usually ineffective.

Studies on the timing of emergence activity of the adult fruitflies from their pupal skins was also made for similar reasons. The fruitfly pupae are not easily reached by chemicals used for control because they are buried in the soil or in the litter. However, newly emerged and hungry adults are more likely to readily feed on poisoned baits. Bardner (1974) developed a suitable method of controlling coffee fruitflies by using an organophosphorus insecticide (Fenthion) and

hydrolysed protein (Buminal), the latter acting as a bait. The mixture was sprayed on every fourth row of coffee and besides minimising the cost, the method was not injurious to most parasites of fruitflies and other pests since only a quarter of the affected area was sprayed.

MATERIALS AND METHODS

Observations were initiated to determine the daily pattern of emergence of fruitfly larvae from inside the fruit and of adults from pupation sites. The larvae for the experiment were reared from berries infested with fruitfly larvae while still in the field. The larvae were kept in a cage (Plate 13) which was divided with a wire mesh into an upper and a lower chamber. The berries were evenly spread on the wire mesh in the upper chamber and the cage was closed and placed out of doors under a coffee tree. After maturing inside the berries, the third instar larvae emerged and dropped to the bottom chamber of the cage from where they were collected and counted daily at hourly intervals starting from 6 a.m. Larvae that emerged in a given hour were divided into two groups and one group was allowed to pupate in small boxes, containing sterilized sand, which were held in out-of-door cage (Plate 14) and the

temperature was recorded on a thermohygrograph. The other group was held indoors at a constant temperature of 24 $\pm$ 2°C. Emerging adult fruitflies were collected and identified.

RESULTS

Emergence of the third instar larvae from fruit

The data in Table 9 shows that most of the larvae of fruitfly emerged from the coffee berries in the morning hours when the temperatures were low. Of the total larvae 22.7% emerged at or before 6 a.m. when the mean temperature was 15°C as compared to 2.5% at 2 p.m. when the mean temperature was 26.5°C. The number of larvae emerging decreased with the rise in temperature. No larvae emerged after 2 p.m., or in the evening when the temperature was low. When daily increase in temperature was relatively rapid, the number of larvae emerging fell away more rapidly after 6 a.m. than when temperatures changed at a less rapid rate. Since larval emergence was observed to take place in darkness, light was thought to play no direct part in inducing emergence. Figure 1 shows the percentage hourly emergence of the larvae against temperature.

Emergence of adults from pupation

The number of adult fruitflies that emerged from the pupation sites under constant and fluctuating temperature is shown in Tables 10 and 11 and Figures 2 and 3. The number of the three species emerging from pupation sites were pooled together since C. rosa and T. coffeae were very few and yet their pattern of emergence was similar to that of C. capitata which was the dominant species. Both under constant and fluctuating temperatures adult fruitflies started to emerge from the sand very early in the morning when temperatures were low. Out of 646 flies that were studied under fluctuating temperature 22.3% emerged at 6.00 a.m. when the mean hourly temperature was 15°C. The rest emerged between 7.00 a.m. and 2.00 p.m. but the percentage emergence decreased as temperature increased (Table 10). At a constant temperature of 24 ± 2°C, 23.9% of 557 adult flies also emerged at 6.00 a.m. and the number emerging at each hourly interval decreased and reached minimum at 2.00 p.m. Under constant temperature the flies that emerged from pupation sites at 2.00 p.m. decreased to 2.6% while under the fluctuating temperatures the number decreased to 1.4%. The pattern of emergence of the adults was therefore similar to that of the larvae. No flies emerged after 2.00 p.m.

DISCUSSION

The results of these experiments show that most mature larvae seeking pupation sites emerged from coffee berries in the morning hours. The emergence pattern of the larvae followed a diurnal periodicity which appeared to be temperature-dependent. Emergence commenced before 6.00 a.m. and the numbers emerging during each successive hour decreased progressively with increasing temperature. The diurnal periodicity was thought to have some biological significance since the greatest number of larvae emerged at a time of the day when they could least suffer mortality due to effects of high temperature. This led to the conclusion that the diurnal periodicity in emergence of the larvae contributed to the survival of the species. However, knowledge of the pattern of emergence, coupled with the fact that emergence took place in the early hours of the morning when temperature were low may help in planning control programmes aimed at the larvae while emerging from the coffee berries.

Adult emergence from pupae also exhibited a diurnal periodicity but unlike the larval emergence, adult activity was temperature-independent. The possibility of light acting as a determinant was ruled out since fruitfly pupae were buried in the

litter or loose soil where light could not penetrate easily. However, Brett (1955) showed that a photoperiod of as little as one minute was sufficient to cause the adults of Drosophila melanogaster Meigen to emerge from pupae at the same time of the day illumination of the larvae had occurred. Similarly, the larvae of the coffee fruitflies were exposed to light for a very short period after emerging from fruits and this could have caused the adults to emerge from pupation sites during the same time illumination on the larvae had taken place. Emergence of most adult flies in the morning hours when the temperature was low is also advantageous in that the callow adults may not suffer high mortality due to effects of high temperature. However, from the farmer's point of view, this knowledge can help him in timing the control measures aimed at the adult flies.

Table 9 Time of emergence of mature larvae of fruitflies under fluctuating daily temperature

Time of emergence in day hours	Numbers emerging	% of emergence	Temperature in ^{o}C
06	219	22.7	15.0
07	184	19.1	16.0
08	150	15.5	16.5
09	121	12.5	17.0
10	107	11.1	18.0
11	78	8.1	20.5
12	53	5.5	21.0
13	29	3.0	25.0
14	24	2.5	26.5
TOTAL	965		

Table 10 Time of emergence of adult fruitflies from pupation site under natural conditions of daily fluctuating temperature

Time of emergence in day hours	Numbers emerging	% of emergence	Temperature in °C
06	144	22.3	15.0
07	123	19.0	16.0
08	101	15.6	16.5
09	81	12.5	17.0
10	72	11.1	18.5
11	52	8.0	20.0
12	36	5.6	21.5
13	20	3.1	24.5
14	17	2.6	26.5
TOTAL	646		

Table 11 Time of emergence of adult fruitflies from pupation site under constant temperature of 24°C

Time of emergence in day hours	Numbers emerging	% of emergence	Temperature in °C
06	133	23.9	24
07	114	20.5	24
08	93	16.7	24
09	70	12.6	24
10	63	11.3	24
11	41	7.4	24
12	24	4.3	24
13	11	2.0	24
14	8	1.4	24
TOTAL FLIES	557		

