THE BIOLOGY, ECOLOGY AND SOME ASPECTS OF ECONOMIC IMPORTANCE OF PYRETHRUM THRIPS *THRIPS TABACI* LIND. AND *THRIPS NIGROPILOSUS* UZEL. IN KENYA.

BY

JOHN JULIUS ANYANGO

A THESIS SUBMITTED IN PART FULFILMENT FOR THE DEGREE OF MASTER OF SCIENCE (ENTOMOLOGY)

IN THE UNIVERSITY OF NAIROBI

1987

DECLARATION

THIS THESIS IS MY ORIGINAL WORK AND IT HAS NOT BEEN PRESENTED FOR A DEGREE IN ANY OTHER UNIVERSITY

SIGNED ---------- 25/5/87

NAME: J.J. ANYANGO

THIS THESIS HAS BEEN SUBMITTED WITH MY APPROVAL AS INTERNAL SUPERVISOR

SIGNED ----------

NAME: PROF. CANUTE P.M. KHAMALA

DEPARTMENT OF ZOOLOGY

TABLE OF CONTENTS

FRONTISPIECE		i
DECLARATION		ii
TABLE OF CONTENTS		iii
LIST OF TABLES		iv
LIST OF PLATES		viii
LIST OF FIGURES		ix
ACKNOWLEDGEMENTS		x
ABSTRACT		xi
1.	GENERAL INTRODUCTION, LITERATURE REVIEW, MATERIALS AND METHODS	
1.10	GENERAL INTRODUCTION	1
1.11	Pyrethrum Industry in Kenya	1
1.12	Importance and Problems faced by Pyrethrum Industry in Kenya	4
1.13	Objectives of the Study	6
1.20	LITERATURE REVIEW	8
1.30	GENERAL MATERIALS AND METHODS	12
2.	THE BIOLOGY OF THE PYRETHRUM THRIPS, THRIPS NIGROPILOSUS UZEL. (THRIPIPAE:THYSANDPTERA)	
2.10	INTRODUCTION	15
2.20	MATERIALS AND METHODS	16

2.20.1	Life History	16
2.20.2	Temperature effects	22
2.30	RESULTS	22
2.30.1	THE LIFE HISTORY OF THRIPS NIGROPILOSUS UZEL.	22
2.30.1.1	The Egg	23
2.30.1.2	Larval Instars	24
2.30.1.3	Prepupa	28
2.30.1.4	Pupa	28
2.30.1.5	Adults	30
2.30.2.	THE EFFECTS OF TEMPERATURE ON DURATIONS OF THRIPS DEVELOPMENTAL STAGES	32
2.40	DISCUSSIONS AND CONCLUSION	33
2.40.1	The Life History	33
2.40.2	Effect of Temperature on Development Durations	32
3.	ECOLOGICAL STUDIES OF PYRETHRUM THRIPS	40
3.10	INFLUENCE OF WEATHER FACTORS ON THE OCCURANCE OF THRIPS IN PYRETHRUM FIELDS IN KENYA	41
3.10.1	INTRODUCTION	41
3.10.2	MATERIALS AND METHODS	42
3.10.3	RESULTS	44
3.20	COMPARATIVE STUDIES OF THRIPS POPULATION DENSITIES ON SIX PYRETHRUM	46

VARIETY/CLONES

3.20	INTRODUCTION	46
3.20.2	MATERIALS AND METHODS	47
3.20.3	RESULTS	51
3.30.3	ALTERNATIVE PLANT HOSTS FOR PYRETHRUM THRIPS	53
3.30.1	INTRODUCTION	53
3.30.2	MATERIALS AND METHODS	55
3.30.3	RESULTS	56
3.40	DISCUSSION AND CONCLUSIONS	58
3.40.1	Influence of Weather Factor	58
3.40.2	Comparative Studies of Pyrethrum Thrips Densities on Pyrethrum Variety/ Clones	60
3.40.3	Alternative Plant Hosts for Pyrethrum Thrips	63
4.	DETERMINATION OF ECONOMIC TMPORTANCE OF PYRE-THRUM THRIPS BY FLOWER YIELDS LOSS ASSESSMENT ON PYRETHRUM PLANTS	65
4.10	INTRODUCTION	65
4.20	MATERIALS AND METHODS	66
4.20.1	Dead flower buds	67
4.20.2	Flower numbers	67
4.20.3	Dry flower weights	67
4.30	RESULTS	69
4.30.1	Thrips effect on flower buds development	69