FIG·1 TIME OF EMERGENCE OF MATURE FRUIT FLY LARVAE UNDER FLUCTUATING DAILY TEMPERATURE AND LIGHT

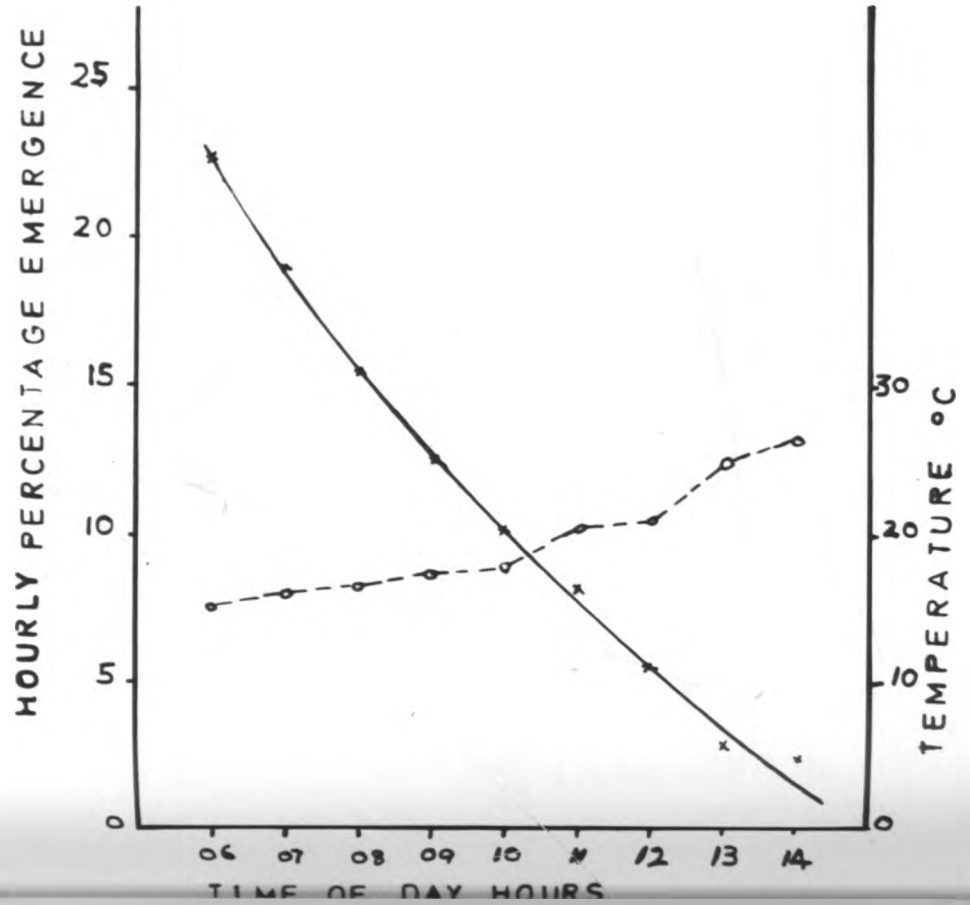


FIG. 2 TIME OF EMERGENCE OF ADULT FRUIT FLIES FROM PUPATION UNDER FLUCTUATING TEMPERATURE AND LIGHT

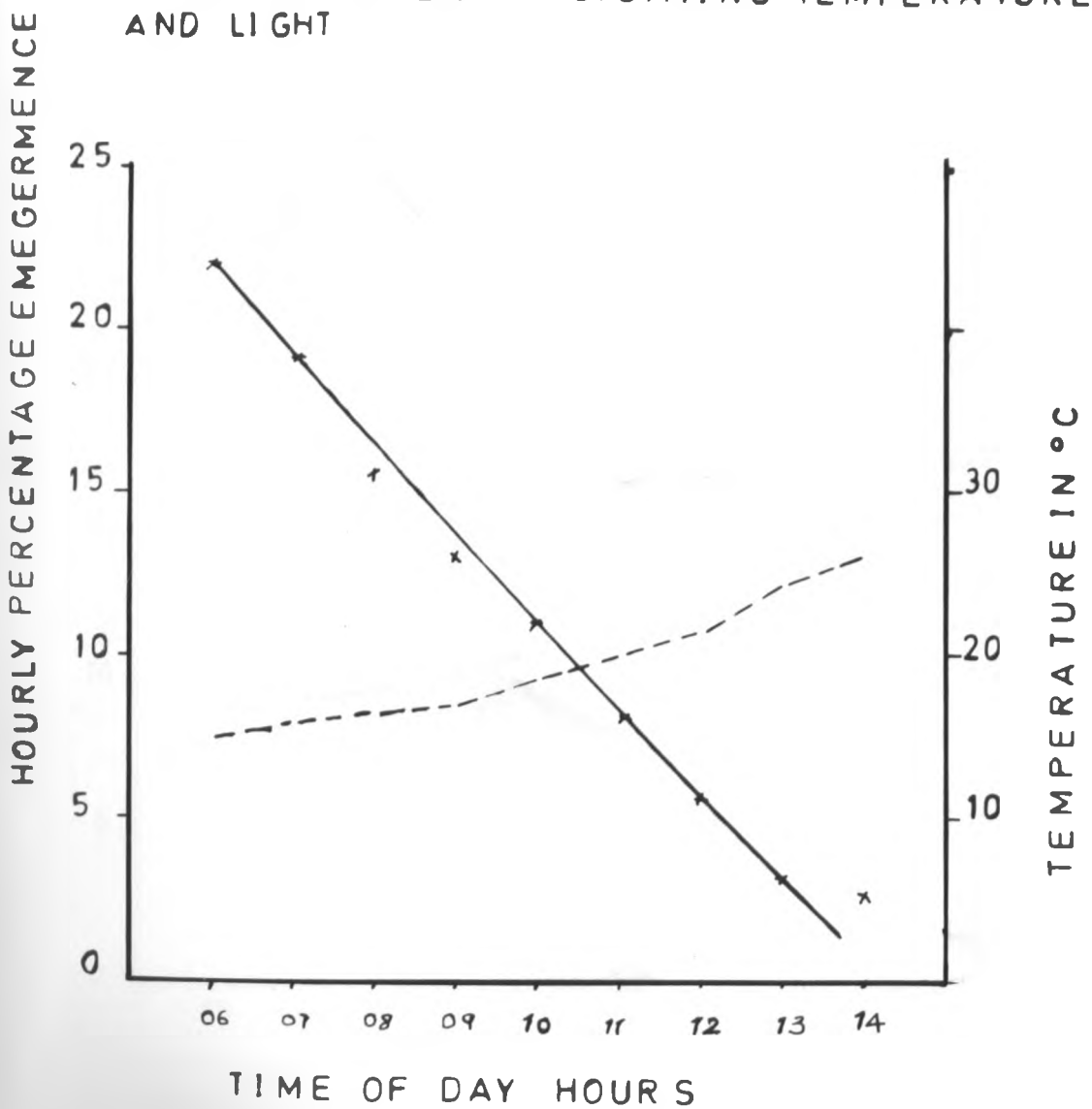


FIG.3 TIME OF EMERGENCE OF ADULT FRUIT FLIES FROM PUPATION AT CONSTANT TEMPERATURE OF 24° C

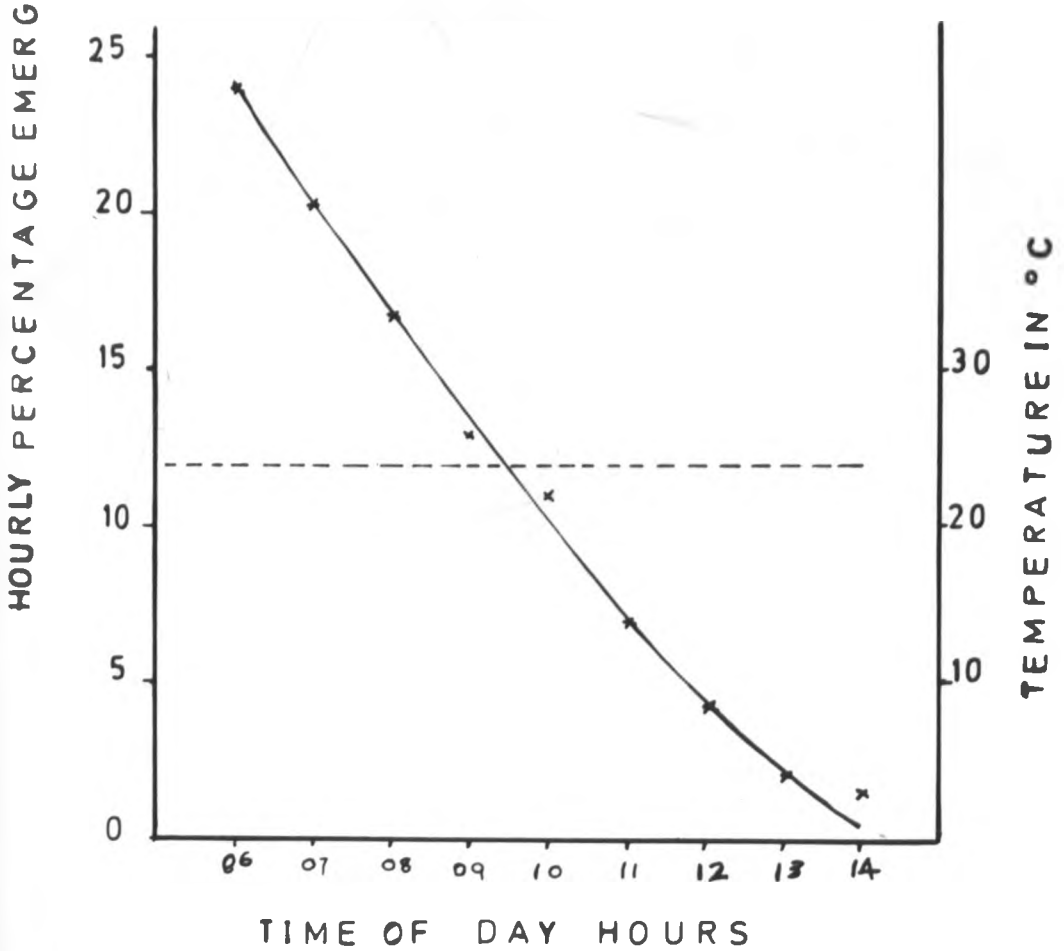


Plate 13 Tin cage for rearing larvae for time of emergence studies.

Plate 14 An out-door cage for rearing fruitflies.

CHAPTER III

COFFEE FRUITFLY BREEDING SEASONS IN KENYA

INTRODUCTION

Hitherto, no studies have been carried out to determine when fruitflies breed in coffee plantations in Kenya although Graham (1959) noted that C. capitata and C. rosa were present in coffee and peach plantations throughout the year. While working in Argentina, South America, McBride (1935) showed that coffee fruitfly build up in any one season was not dependent on humidity, temperature or rainfall. It has not been shown in Kenya whether these parameters would influence the occurrence of coffee fruitflies. In Brazil, Bondar (1926) observed that adult populations of C. capitata were present in every fruiting season of coffee. The present study was carried out partly to confirm whether this was the case in Kenya and partly because the knowledge obtained from the study would help in the synchronisation of any control programme of the coffee fruitflies.

MATERIALS AND METHODS

Studies on the seasonal history of the three species of fruitflies which breed in coffee in Kenya were carried out on the University of Nairobi farm at

Kabete and on the two estates, Jacaranda and Rukera, at the Coffee Research Station, Ruiru. The studies were done between July 1973 and June 1974. The two locations were selected for their different altitudes, Ruiru being lower than Kabete by 300 m. No attempt was made to change the system of naming the coffee plots at the Research Station. For that reason only plots 1, 3, 4 and 6 were selected from Jacaranda Estate while plot 'H' was selected from Rukera Estate. Rainfall and temperature records were maintained at the Coffee Research Station and monthly samples of ripe or unripe coffee berries from all plots were cultured at the beginning of each month. From each of the plots at Jacaranda 500 berries were cultured every month and from Rukera and the University farm a similar amount of berries was cultured from each site every month. The samples from every plot were separately incubated in breeding cages in the insectary at a temperature of 24 $\pm$ 2^{o}C and records of the species of fruitflies emerging from these berries were kept.

RESULTS

Figures 4 to 8 show the numbers and species of the fruitflies breeding in coffee berries from the areas of study. At Jacaranda, for example, ripe coffee berries were not available in plot 1 during the months of February, March, April and May 1974.

Samples of green berries taken from this plot during these months failed to yield any fruitflies after being cultured for more than one month. This indicated that the berries had not been infested with fruitflies. Fruitflies were obtained from ripe coffee berries sampled from the same plot in the remainder of the year showing that the ripe berries were infested with fruitflies (Fig. 4). T. coffeae was the most abundant species breeding in coffee berries in this plot and its peak coincided with peaks of ripening berries between July and September 1973. An earlier experiment on the study of the life cycles of the fruitflies had shown that the life cycle of each of the three species took approximately a month. A sample of ripe coffee berries taken in June 1974 produced the first generation during the second year of the study since the green berries taken in May did not yield fruitflies. It took approximately one month before any fruitflies emerged from this sample and this was the same period required for a complete life cycle.

In August 1973 and between February and May 1974, only green coffee berries were available on plot 3 at Jacaranda. Samples of green berries taken from this plot during these months did not produce

fruitflies indicating that they were not infected. During the rest of the year, monthly samples of ripe coffee berries yielded fruitflies showing that infestation had occurred. Unlike in plot 1, C. capitata was the most abundant in the plot followed by C. rosa and T. coffeae in that order. Also, C. capitata emerged most abundantly from samples of coffee berries taken in July, September and December 1973 than during any other time of the investigation. The high populations of C. capitata coincided with the bulk of the ripening crop and this suggested that breeding was accelerated when the crop started to ripen. Although there were few ripe coffee berries in January 1974, a heavy infestation of the berries suggested a competition on the breeding media by the adult flies which had emerged from pupation in December 1973 (Fig. 5).

Figure 6 shows the results of fruitflies breeding in coffee in plot 4 at Jacaranda. Samples of green berries taken in September 1973 and in March and April 1974 failed to yield any fruitflies. This suggested that infestation on this plot had not occurred by then. Ripe coffee berries sampled from the plot during the rest of the months produced fruitflies. Large numbers of C. capitata emerged from berries sampled in November to December 1973

and January 1974 when the harvesting season was in a peak. T. coffeae was the rarest species breeding in coffee on this plot. Although the green coffee berries samples from the plot in April 1974 failed to yield any fruitflies, ripe fruits of Kei-apple Dovyolis caffra L sampled from a hedge next to the plot yielded 20% C. capitata, 65% C. rosa and 15% Drosophila sp. and no T. coffeae. This was a clear indication that in the absence of ripe coffee berries, ripe fruits of the plant could serve as alternative host and act as a source of re-infesting coffee berries when the latter became available. The number and species of fruitflies sampled from coffee berries on plot 6 are shown in Figure 7. As in any other plot C. capitata was the most abundant species followed by C. rosa and T. coffeae in that order.

Ripe coffee berries sampled from plot 'H' at Rukera Estate during all other months except April 1974 yielded fruitflies of the three species. Failure of flies to emerge from the sample of green berries in April 1974 indicated that no fruitfly infestation had occurred on the plot by then. C. capitata was the species breeding most abundantly in ripe coffee berries on this plot. For six months

it accounted for more than 60% of the total fruitfly population. There were large populations of C. capitata in July 1973 and between February and May 1974. C. rosa was, however, more abundant than C. capitata in August, October and December 1973.

On the University of Nairobi farm at Kabete, samples of green coffee berries taken in March and April 1974 failed to yield any fruitflies and this was an indication that there was no infestation during that period (Fig. 9). Samples of ripe coffee berries cultured during the rest of the period yielded fruitflies of the three species. Only three specimens of T. coffeae were, however, recorded during the period of the study. This suggested that T. coffeae was a rare species in the area probably due to the difference in altitude, Kabete being higher than Ruiru by almost 300 m. There were two breaks of the breeding cycles at Ruiru which occurred in August and September and between February and May whereas only one break was observed at Kabete in March and April.

FACTORS AFFECTING FRUITFLY ABUNDANCE

The data in Table 12 show the numbers of fruitflies that were cultured from berries at Ruiru Coffee Research Station, the monthly mean temperature

and the total monthly rainfall at the Station. This data shows that fruitfly abundance was not directly influenced by rainfall or temperature. In plots 1, 3 and 4, for example, the largest number of fruitflies occurred in July 1973 and this was the coldest and the third driest month during the period of the investigation.

In contrast, February 1974 was the hottest month but yielded the highest number of fruitflies in plot 6. The rainy season occurred in March through June 1974, and although this period was marked with high temperatures few or no fruitflies emerged from coffee berries sampled over the period. The abundance of fruitflies was directly influenced by the abundance of ripening coffee berries.

DISCUSSION

Adult populations of C. capitata in Brazil have been found to occur in every fruiting season (Bondar, 1926). McBride (1935) also found that fruitfly population build up in any one season in Argentina was not dependent on temperature, rainfall or humidity. This was supported by studies made in the same country by Puzzi and Orlando (1965). The present studies show that fruitflies were present in Kenya for most of the year. Their occurrence appeared to be determined simply by the availability of the ripening or ripe coffee berries which offered the breeding media. In Uganda, Greathead (1972) found that the occurrence of T. coffeae in Robusta coffee corresponded with the availability of ripening berries. At Ruiru, the author of the present work has observed that rainfall or overhead irrigation alternated by suny days would accelerate ripening of mature coffee berries and such conditions accelerate the build up of fruitfly populations. During the whole period of this study, it was also observed that frequent overhead irrigation was responsible for opening of coffee flower buds at different times of the year. This tended to encourage continuous breeding of

fruitflies for most of the year due to availability of ripe coffee berries resulting from the different flowerings.

The most dominant species of fruitfly breeding in coffee berries in Kenya is C. capitata. C. rosa and T. coffeae also occur in Kenya but in smaller populations than C. capitata. Since T. coffeae was found by Greathead (1972) to be the most abundant fruitfly breeding in Robusta coffee in Uganda, it would appear from the present studies that Arabica coffee is probably less attractive than Robusta coffee as a breeding source for this species. The practice of hedging coffee plots with Kei-apple should be discouraged since it appears to be a good alternative host of fruitflies from which re-infestation occurred with the availability of ripe coffee berries.

Table 12 Insects reared monthly from Arabica coffee samples

Month	Plot 1	Plot 3	Plot 4	Plot 6	Plot 'H'	Mean temp. °C	Rainfall
July 1973	638	638	564	215	1010	16.8	6.8
August	411	-	244	147	9920	17.5	4.7
September	608	332	-	-	1381	19.0	37.0
October	279	479	536	282	1221	20.2	34.6
November	411	526	148	117	2343	20.0	128.1
December	107	277	270	144	3231	18.9	28.1
January 1974	55	298	140	205	251	19.4	Nil
February	-	-	131	325	350	21.0	20.2
March	-	-	-	-	416	20.7	118.7
April	-	-	-	-	-	20.2	279.6
May	-	-	205	-	666	22.0	70.2
June	185	116	38	54	71	17.1	105.0