4.30.2	Thrips effect on harvestable flower numbers	74
4.30.3	Thrips effect on flower weights.	74
4.40	DISCUSSION	75
4.40.1	Dead buds	75
4.40.2	Flower numbers	78
4.40.3	Flower weights	80
4.50	CONCLUSION	80
LITERATURE CITED		83
APPENDICES		93

LIST OF TABLES

Table 1. Mean lengths and widths for eggs, instars and adults of T. nigropilosus

2. Approximate durations (days and hours) of developmental stages of 25 T. nigropilosus

3. History and major characters of Pyrethrum clone/variety used in the thrips population studies

4. (a) Pest-cultivars population densities

(b) Two way table for thrips ecological niches

5. Alternative hosts - thrips population

6. The effects of pyrethrum thrips on dead flower buds

7. The effects of pyrethrum thrips on flower numbers produced

8. The effects of pyrethrum thrips on dry flower weights (g)

LIST OF PLATES

Plate 1. The multiple temperature incubator where the thrips biology study was conducted

2. Intercropped pyrethrum cultivars at Limuru Agricultural substation

3. Caged pyrethrum plants in green house for the pest economic importance studies

4. Thrips effects on the shape of pyrethrum flower shapes.

5. Dead and blasted flower buds and vegetative growths, the result of the thrips damage.

LIST OF FIGURES

Fig. 1. An oviposition cage

2. A rearing cage

3. (a) An egg of T. nigropilosus 3-4 days old

(b) First instar larvae of T. nigropilosus at hatching

(c) Second instar larvae of T. nigropilosus

(d) Prepupa of T. nigropilosus

(e) Pupa of T. nigropilosus

4. (a) Posterior end of T. nigropilosus female abdomen

(b) Posterior end of T. nigropilosus male abdomen

(c) A macropterous wing bud of T. nigropilosus

5. Developmental period (A) and developmental rate (B) for eggs, larvae, pupae and egg-adult of Thrips nigropilosus at various temperature points

6. Rainfall (mm) temperature (^{o}C), Relative humidity (%) and thrips population curves over one year period.

ACKNOWLEDGEMENTS

I am greatly indebted to my supervisor Prof. C.P.M. Khamala of the University of Nairobi, Department of Zoology, for his unfailing guidance and constant encouragement throughout the course of these investigations and for reading the manuscripts. I very much appreciate his initial suggestions on the objectives for study, materials to be used and constructive criticism at the time of writing, pointing out errors, and suggesting improvements to the end.

I very much appreciate the cooperation and technical assistance I received from those incharge of the laboratory and green houses at the Crop Sciece Department, Faculty of Agriculture, University of Nairobi. Similar sentiments are expressed to the Senior Technician, Zoology Department Mr. J. Moilo, Biometric Section Ministry of Agriculture and National Museum, Nairobi for placing their expert knowledge at my disposal.

Last but not least, I am also very grateful to my wife Mary, Children Cavin, Anne, Sandi and Jack for their patience and silence during the course of my studies.

ABSTRACT

The biology of Thrips nigropilosus was studied using Pyrethrum leaves as the rearing medium in a growth chamber in a laboratory. Its life history is divided into a series of stages: eggs, larvae, pupae and adults with three instars between the stages. The average durations of development egg to adult was 25.7 (± 0.43) days at 20°C and 70% RH. The sex ratio for adults were established under this laboratory conditions as 9:1 female-male suggesting the presence of pathogenetic type of reproduction. The longevity period for adult stood at between 1 to 21 days. Other than the pupal stage that moults in soil, all other developmental stages occur on the Pyrethrum plant tissues giving room therefore for an effective chemical spray to be directed on the soil surface to reduce emerging adult numbers, hence, an effective and economical method of the thrips control.