FIG 4 PERCENTAGE OF SPECIES OF FRUIT FLIES EMERGING FROM COFFEE BERRIES FROM PLOT 1 AT JACARANDA ESTATE

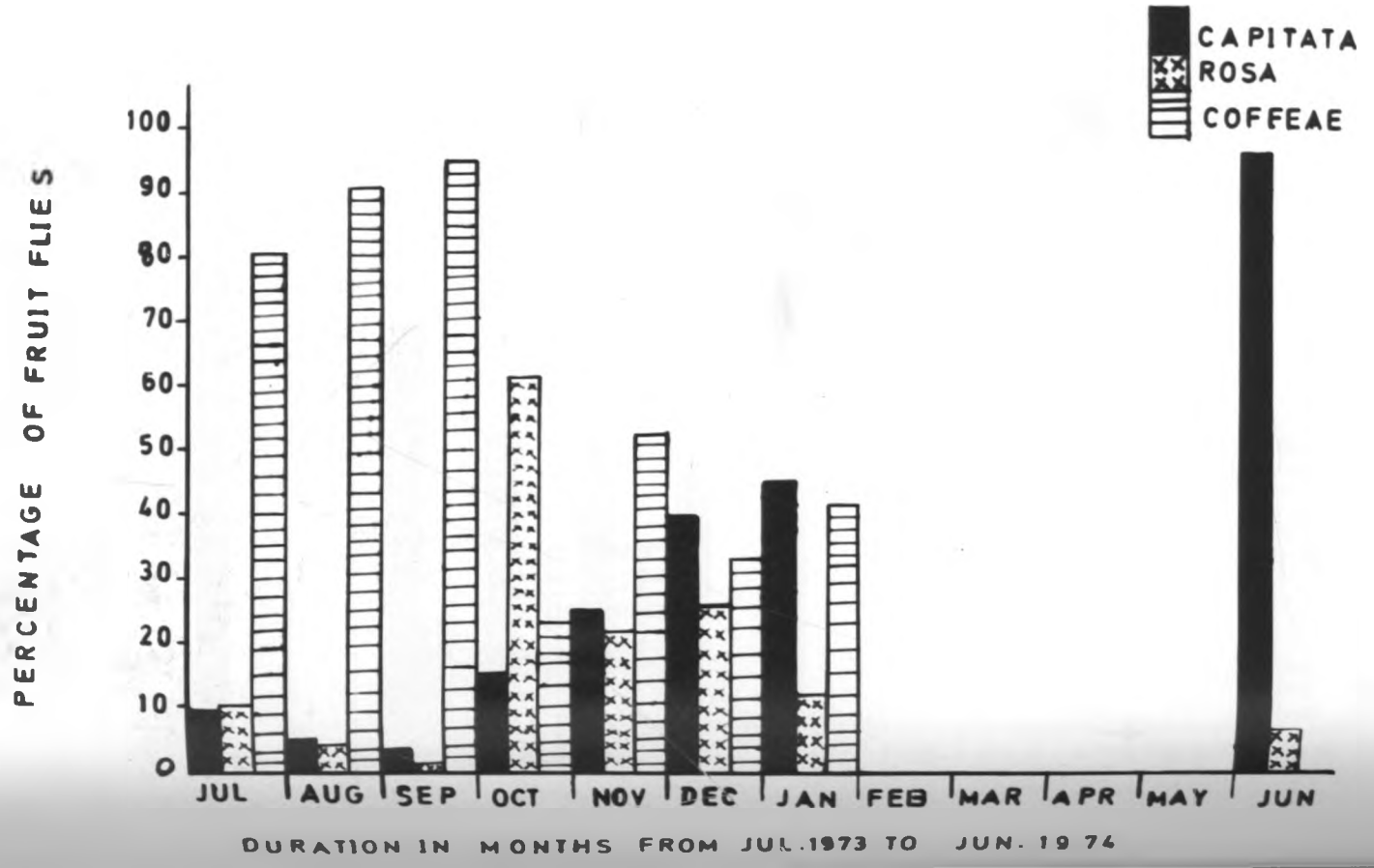


FIG. 5 PERCENTAGE OF SPECIES OF FRUIT FLIES EMERGING FROM COFFEE BERRIES FROM PLOT 3 AT JACARANDA ESTATE

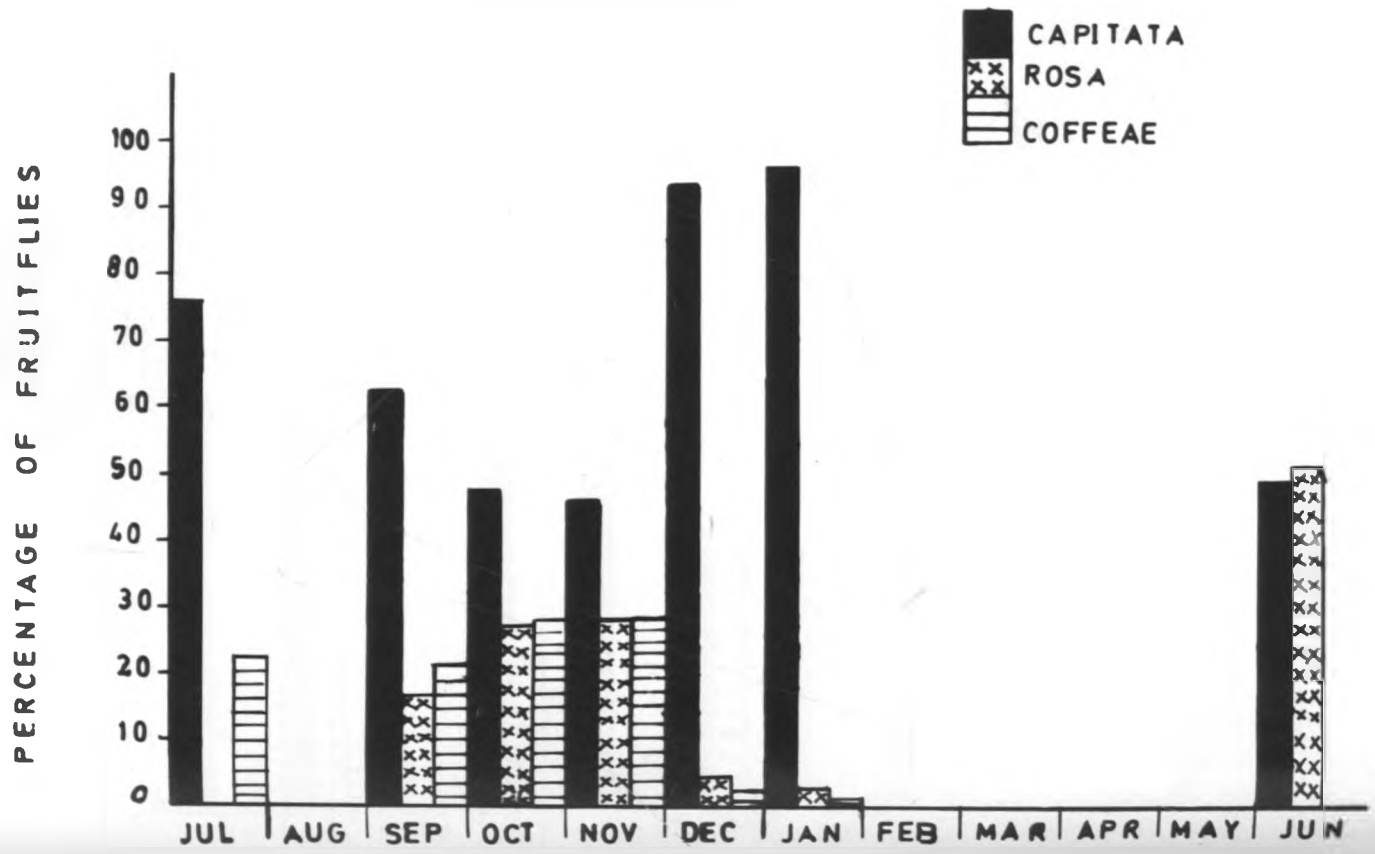


FIG. 6 PERCENTAGE OF SPECIES OF FRUIT FLIES EMERGING FROM COFFEE BERRIES FROM PLOT 4 AT JACARANDA ESTATE

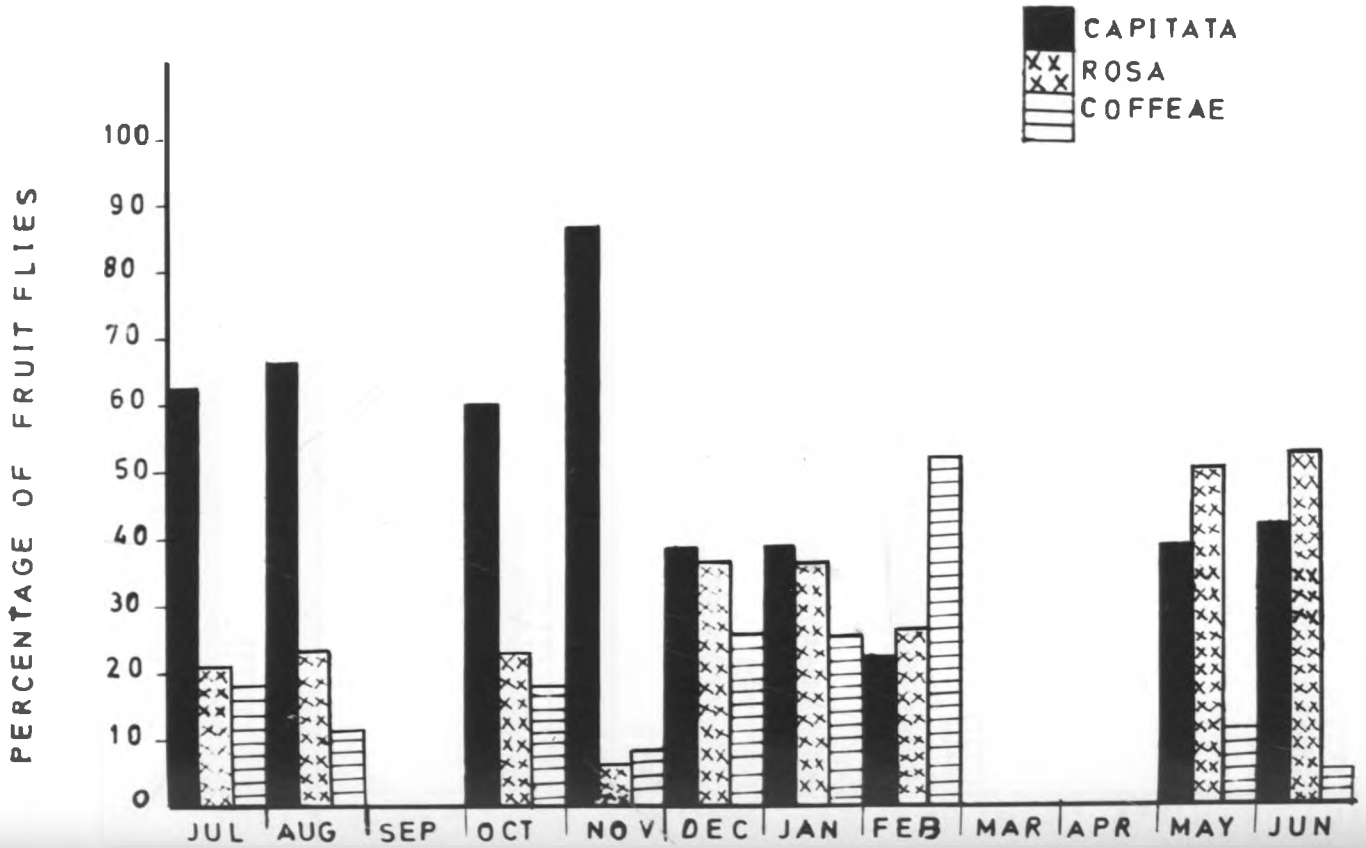


FIG. 7 PERCENTAGE OF SPECIES OF FRUITFLIES EMERGING FROM PLOT6 AT JACARANDA ESTATE

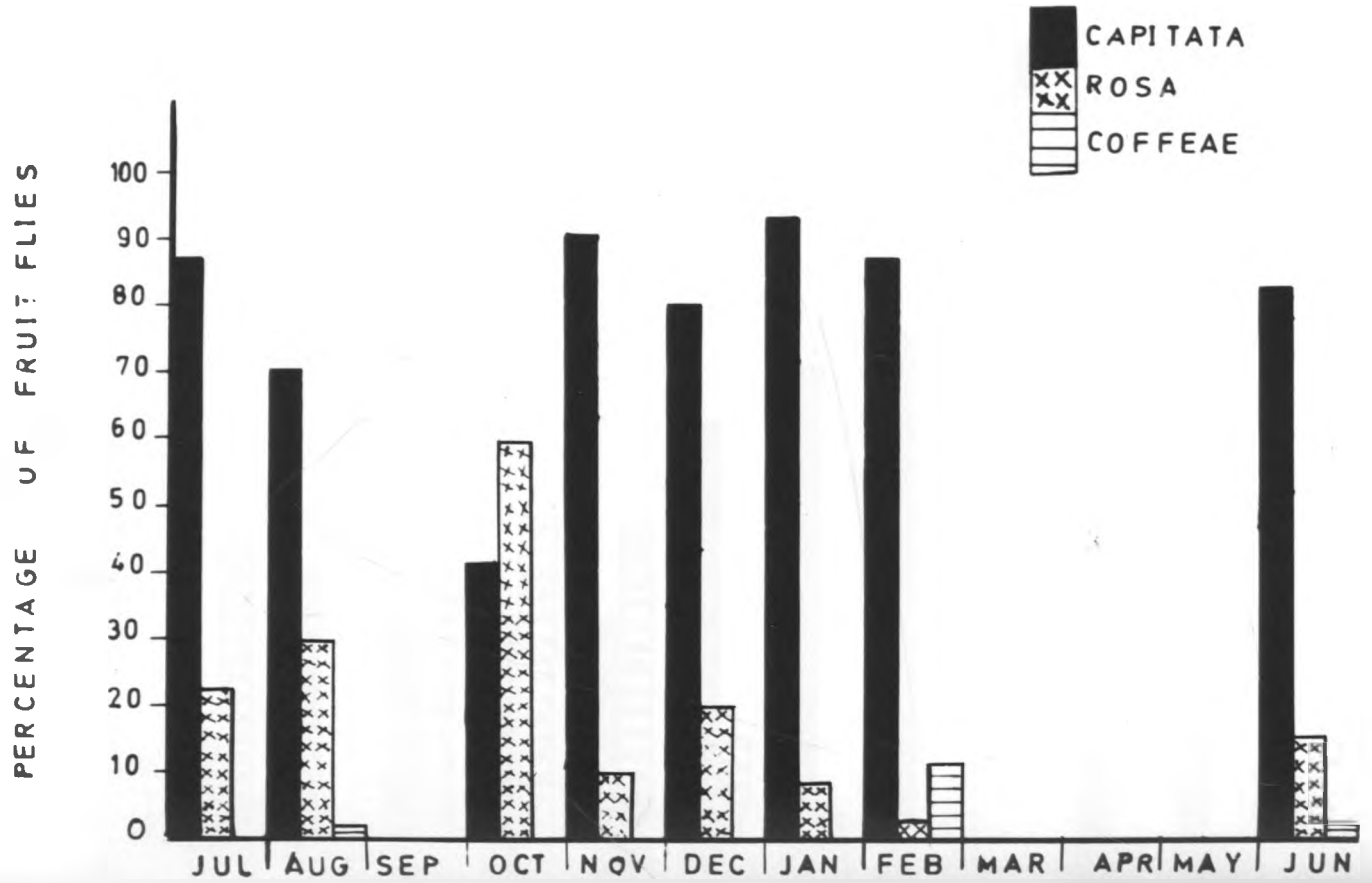


FIG. 8 PERCENTAGE OF SPECIES OF FRUIT FLIES FROM COFFEE BERRIES FROM PLOT 'H' AT RUKERA ESTATE

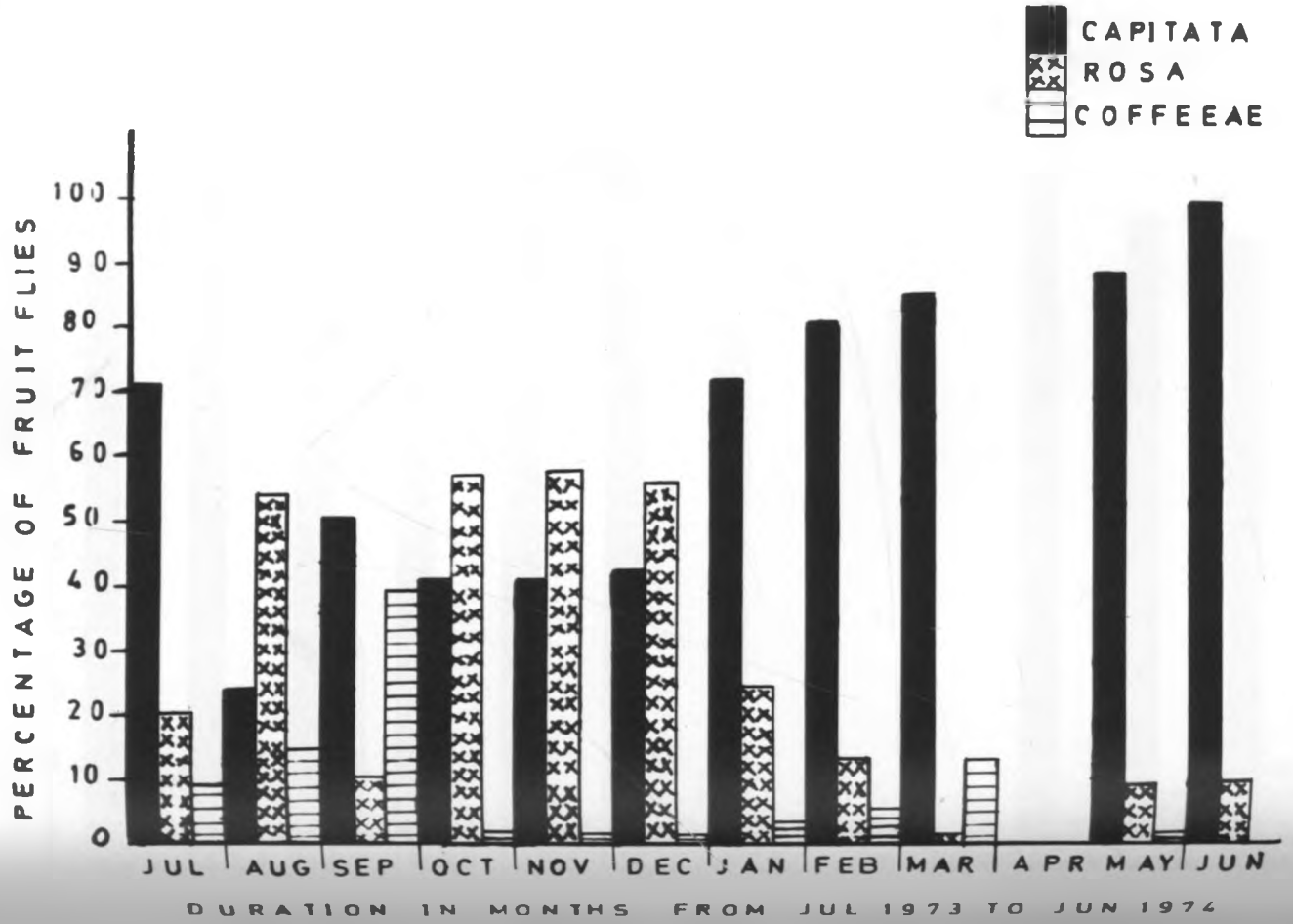
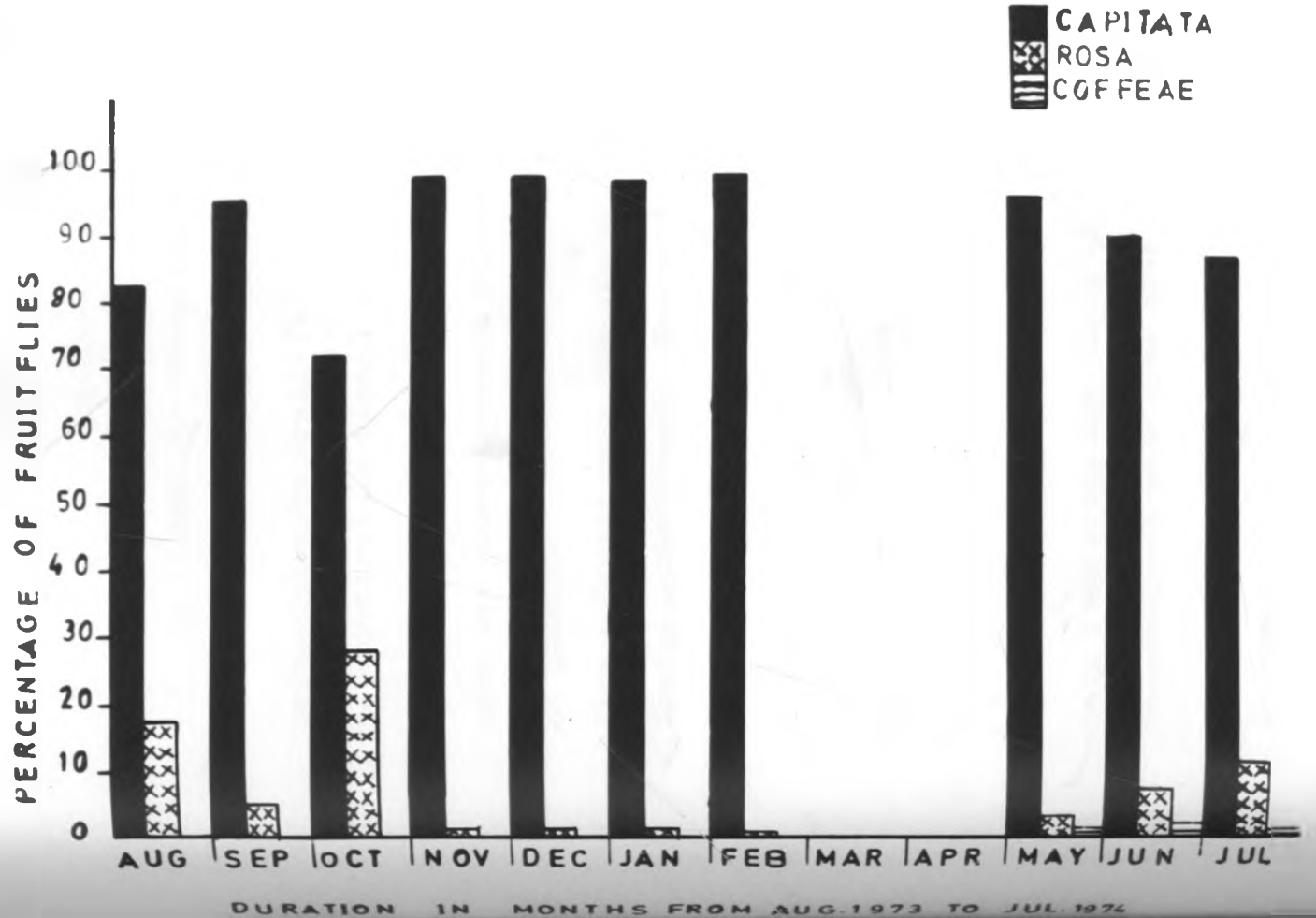


FIG. 9 PERCENTAGE OF SPECIES OF FRUIT FLIES EMERGING FROM THE UNIVERSITY FARM AT KABETE



CHAPTER IV

OVIPOSITIONAL BEHAVIOUR OF C. capitata WITH REFERENCE TO COFFEE BERRY AGE

INTRODUCTION

Up to now, no investigations have been made to establish the coffee berry age preferred for oviposition by fruitflies. Such information could be important in planning strategies for control programmes of the fruitflies. Martin (1950) showed that the attractiveness of fruits to ovipositing C. capitata females varied with different fruits. Citrus fruits were not attractive until the first few fruits had ripened. The studies reported here were made at Ruiru Coffee Research Station to determine the age-group of coffee berries preferred for oviposition by C. capitata. The coffee age-groups were categorised as follows: immature green berries, mature green berries, mature green-yellow berries, mature yellow-red berries and mature red berries. Both laboratory and field experiments were used. Observations were also made on the actual activities of the female C. capitata leading to oviposition and during the act of oviposition to ascertain any behavioural peculiarities in the fly. It was hoped that such knowledge would provide additional information on the causes of premature coffee berry-drop in the various age groups.

MATERIALS AND METHODS

Developing coffee berries were categorised as indicated above and coded as follows: immature green berries (A), mature green berries (B), mature green-yellow berries (C), mature yellow-red berries (D) and mature red berries (E). The berries used for laboratory observations were free from prior infestation since they had developed on coffee branches previously enclosed in sleeve cages (Plate 15) immediately the development of the berries had reached the pinhead stage. For each of the categories, 20 berries were picked separately, and all the berries from the five categories were thoroughly mixed together in a small tray before presenting them to gravid female fruitflies. The berries were exposed to the flies for 24 hours before they were removed and examined for oviposition punctures. Those ovipunctured were dissected under a microscope to examine for eggs. The experiment was replicated five times.

Field observations were also carried out to determine whether the age group of berry preferred for oviposition in the laboratory was simulated in the field. For each category, 500 berries were randomly picked from the field and examined for oviposition punctures. The punctures were then examined for fruitfly eggs or larvae and the numbers recorded. The experiment was also replicated five times.

Twenty berries from the mature yellow- red category which appeared to be favoured for oviposition by C. capitata were presented to gravid females of the same fly with the aim of determining behavioural activities of the insect during oviposition. The berries were presented to the fly and its behaviour from then on observed until it engaged into the act of egg-laying on one of the berries. All the berries with punctures were dissected and examined for eggs to ascertain whether oviposition actually took place immediately following the activities leading to puncturing the berry.

RESULTS

The data obtained from laboratory observations have been compiled (Tables 13 and 14) to show the coffee berry age-group preferred for oviposition by the gravid females of C. capitata. No eggs were laid in immature green berries (group A),but eggs were found in varying quantities in the other four berry categories. The largest number of eggs (43.5%) was laid in the mature yellow-red berries (category D). The next largest number amounting to 29.2% was in the mature red berries (category E). Category C, the mature green-yellow berries had 23.8% of the total eggs, while the lowest number

occurred in category A, the mature green berries. The number of eggs laid in mature yellow-red berries (category D) was statistically significant both at P = 0.05 and P = 0.01 suggesting that this age-group was the most preferred for oviposition by C. capitata.

Date obtained from field collected berries are shown in Tables 15, 16 and 17. No eggs or larvae were found in the immature green berries confirming the finding in the laboratory for this category of berries. Eggs and larvae were, however, found in varying quantities in the other four categories of berry. The largest number of eggs (66.6%) was in category C, the mature green-yellow berries. The mature yellow-red berries (category D) ranked second with 15.1% of the total eggs. This was closely followed by the mature green berries (category B) which had 11.2% of the total eggs. The lowest number of eggs amounting to 7.2% was found in category E, the mature red berries. Statistical analysis showed that the number of eggs in category C, the mature green-yellow berries, was significant both at P = 0.05 and P = 0.01. The highest number of larvae in this experiment was found in mature red berries (category E) suggesting that these larvae had hatched from eggs laid in a younger category of berries.