At high temperature 30°C the average duration of development shortened to 14.2 (± 0.18) days and lengthened to 50.2(± 0.67) days at 12°C, thus expressing the significance played by temperature on the thrips development. The temperature range (12-30)°C

however, were found to be within the condusive range for the thrips development. Higher temperatures 25-30^{o}C induced faster rate of development which can also be significantly responsible for faster rates of thrips reproduction generations in a given season.

The aims of the ecological studies were to help understand the importance of weather factors on the Thrips in Pyrethrum fields, compare thrips populations on commercially grown Pyrethrum plants, and to evaluate their alternative host plants for which series of experiments were conducted to assess.

From the studies it was observed that high rainfall above 40 mm per month reduced drastically the thrips population in the Pyrethrum fields. Similarly the thrips population achieved importance after 2 months of continuous drought rising to about 20 per plant when chemical control becomes a necessity.

Among the six pyrethrum clones/variety tested for thrips population density, clone Mo/70/1013 and variety P4 with less well developed leaves and floral structures to harbour the thrips and secondly

with higher pyrethrin content of 1.9% and more were least preferred by the thrips compared to other tested clones: 4331,SB/66/107, O/64/219 and Ma/63/1889. The general level of population density of T. tabaci in flowers influenced the total populations per cultivar. T. tabaci infested mainly open flowers and T. nigropilosus occupied the leaves and vegetative growth.

And studies on alternative host plant suggested that Thrips tabaci is polyphagous, and T. nigropilosus oligophagous. The reason for the low population of T. nigropilosus compared to T. tabaci is the result of limited geneflow as they possess fewer alternative hosts. Frequent weeding is believed to be one agronomic practice that would further limit the population of these Thrips.

Finally, the effect of Pyrethrum thrips (Thrips tabaci and Thrips nigropilosus) on the crops development was studied in a green house using pyrethrum clone 4331 exposed to varying thrips populations. There was a definite pattern of the flower bud deaths with plants exposed to high thrips population of 100 to 500 dying first and the trend shifting to plants exposed to low (10) thrips population 2 to 3 months

later. Flower number and weights were similarly faster reduced after a month's exposure at high thrips number (500) compared to two months at moderate number (100) per plant. Plants exposed to low thrips number (10) realised low flower number and weight after about 3 months. Field observations showed that the harvestable flowers from exposed plants thrips were generally smaller, spiralled and hence the reason for the low yield. High thrips population caused immediate yield reduction and eventual deaths hence the need for their control on routine sprays.

CHAPTER 1 GENERAL INTRODUCTION, LITERATURE REVIEW, MATERIALS AND METHODS

1.10 GENERAL INTRODUCTION

The Pyrethrum thrips, Thrips tabaci Lind. and Thrips nigropilosus Uzel are among the most serious insect pests attacking the pyrethrum plant in the field in Kenya. The attacked plants have their leaves turned silvery and leathery. Heavy attacks results not only into wilting of young plants, but also into decreased flowering thus considerably affecting the harvestable flower yields from which insecticides called pyrethrins are extracted.

1.11 Pyrethrum Industry in Kenya

The Pyrethrum plant, Chrysanthemum cinerafiefolium Vis. is a perennial herb in the Family Compositate with deeply lobed leaves, fibious root system and a white daisy-like flower. It is an important cash crop grown in Kenya with its early records dating back to the first century (A.D.) during the 'CHUO' dynasty in China. It is grown commercially for extraction of insecticides. The actual date of the recognition of its insecticidal use is unknown due to the

secrecy that surrounded its production then, but was believed to have originated in Persia (Iran), (Gradianger, 1936a & b).

The crop was first produced in Dalmatia, Yugoslavia about 1840 from there it spread to Europe and the U.S.A., South America and Japan. Before World War I. Yugoslavia was the leading world producer but this became impossible after 1914 when Japan took over the world market. The Japanese domination did not last before being replaced in the years between 1935 and 1941 by Kenya. World War II completely shut off the supply from Japan, but increased production in other countries including Brazil, New Guinea, Peru, Zimbabwe, Rwanda and Tanzania (Glynne Jones, 1973).

Pyrethrum was first introduced in Kenya in 1928 from Yugoslavia through the efforts of two men, Captain Gilbert Walker who farmed at Bahati near Nakuru and Dr. V.A. Beckley who was the Senior Chemist at what is now the National Agricultural Laboratories (Beckley, 1938). Following the experiments carried out by Dr. Beckley, the crop was found to be suitable for the high altitude areas on each side of the equator where low night and warm diurnal temperatures

combined with adequate rainfall favoured vigorous growth and flower yields which were better than those obtained in the temperate regions of its origin. Secondly when the Mclaughlin Gomlay King Company (GMK) in U.S.A. extractors of botanical materials of flowers established that Kenya pyrethrum flower content of pyrethrins was superior to that of either Japanese or Yugoslavia, and that their yield were much higher per hectare than those from other parts of the world, the company aggressively encouraged pyrethrum cultivation and export in Kenya. Accompanied by high price and adequate available cheap labour, many white settlers engaged in extensive cultivation of pyrethrum in late 1930's.

Later, the acreage increased due to a number of reasons. Firstly, during the World War II, Pyrethrum was declared a strategic material for malaria control (Knowlson, 1942). Since at the time Japan had war problems, the only major producing country left was Kenya. Secondly, the 'Mark Commission that evaluated pesticides in relation to environmental health recommended pyrethrum as an insecticide with no residual effects. Thus accompanied by the newly introduced effective synergist, piperonyl butoxide

(Wachs, 1944), pyrethrum gained acceptance by the Commission as an effective insecticide. Thirdly, with the introduction of the Swynnerton Plan of 1954 (Muturi, 1976) that permitted the Africans to grow the crop and with change of land to African hands following independence more land in Kenya came under pyrethrum cultivation. Accompanied with recently raised producer price of 1985, the crop production in Kenya was highly intensified such that Kenya is now the world's largest pyrethrum producer with an 80% market share (Anonymous, 1985-6). The crop is now grown extensively in Elgeyo-Markwet, Embu, Kericho, Kiambu, Kisii, Nakuru, Nyeri and Nyandarua Districts. More recent introductions have occured in parts of Baringo, Bungoma and Meru Districts (Anonymous, 1960-86).

1.12 Importance and Problems Faced by Pyrethrum Industry in Kenya

The insecticidal components in the Pyrethrum plant are Pyrethrin I and II, Cinerin I and II and Jasmolin I and II collectively called pyrethrins esters. They are located in all parts of the plant but more abundant in the developing flower achemes

(Head, 1967; Brewer, 1973). The powder extract prepared from these components have unique properties, namely:

(i) The ability to be highly synergised (Nash, 1954).

(ii) Repellent, knockdown, paralytic and toxic for a great variety of insects (Sylvester et al 1967).

(iii) Almost complete harmless to man and other warm blooded animals (Malone et al. 1968).

(iv) Rapid knockdown and no persistence of residue (Glynne Jones 1960).

(v) Hardly any built up of resistance in insect populations so far (Busvine, 1960).

These properties permit the use of pyrethrum against insects pests in houses, stores and on livestock. And on agricultural and horticultural harvests even when the treatment is done prior to harvests, thus requiring no safe period after treatments. The pyrethrum extract is effective on mosquitoes, tsetse flies and tabanids at low dosage (Casida, 1973). Lastly, Pyrethrum marc, a byproduct is also a protein-rich

supplement for dairy and beef cattle feeds (Njokah, 1979).