Before engaging into the act of oviposition, the gravid females of C. capitata explored the surface of the berry by walking hurriedly either on one berry or from berry to berry. During this exploration the fly maintained its ovipositor permanently in contact with the surface of the berry. Having located a suitable site for oviposition the fly remained still and protruded the ovipositor to its full length ready for insertion into the berry tissues. A prolonged, exhaustive probing of the fruit surface followed. During the act the fly raised and lowered her body simultaneously contorting her abdomen to pierce through the skin of the berry and enlarge the puncture. The fly then remained motionless except for abdominal contractions usually ranging from 1 - 6 minutes. The ovipositor was then withdrawn and the fly explored the same berry for another oviposition or moved to another berry to look for an ovipositional site there.

DISCUSSION

In the light of the laboratory and field observations in the present study, it is clear that C. capitata preferred for oviposition either category C, the mature green-yellow berries or category D, the mature yellow-red berries. According to Martin (1950), attractiveness of fruits to

ovipositing C. capitata varies with different fruits since citrus were attractive shortly before ripening and apricots after the fruits had ripened. Lack of eggs in immature green berries presented to gravid C. capitata females under the present study both in the laboratory and field suggested this category was not attractive to ovipositing C. capitata. Likewise it appears that the completely ripe berries are not also preferred. Colour does not probably play an important role in selecting suitable fruits for oviposition because Takana (1965) showed that yellow and green coloured artificial egg-laying receptacles were equally attractive in stimulating oviposition by C. capitata. It could not be confirmed in this study whether the flies used visual senses or olfactory senses to locate suitable fruits for oviposition although Bateman (1972) suggested that visual senses are involved. Severin (1913) observed that in case of Dacus dorsalis Hendel, bristles on the ovipositor of the fly served as tactile organs for detecting suitable sites for oviposition. Similar bristles were observed on the ovipositor of C. capitata during the present study. Since the flies walked on the green berries and rejected them in favour of the ripening berries, it was concluded that both visual and olfactory senses may be useful to the fly in locating suitable sites on fruit surfaces for oviposition.

Table 13 Coffee berry age-groups preferred for oviposition by C. capitata in the laboratory

Berry category	Total number presented	No. of eggs	% of eggs per category
Immature green (A)	100	0	0
Mature green (B)	100	14	3.4
Mature green-yellow (C)	100	97	23.8
Mature yellow-red (D)	100	177	43.5
Mature red (E)	100	119	29.2

Table 14 Statistical analysis on the number of eggs in five categories of berries presented to *C. capitata* in the laboratory

Category of Berry	Replicates 1	2	3	4	5	Category Totals	Category Means
A	0	0	0	0	0	0	0.00
B	0	3	9	0	2	14	2.80
C	18	25	33	17	4	97	19.40
D	35	58	25	34	25	177	35.40
E	31	35	16	25	12	119	23.80
Replicate Totals	84	121	83	76	43	407	16.28

Total observations = 25
Grand total = 407
Correction factor = 6625.9600

Source of Variation	Sum of squares	D.F.	M.S.	V.R.	Required V.R. 5%	1%
Categories	4393.0400	4	1098.2600	17.4369	5%	1%
Replicates	616.2400	4	154.0600	2.4460	3.01	4.77
Residual	1007.7600	16	62.9850			
Total	6017.0400	24	-			

Standard Error of means = 3.5492

S.E. of difference between any two means = 5.0193

L.S.D. = 5% = 10.6409
1% = 14.6614

Table 15 Age of berry preferred for oviposition by fruitflies in the field

Category of berry	Total number of berries	No. of eggs/category		No. of larvae per category		Egg and Larvae
		Total	%	Total	%	
Immature green (A)	500	0	0	0	0	0
Mature green (B)	500	155	11.2	3	0.7	158
Mature green-yellow (C)	500	922	66.6	508	12.3	1430
Mature yellow-red (D)	500	209	15.1	1753	42.3	1962
Mature red (E)	500	100	7.2	1880	45.4	1980

Table 16 Statistical analysis on the number of eggs found in the five categories of berries sampled from the field

Category of Berry	Number of eggs per replicate					Category Totals	Category Mean
	1	2	3	4	5		
A	0	0	0	0	0	0	0.00
B	23	70	10	32	20	155	31.00
C	206	200	205	200	111	922	184.40
D	59	39	26	45	40	209	41.80
E	30	17	37	9	7	100	20.00
Replicate Totals	318	326	278	286	178	1386	55.44

Total observations = 25
Grand Total = 1386
Correction factor = 76839.84

Source of variation	S.S.	D.F.	M.S.	V.R.	Required V.R. 5%	1%
Category	108718.1600	4	27179.54	58.9655		
Replicates	2792.9600	4	698.24	1.5148	3.01	4.77
Residual	7375.040	16	460.94	-		
Total	118886.1600	24				

Standard error of means = 9.6015
S.E. of difference between any two means 13.5785
L.S.D. 5% = 28.7864
1 = 39.6628

Table 17 Statistical analysis of larvae found in five categories of berries sampled from field

Category of Berry	Replicates 1	2	3	4	5	Category Totals	Category Means
A	0	0	0	0	0	0	0.00
B	0	3	0	0	0	3	0.60
C	209	78	70	70	81	508	101.60
D	407	288	400	300	358	1753	350.60
E	455	345	308	400	372	1880	376.00

Total observations = 25
Grand Total = 4144
Correction factor = 686,909.4400

Sources of Variation	Sum of squares	D.F.	M.S.	V.R.	Required V.R. 5%	1%
Categories	686186.9600	4	171546.7400	120.7429		
Replicates	15638.9600	4	3909.7400	2.7519	3.01	4.77
Residual	22732.1600	16	1420.7600	-		

Standard error of means = 16.8568

S.E. of difference between any two means = 23.8389

L.S.D. 5% = 50.5385
1% = 69.7320

Plate
~~Table~~ 15 A sleeve cage enclosing expanding green coffee berries

CHAPTER V

SAMPLING METHODS USED TO ESTIMATE COFFEE FRUITFLY POPULATIONS IN THE FIELD

INTRODUCTION

These are the first studies in Kenya on estimating fruitfly populations in the field. However, such studies have been done in other countries (Bondar, 1926; McBride, 1935, Puzzi and Orlando, 1965). Graham (1959) merely reported the presence of large populations of C. capitata and C. rosa in coffee and peach plantations in Kenya. In view of Graham's report, the present investigations were designed to determine relative population numbers of coffee fruitflies in the field and the causes for their fluctuations. Such studies would be useful in planning control programmes against adult fruitflies.

MATERIALS AND METHODS

The relative populations of the adult coffee fruitflies were studied in the field using trimedlure and medlure baited traps, suction traps and emergence traps (Plates 16 to 18). Medlure and trimedlure are the respective secondary and tertiary butyl esters of

4 or (5) chloro- and bromo - 2 methyl-cyclo-hexane carboxylic acid. They were selected because they are male attractants which were used for eradication of C. capitata in the United States (Beroza et. al., 1961; Gertler et. al., 1958; Ruffinelli et. al., 1962; Jacobson, 1966). The chemical baited traps were devised from cylindrical glass jars open on one side. The open end was fitted with a polythene funnel fastened in position with a wire. Part of this wire was also used to tie a cotton wick which was coiled and inserted into the jar through the funnel. Trimedlure at the rate of 1 ml per trap and an insecticide, gardona, at the rate of 0.4 ml per trap were applied on the cotton wicks of five traps. Medlure and gardona were also applied to the cotton wicks of other five traps at the same rate. The attractants and the insecticide were renewed after every two weeks. The traps were fixed on multiple stem coffee trees selected randomly in plot 'H' at Rukera Estate at a height 1.2 m. The baits were 4.2 m apart between the rows and 10.5 m apart within the rows. The suction trap was fixed in the middle of the plot where power source was available. Nine emergence traps were also placed in the plot in such a way that the first was placed next to the main trunk of the tree, the second below the canopy and the third centrally between two adjacent coffee bushes. Care was taken to make the

base of the traps firm and fly-proof by putting soil all round the base. The flies were attracted by light to a 2 x 15 cm glass tube fitted centrally at the top of one side of the trap. Records of flies from all traps were kept.

RESULTS

Tables 18 to 25 show the number of adult fruitflies caught with the three types of traps. The traps containing sex attractants caught most of the flies, probably due to the fact that the baits were specific for males of the fruitflies, especially C. capitata. The traps baited with trimedlure had a total catch of 31617 fruitflies. Of these 81.8% were C. capitata, 18% C. rosa and 0.2% T. coffeae. The traps baited with medlure caught a total of 22590 fruitflies and, of these, 94% were C. capitata, 5.9% C. rosa and 0.5 % T. coffeae. Both the suction and emergence traps caught comparatively fewer number of fruitflies and were thought unsuitable for studies concerning estimation of populations in the field. The catches with the sex-attractant baited traps were subjected to Kono's (1953) method of analysis reported by Southwood (1971) as one of the methods for converting relative numbers to absolute numbers. The method postulates that the exponential

relationship between the numbers collected at any time may be discovered by the consideration of the catches at just three time points (t_1, t_2 and t_3) such that $\frac{1}{2}(t_1 + t_2) = t_3$ and under these conditions

$$P = \frac{n_3^2 - n_1 n_2}{2n_3 - (n_1 + n_2)}$$

where n_1, n_2 and n_3 = accumulated catches at times t_1, t_2 and t_3 respectively. Using this method, t_1, t_2 and t_3 were taken as the first, eleventh and sixth month of trapping respectively. The estimated population from the trimedlure baited traps consisted of 26,784 C. capitata, 5,243 C. rosa and 57 T. coffeae for the whole of the twelve months of trapping. For the same period, the estimated population from the medlure baited traps consisted of 20, 852 C. capitata, 1,297 C. rosa and 11 T. coffeae.

Adult fruitfly populations started to build up from September 1973 to February 1974 but the numbers started to decrease from March to June 1974 (Tables 18 and 20). This was the time when ripe coffee berries were not present in the field. During this latter period, rainfall and temperature were high. The fluctuation of fruitfly populations in the field was due to availability of the ripe coffee berries rather than due to fluctuations in temperature or rainfall.