The major problems with the pyrethrum industry in Kenya are fluctuating market demand synthetic Pyrethrins (Njokah, 1979), and as we have already noted, reduced yields due to pest attacks. Other arthropod pests in addition to thrips known to attack the pyrethrum crop in the field include the red spider mites, Tetranychus ludeni Zacher. aphids, Brachycaudus helichrysi Kalt. and Myzus persicae (Sulz.), miridbugs, Nysius sp and root knot nematode Meloidogyne hapla Chit (Bullock,1963b; Njoroge, 1979). The direct and indirect effects of these pests on pyrethrum yields has not been adequately studied. Therefore, the economic implications of their control are not fully known. The present investigations were, therefore, initiated with the objectives listed below in mind.

1.13 Objectives of the Study

Despite the long associations of the pyrethrum thrips to the crop no serious and detailed studies have been undertaken on their biology and ecology in Kenya. To promote the industry, it is necessary to

improve on increased yields per hectare and on the content of pyrethrins in individual flowers. Since insect pests are still the main stumbling block in this direction, the objectives of these investigation were four folds:-

(i) To determine and describe the life history of T. nigropilosus which currently is incomplete, including observations on the influence of temperature on the rate of development.

(ii) To establish the effects of seasonal weather factors (temperature, rainfall and relative humidy) on pyrethrum thrips population densities in the field.

(iii) To assess the population densities of the pyrethrum thrips on commercially grown pyrethrum plants in the field.

(iv) To establish the alternative plant hosts of the pyrethrum thrips.

(v) To evaluate the damage caused by pyrethrum thrips on mature plants in order to assess

the pest density at which control must be applied to prevent the infestation rising to the damaging economic injury level (the economic threshold).

1.20 LITERATURE REVIEW

Bullock (1963) asserted that the life history of Thrips nigropilosus has not been adequately studied except for a few scanty descriptions of the developmental stages. Its counterpart on Pyrethrum the Thrips tabaci Lind., however has received detailed studies on its biology from other crops. Data on oviposition period indicated that T. tabaci laid almost three times as many eggs in the first 10 days of the oviposition period than the last 10. Gawaad et al (1970) were concerned with its embryogenesis and found out that the eggs undergo changes gradually as the embryo inside develop. The egg size increases and its colour darkened with time. Ghabn (1948) reported that egg batches of T. tabaci incubated at high temperatures developed quicker and more successfully than those at low temperatures which also affected the number of generations produced per year (Harris et al. 1936).

T. tabaci life history had four instars

between egg and adult, namely, two feeding instars or larvae and two non-feeding, pupae. This grouping of thrips instars has been disputed by many scientists. for example, Bailey (1957) who pointed out that some aspects of their unique development resembled the development of typical hemitabolous insects whose young are called nymphs. Lewis (1962), however, maintained the grouping when he reviewed the life history for members of the order Thysanoptera.

Detailed description of T. tabaci larval morphology and the subsequent changes they undergo through to adult have been discussed by Priesner (1964). The second stage larvae pupated under an earthern cell with a slower physiological processes (Standard, 1969).

Warm, sunny, dry summers in temperate region encourage thrips production and survival as opposed to cloudy, wet weathers that discouraged breeding. T. tabaci infestations on onion remains small and do not become economically important until the daily mean Temperature rise above 14.5^{o}C, (Harding, 1961). When rainfall was reported heavy, the T. tabaci larvae and adults population of thrips in India also declined with onset of moonsoon (Dev, 1964). T. tabaci

importance however, were only realised on pyrethrum during drought when flowering decreased (Bullock, 1961).

The thrips at the soil dwelling stage (pupae) are also reported to be vulnerable to changes in soil moisture. They survived most in soil moisture between 10 and 13%. With very dry soils these pupae died (Andrewarth, 1934).

Natural enemies although small in the field for thrips could be critical in determining abundance over period of time as in the case between T. tabaci and its parasite Thripoctenus brui in Japan (Sakimura, 1973, 1987).

Cases of pyrethrum resistance to its pests have not been reported before; however, cases of other crops developing resistance to Thrips tabaci are recorded. Some species of cabbages are less susceptible to T. tabaci enabling easy management in the field by the use of resistant varieties (Shelton et al., 1983). Elsewhere Mote et al. (1977) noticed that resistant onion varieties were least injured in the field. On other thrips species resistance to legume bud thrips (Megalurothripi sjostedti) were reported on varieties of cowpea(Khamala et al. (1981).

Thrips nigropilosus were found to rarely enter flowers though thousands were in leaves by Ward (1966). Discrete occurences of Thrips tabaci on onion were also reported by Priesner (1964). Morison (1957) in his study of the glasshouse thrips noticed definite patterns of thrips distribution on plants. Similar reports were given by Healey (1964) on a different thrips species.

Thrips tabaci is a cosmopolitan pest of onion grown between sea level and 2,000 m found in Fiji, Australia, Central and South America and Africa (Lewis, 1973). Polyphagous species occuring on several unrelated plant species and are more common as oligophagous but not monophagous which generally are uncommon in the fields. Thrips tabaci was reported on more than 355 species of flowering plants and two ferns in British Isles alone (Morison, 1949), and on a number of plant species elsewhere (Ghabn, 1948).

Thrips nigropilosus on the other hand has been reported on wheat and chrysanthemum (Speyer, 1935), some flowering plants (Priesner, 1928) and on Bidens pilosa (Bullock, 1961).

Wilkinson (1939), Harris (1945) and Gaddum (1949) were the first to record Thrips tabaci on pyrethrum and regarded it as a pest of little significance except during the dry season. It was not until in 1960's that thrips were reported to be impairing seed production (Bullock, 1961) and as distorting the plants to produce only small flowers (Bullock, 1963a). On other crops, Thrips tabaci lowered the marketability of onion, cabbage and tomatoes (Shelton, 1982; Grand Hale, et al., 1984; Daiker, 1985). Similarly, the same thrips species was also incriminated as a vector of virus spotted with of tomatoes (Sakimura, 1947).

Thrips nigropilosus on the other hand rendered a characteristic damage effects on leaves (Bullock, 1963b). It was proven important on Chrysanthemum cuttings (Speyer, 1935); Cucurbitaceae (Andison, 1959); Lettuce (Bailey, 1940). It was, however, not found to transmit any virus disease (Sakimura, 1939).

1.30 GENERAL MATERIALS AND METHODS

The experiments were conducted at the Pyrethrum Research Station, Molo, and at the substation, Limuru, and at the Faculty of Agriculture Field Station,

University of Nairobi. The three locations are situated at 2000-2500 m above sea level with suitable climate for pyrethrum growing. Experimental plots at Molo and Limuru were one hectare each, and those at the University consisted of potted plants in greenhouses. Plant seedlings were planted in holes 60 x 30 cm and fertilized with N at 50 kg/ha and P_2O_5 and K_2O basal dressing at 80:40 kg/ha. The plots were weeded every three weeks and treated to all the necessary agronomic requirements as recommended by Mwakha (1974); Chandra (1981) and Rao et al (1982).

Thrips larvae and adults were obtained from the Pyrethrum fields by making collection of infested leaves and flowers. In the greenhouses, thrips were transfered onto potted plants and the two thrips species were identified and reared on the two groups of the potted plants put 20 m apart to avoid late minglings for eventual biology and ecology studies. The thrips were separated from each other after inactivating them on plant tissues by cooling in a refrigerator for ten minutes. After shaking the plant tissues on a white paper, a fine camel-hair brush (size 00) slightly moisted with water was used to pick the thrips onto different groups of potted plants.

A magnifying glass was used to help in identifying the thrips species.