DISCUSSION

These experiments confirmed earlier studies that whether or not there are ripe coffee berries in the field, fruitflies are present throughout the year. The flies are, however, more abundant during the season when ripe coffee berries are also present. The finding confirmed the works of Bondar (1926), McBride (1935) and Puzzi and Orlando (1965). The sex-attractant baited trap with either trimedlure or medlure was the most effective of the three traps. The suction trap and the emergence trap caught relatively fewer fruitflies indicating that these methods would not be suitable enough for assessment of the pest in coffee plantations. The analysis of the relative number of fruitflies confirmed that in terms of absolute population, the most abundant species of fruitflies in the coffee plantation under the study was C. capitata, followed by C. rosa. T. coffeae was the least abundant. Thus any fruitfly control measure in Kenya should aim at C. capitata. However, the importance of the other two species in terms of population numbers should not be underestimated. Although it has been shown by Beroza et. al., (1961), Gertlet et. al., (1958), Ruffinelli et. al., (1962) and Jacobson (1966) that both the attractants used in this study had been used for eradication of C. capitata in the United

States, these studies have also revealed that the same attractants can be used, in conjunction with an insecticide, for control of C. rosa which occurs in Kenya but has not been reported in the United States.

Table 18 Number and species of fruitfly caught by medlure-baited traps

Month	Number and species caught		
	capitata	rosa	coffeae
1973			
September	239	27	0
October	456	12	0
November	2056	89	1
December	3552	736	0
1974			
January	6959	392	6
February	3621	28	1
March	879	0	0
April	170	0	0
May	381	1	1
June	287	0	0
July	1488	12	1
August	920	36	1
Total	21246	1333	11

Table 19 The efficiency of medlure-baited traps in catching coffee fruitflies

Species	numbers caught	Efficiency (%)
C. capitata	21246	94.05
C. rosa	1333	5.90
T. coffeae	11	0.05

Table 20: Numbers and species of fruitfly caught by trimedlure-baited traps

Month	Number and species caught		
	capitata	rosa	coffeae
1973			
September	1016	1316	1
October	1153	332	1
November	2386	935	2
December	4105	1384	43
1974			
January	5783	547	3
February	4427	172	3
March	629	3	0
April	224	11	0
May	614	23	0
June	820	40	0
July	3195	401	3
August	1517	528	0
Total	25869	5692	56

Table 21 The efficiency of trimedlure-baited traps in catching coffee fruitflies

Species	Numbers caught	Efficiency (%)
C. capitata	25869	81.82
C. rosa	5692	18.00
T. coffeae	56	0.18

Table 22 Number and species of fruitfly caught with suction trap

Month 1974	Number and species caught		
	capitata	rosa	coffeae
January	134	22	197
Febuary	140	2	49
March	20	3	18
April	0	0	0
May	1	0	0
June	4	7	8
July	12	7	5
August	4	0	0
September	6	1	0
Total	321	37	277

Table 23 Efficiency of suction trap in catching coffee fruitflies

Species	numbers caught	Efficiency (%)
C. capitata	321	50.55
C. rosa	37	5.83
T. coffeae	277	43.62

Table 24 Number and species of fruitfly caught with emergence trap

Month 1974	Number and species caught		
	capitata	rosa	coffeae
January	8	13	29
February	1	1	4
March	0	0	0
April	0	0	0
May	0	0	0
June	1	2	0
July	2	25	23
August	1	5	2
September	1	2	8
October	0	2	6
November	0	4	0
December	0	1	0
Total	14	55	72

Table 25 Efficiency of emergence traps in catching coffee fruitflies

Species	numbers caught	Efficiency (%)
C. capitata	14	9.93
C. rosa	55	39.01
T. coffeae	72	55.06

Plate
~~Table~~ 16 An emergence trap for catching flies from the ground after pupation

Plate
~~Table~~ 17 A suction trap for catching aerial population of fruitflies

Plate
~~Table~~ 18 A plastic trap for catching adult fruitflies

CHAPTER VI

ECONOMIC IMPORTANCE OF *Ceratitis capitata* IN KENYA

INTRODUCTION

Ceratitis capitata has been known to cause pre-mature drop of coffee berry in Kenya and the drop was at first attributed to the feeding on the berry stalk by the fly (Ritchie, 1928). Studies to assess the extent to which *C. capitata* caused the immature coffee berries to drop were initiated in an attempt to determine the economic importance of this species as an agent causing pre-mature berry drop. Besides, Graham (1959) while working in Kenya claimed that *C. capitata* did not do any damage to the coffee crop. Stolp (1960), on the other hand, caused an alarm by stating that the "potato flavour" in coffee liquor in Zaire was due to a *Xanthomonas* type of bacterium introduced into the coffee berry by the fruitfly, *Trirhithrum inscriptum* Grah. during the process of oviposition. In Kenya the presence of stinker beans was reported by Northmore (1969). During the following year Gibson (1970), apparently on circumstantial evidence, linked the presence of such beans to the presence of fruitfly larvae in the ripening coffee berries.

A stinker bean was described as "any bean in the raw state which at the time of cutting open and

immediately placed under the nose gives off a fermented or a maladorous smell" (Lydall, 1973). Gibson (1970) also described a stinker bean as "waxy and brittle with an acidic reaction to litmus and possessing a dead embryo". Whereas pre-mature drop of coffee berries is likely to reduce the yield of the crop, stinker beans would reduce the quality of the marketable crop. Hence, the aim of this investigation was to assess the amount of pre-maturely dropping berries after the attack by C. capitata and the role of the latter in causing stinker beans.

MATERIALS AND METHODS

Experiments to induce pre-mature drop of coffee berries were carried out on multiple stem Arabica coffee trees by infesting the expanding stage of the berries with adult C. capitata. From eight different coffee trees, eight primary branches were selected randomly and enclosed in sleeve cages each measuring 45 cm long and 20 cm diameter (Plate 15, Chapter IV). The branches were ensleeved when the berries on them were in the pinhead developmental stage and after such berries had been counted. The berries then developed within the cages. Four of the cages were infested with 80 C. capitata females and a

similar number of males when the berries in the cages had developed and reached the "expanding stage". This is the stage when coffee berries are large but the endosperm in them is still soft. There was a total of 547 such berries in the four cages and these were exposed to the flies for four weeks. The flies were fed on a solution made from 10 parts honey, 10 parts of buminal which is a hydrolysed protein and 80 parts water by volume. This diet was supplied in small petri dishes containing cotton wicks. The cages were examined daily for pre-maturely dropped berries and records of these kept. The berries were then dissected under a microscope and examined for eggs. There were punctured berries that failed to drop and these were identified and labelled with plastic tapes for further observations. The four control cages contained 488 expanding berries and if any berry dropped from these cages, it was similarly examined for the presence of fruitfly eggs.

The berries used in the stinker induction tests included (1) those which were ovipunctured by the fruitfly and matured normally on the tree and (2) ripe coffee berries picked from the field after natural infestation by fruitflies. Berries from the control cages in the pre-mature berry drop

investigation were also used as control during the investigation of stinkers. This means that the sleeve cages were not removed from the branches until the crop had ripened, picked and factory processed. The coffee beans from these berries were then dried and the parchment, the hard skin that encloses the bean, was removed to allow for examination of stinkers both under natural light and ultra-violet light. The beans were then coded and sent to the liquorers of the Coffee Board of Kenya for re-examination of stinkers. Visible stinkers can be seen with the naked eye using the characteristics described under the definition of a stinker. After the samples were examined by the liquorers of the Coffee Board of Kenya they were sent to the East African Industrial Research Organisation for detection of hidden stinkers under ultra-violet light. Under this kind of light, the stinker bean shows an overall uniform fluorescence both on the surface and within the interior of the bean. The overall nature of this fluorescence may sometimes be obscurred due to a heavy coating of the silverskin.

In a separate investigation, 0.25 kg of ripe coffee berries containing fruitfly larvae were fermented to obtain bacterial flora. The fermentation period lasted four days during which time samples of fermentation water were quantitatively plated out on

nutrient agar (pH 7) at 27°C to determine the type of bacteria growing in it. The fermentation treatments were as follows:

(a) Sterile water + sterile beans

(b) Sterile water + unsterile beans

(c) Unsterile water + sterile beans

(d) Unsterile water + unsterile beans

The beans were then examined for stinkers and then sent to the liquorers of the Coffee Board of Kenya for quality assessment. Another attempt was made to isolate the bacterial flora from within the fruitfly larvae.

RESULTS

I Premature Coffee Berry Drop

The results of this investigation are summarized in Table 26. Out of 547 berries in the infested cages, 99 had oviposition punctures and 40 (40.4%) of these dropped pre-maturely. The berries started to drop ten days after the first batch of flies were introduced into the cages. The berries that dropped pre-maturely represented only 7% of the total berries in the infested cages indicating that the loss due to fruitfly alone would not be very high. Ovipunctured berries continued to drop a month after the last batch of the fruitflies were introduced into the cages. By

this time all the berries in the cages had reached the "hardened stage" as a result of the hardening of the endosperm. Of the ovipunctured berries 60% developed and ripened normally on the tree, but those that dropped pre-maturely did not have berry stalks. A "posho" substance developed on the scars left by the detached berry stalks. On examination these scars did not have fungal growth. The punctures on the dropped berries contained eggs which were inserted in the endosperm. Where the endosperm was punctured, the tissues surrounding the punctures turned brownish in colour. The 7 berries which dropped from the control cages had their stalks intact. This showed that lack of berry stalks on pre-maturely dropped berries was one characteristic connecting the damage with fruitflies. There were no punctures on the berries which dropped pre-maturely in the control cages. The presence of punctures on pre-maturely dropped berries was another characteristic connecting the damage with fruitflies. The remainder of the berries in the control cages developed normally.

II Stinker Investigation

Out of the 99 ovipunctured berries in the cages infested with fruitfly, 59 of them developed and ripened normally on the tree. These were picked and processed and yielded 119 beans, 14 (12%) of

which showed obvious insect damaged characterised by small wounds where the insect had oviposited. The rest of the beans were normal, similar to those from the control cages. The liquorers of the Coffee Board of Kenya did not find stinker beans either from the infested samples or from the control samples. This suggested that fruitflies are not possibly the causers of stinkers. Hidden stinkers were not found when the same sample was viewed under ultra-violet light. The punctured berries were, however, very small in size (grade C) and about 90% of them were heavily coated. The greenish appearance of the silverskin coating and the green bean colour were visible in some of the beans. The beans from the control cages were also small, the majority of them being of B and C grades. This suggested that the small size of the beans in the infested cages was not due to attack by fruitfly. Silverskin coating was apparent only on a small amount of the beans but a brownish colour existed in the silverskin in the centre-cut region of the bean.

In most cases, the high degree of coating in the sample infested by C. capitata caused problems in viewing the bean surface under ultra-violet radiation light. Approximately 5% of the beans showed white/blue fluorescence on the centre cut side of the bean but

this did not appear to involve the total volume of such beans indicating that the beans were not stinkers. A fluorescent spot that was fairly intense and localized and extending below the surface of the bean to a considerable depth was detected in only one instance. The beans from the control cages had a fairly pronounced blue fluorescence which was due to poor processing conditions and the age of the sample.

III Bacterial flora in fruitfly infested berries and fruitfly larvae

Table 28 shows the type of bacteria cultured from the coffee berries infested with fruitfly larvae while still in the field. A *Pseudomonas* type of bacterium appeared in the unsterile water treatments while a coliform type of bacterium appeared in both sterile and unsterile water treatments. The liquorers from the Coffee Board of Kenya did not detect stinker beans from the fermented samples. From the fruitfly larvae only two specimens of *Erwinia* spp. were isolated.

DISCUSSION

Ceratitis capitata has been shown to be a pest of many fruits including citrus which has been observed to fall pre-maturely after being ovipunctured at the green stage by the female fly (Pennisi, 1953). Carnegie (1962 also observed that *C. capitata* ovipunctured passion fruits but larvae failed to develop in the fruit. The latter therefore developed normally to maturity. It was shown further that eggs laid in immature fruits failed to hatch and some of them were expelled by exudations from such fruits (Carnegie, 1962; Soria and Yana, 1959). Other edible fruits which are attacked by this fly include surinam cherry, peach, mango, papaya, loquat, rose apple, almond (Christenson and Foote, 1960), plums, pears and quinces (Matelli, 1947), apricots (Martin, 1950). Morello cherry (Bohm, 1959) and bananas (Jenkins, 1948). Pre-mature drop of coffee berries in Kenya was attributed to the feeding on the berry stalk by *C. capitata* (Ritchie, 1928). The present and other findings such as those of McCrae (1956) and Le Pelley (1968) have, however, shown that pre-mature berry drop of coffee is not due to eating of the berry stalk by the fly but is due to oviposition into the berry by the female fly. Abasa (1972) showed that 7.9% of the coffee berries ovipunctured by the fly at the expanding

stage dropped pre-maturely and this led him to conclude that the insect did not have significant economic importance to the coffee industry. In the present study, however, a much higher percentage (40%) of dropping pre-mature berries was found. This suggested that C. capitata may have a more economic significance than it was previously thought. The abscission layer observed by Ritchie (1928) was also confirmed in the present studies although the cause was not the feeding on the berry stalk by the insect. Only 18% of the total crop in the infested cages was ovipunctured by the fly. Since not all berries that were punctured dropped pre-maturely, more work is needed to determine the cause of drop of the berries ovipunctured by C. capitata. The pre-maturely dropped berries were found to contain eggs but in no instance were larvae found. Larvae were, however, found in the ovipunctured berries that developed and matured normally on the tree. The presence of fruitfly larvae in such ripe berries five months after oviposition suggested that the eggs may have aestivated in the green berries until such time the berries ripened and offered conditions that were conducive to hatching. Such a conclusion was reached because the berries were enclosed within the sleeve cages throughout their development and under normal circumstances the insect's life cycle does not take so long.

Physiological factors such as overbearing of the crop and nutritional imbalance may also cause pre-mature berry drop (Huxley and Ismael, 1969). Colletotrichum coffeanum Noak is the Coffee Berry Disease fungus which also may be responsible for premature drop of coffee berries (Rayner, 1952; Griffiths and Gibbs, 1971). A heavy infestation of Antestia bug is also known to cause pre-mature drop of coffee berries (Anon. 1967). In all these cases, however, the berries dropping pre-maturely do not have oviposition punctures characteristic of berries dropping after being ovipunctured by C. capitata.

An investigation to ascertain whether C. capitata was responsible for stinker coffee beans was carried out using the ovipunctured berries that remained on the trees since Gibson (1970) linked such beans with fruitfly larvae in the berry. The study did not reveal any stinker beans either in the ovipunctured sample or the control sample. The ovipunctured berries, however, produced very small beans of grade C and about 90% of them were heavily coated. Of these beans 12% showed lesions indicating the site of oviposition. In most cases the lesions were localised except in 5 cases where the lesions were extensive (1 - 3 mm) and resembled those described by the liquorers as "hail damage". The absence of any discernible

stinker from the caged coffee trees experiments with C. capitata suggested that the ovipositing activity by the insect has no influence on the field formation of stinkers. The physical bean damage caused by oviposition may, however, create a more favourable environment for secondary infection leading to stinker initiation. The absence of any marked localised fluorescence at the observed green bean oviposition sites clearly showed that no secondary microbiological attack had occurred and, from this, it may be inferred that the female C. capitata were not carrying micro-organisms at the time of oviposition.

An investigation to find out the type of bacteria that grew on fermenting coffee beans previously infested with C. capitata larvae and eggs showed only coliform and Pseudomonas types of bacteria. These types of bacteria did not cause coffee beans to have stinker beans or off-flavours. No Xanthomonas type of bacteria which Stolp (1960) claimed as the cause of 'potato flavour' was isolated from the coffee beans or fruitfly larvae. From the fruitfly larvae, however, Erwinia sp. was isolated but this too did not play part in stinker formation. A clear conclusion from this study is that whereas C. capitata is likely to cause crop loss through

premature drop of coffee berries, it is still doubtful whether the insect is responsible for causing stinker beans.

Table 26 Premature coffee berry drop as a result of infestation by C. capitata

Cage No.	Total berries per cage	No. and % of ovipunctured berries/cage		No. and % of dropped x berries/cage		% of berries dropping/cage xx
		Number	%	Number	%	
1	121	25	20.66	10	40.0	8.3
2	240	31	12.92	13	41.9	5.4
3	132	28	21.21	12	42.9	9.1
4	54	15	27.78	5	33.3	9.1
Total	547	99	18.1	40	40.4	7.3

x Expressed as a percentage of ovipunctured berries/cage

xx Expressed as a percentage of total berries per cage

Table 27 Prematurely dropped coffee berries in the control cages

Cage No.	Total berries per cage	No. of dropped berries	% of dropped berries/cage
1	63	2	3.2
2	246	0	0
3	113	0	0
4	66	5	7.6
Total	488	7	1.4

Table 28 Type of bacteria from 0.25 kg of fermenting coffee beans infested with fruitfly larvae

Fermentation period in days	Type of bacteria per treatment			
	Treatment A	Treatment B	Treatment C	Treatment D
1	None	Coliform group	Coliform + Pseudomonas	Coliform + Pseudomonas
2	Coliform group	Coliform group	Coliform + Pseudomonas	Coliform + Pseudomonas
3	None	Coliform Group	Coliform + Pseudomonas	Coliform + Pseudomonas
4	None	None	None	None

CHAPTER VII

GENERAL CONCLUSIONS

The present study has shown that three species of fruitfly, namely, C. capitata, C. rosa and T. coffeae breed in ripening coffee berries throughout the year in Kenya. The eggs of these flies are laid under the skin of the ripening berry and after hatching, the larvae live inside the berry feeding on the mucilage. The study showed that at 23.8 $\pm$ 2°C, the incubation period of C. capitata was 2 to 5 days; that of the other two species was 3 to 5 days. The larva of C. capitata took 6 to 12 days and the same duration was taken by the larva of C. rosa. That of T. coffeae took 8 to 14 days. The pre-pupal and pupal stages of C. capitata took 12 to 16 days, those of C. rosa took 12 to 15 days while those of T. coffeae took 14 to 19 days. The pre-oviposition period was 5 to 7 days for C. capitata, 5 to 9 days for C. rosa and 9 to 11 days for T. coffeae. To some extent, the incubation period of C. capitata agreed with that recorded by Back and Pemberton (1918), Christenson and Foote (1960) and Carnegie (1962). The larval feeding period agreed with that recorded by Ong'ute (1970). Weather conditions were found to prolong or contract the larval feeding

period and unripe fruits also prolonged the period (Christenson and Foote, 1960; Carnegie, 1962).

Fruitfly larvae emerging from ripe coffee berries to seek suitable pupation sites in the soil were found to have a temperature-dependent diurnal periodicity. However, adult fruitflies emerging from pupation sites were found to have a diurnal periodicity which was temperature-independent. The adults emerged over the same time the larvae had emerged from the coffee berries and in the light of Brett's (1955) similar observation on the larvae and adults of Drosophila melanogaster Meigen, it was concluded that exposure of larvae to light for the short duration between emergence from the berry and pupation may have set up a time mechanism which influenced the adults to emerge over the same period. Since both stages of the insect emerged at a time of the day least likely to suffer catastrophe through lethal or otherwise unfavourable effects of high temperature, the phenomenon had a biological significance for the survival of the insects.

The breeding seasons of the fruitflies found on coffee depend on the availability of ripe coffee berries which are the suitable media for oviposition. Where there are two ripening seasons, most breeding

would take place during the same seasons. Irrigation, however, which is usually practised to supplement the crop's water requirement is also known through the author's experience to lead to more frequent but small amount of ripening which would also induce the fruitfly to breed more frequently. C. capitata is the most dominant species of fruitfly breeding in coffee in Kenya. The rare occurrence of C. rosa and T. coffeae suggests that the two species may not have adopted themselves to breeding in coffee in Kenya. In the absence of ripe coffee berries C. capitata and C. rosa were found to breed in the fruits of Dovyolis caffra, a plant used as a hedging material in many estates and homesteads. This showed that the plant could act as a source of coffee re-infestation by the flies and any control measures against the flies should be applied not only to coffee but also to hedges made from the Kei-apple plant.

In the laboratory, the present studies revealed that C. capitata preferred to oviposit in ripening coffee berries rather than the immature green, mature green or completely red-ripe coffee berries. In general, this preference was simulated in the field by fruitflies - indicating that if an alternative of ripening coffee berries existed in

the field, fruitflies would not oviposit in the expanding stage of the green berries. The reasons for preferring the ripening berries was not known but it can be deduced that eggs laid in such berries have enough time to hatch and the larvae have similarly enough time for development before the berries dry up. Takana (1965) showed that yellow and green-coloured artificial egg laying receptacles were equally attractive in stimulating egg laying by C. capitata and this indicated that colour of the berry may not be the primary factor stimulating oviposition. However, it had been found by Severin (1913) that bristles at the end of the ovipositor of Dacus dorsalis Hendel were used to detect suitable ovipositional sites and since C. capitata has similar bristles, it may be possible that they are used for a similar purpose.

Contrary to earlier findings (Abasa, 1972), the present study has found that upto 40% of the berries ovipunctured by C. capitata during the expanding stage of their development fell prematurely. This suggested that the insect may be of more economic significance to coffee than Abasa thought. No stinker beans were, however, found in the ovipunctured berries and this confirmed Abasa's (1972) finding that fruitflies did not cause stinker beans in coffee.

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