Studies on thrips population densities on different pyrethrum cultivars, seasonal factors on population densities and alternative hosts were conducted using Bullock[15] (1965) techniques with slight modifications. Plant leaves and flowers were picked and placed into wide-necked jars covered with screw tops. In the laboratory, the material was washed to recover the thrips. The recovery process involved filling the jars with methylated spirits and shaking vigorously. The jars were then allowed to stand for two minutes before the plant tissues were removed one at a time shaking the excess liquid back into the jars. Five mls. of petrol was added onto the jars contents and shaken to mix. The resultant mixture was tipped into glass petridishes and a little water added until the petrol formed bubbles and started to settle out on top of the methylated spirit. After two minutes, thrips floated at the intersurface between the separate liquids of petrol and spirit. A drop of Gelatin violet which turns the spirit bright blue and makes the thrips more easily visible was added before thrips under were counted under a stereo microscope.

CHAPTER 2 THE BIOLOGY OF THE PYRETHRUM THRIPS, *THRIPS NIGROPHILOSUS* UZEL. (THRIPIDAE: THYSANOPTERA)

2.10 INTRODUCTION

Compared to other Pyrethrum pests, no detailed studies have been conducted on *Thrips nigropilosus* Uzel. Perhaps this is partly because they can only be found by diligent searching and capture specimen need careful preparations and mounting for microscrope examination; and partly perhaps because of its recent reporting on Pyrethrum as a pest (Bullock, 1963a) giving way for more obvious pyrethrum pests earlier to study. These studies were initiated primarily to determine in detail the life history of *T. nigropilosus* using its host plant Pyrethrum as the rearing medium. And secondly, to assess the effect of temperature changes on the developmental instars of *T. nigropilosus*.

Sound knowledge and understanding of the pest biology are necessary in order to help formulate effective and practical control methodology at its weakpoint in their life cycle as Pickford (1983) did with *T. tabaci* larvae which were sprayed and were successfully killed with insecticides on sheets of

plastics on ground beneath soil and not spraying the whole plant.

Again since Pyrethrum are grown in a wide range of climatic zones in Kenya with varying temperature which would influence the thrips development and hence its status, the information obtained would indicate the favourable temperature ranges the thrips immature stages would develop rapidly maintaining high populations on the crop.

2.20 MATERIALS AND METHODS

2.20.1 Life History

Life history studies on Thrips nigropilosus were conducted in a multiple temperature incubator or growth chambers (Plate I) using stock thrips material from greenhouse (see 1.30 above). The chambers were fitted with oviposition, rearing and pupation cages similar to those used by Bailey (1932). The oviposition cage consisted of a large conical flash 20 cm long and 5 cm in diameter (Fig. 1). The rearing cages were made from section cuttings of glass tubing 10 cm long and 2 cm in diameter (Fig. 2). The pupation cages were similar to the oviposition cages but the flasks were darkened quarter way (5 cm) at the sides

by black paints to encourage pupation at the sand surface.

Twenty five adult female T. nigropilosus were drawn into an oviposition cage with clean pyrethrum leaves on which to oviposit. A fine camel hair brush was used to sweep the thrips into the cages which were then covered with muslim cloth, securely fastened with a rubber band which allowed free air circulation. After 24 hours the leaves were transfered from the oviposition cage to similarly clean conical flasks to incubate and all adult thrips removed from the leaves. The leaves in the incubation cages were examined after every 12 hours under magnifying lenses for the emergence of the first instar larvae.

The leaf tissues into which the eggs were embeded were assessed after the chlorophyll were removed using Hibbs (1962) methodology. Details of the instar changes including colour and size changes for eggs, larvae and pupae were assessed daily. The instars were removed from the running experiment then observed under a calibrated microscope eye-piece and stage micrometer then discarded.

The hatched larvae 1 were then transferred

each into a rearing cage (Fig. 2) which totaled twenty five. Caps of cellophane were thereafter glued on the upper end of the cages to prevent the thrips from escaping but allowed for free air circulation. The tubes were held upright by inserting into a hole bored on a cardboard wood. The wood was set upon a petri-dish containing water and the petioles of the leaves and access to water. When it was necessary to change the leaves, the tubes were withdrawn from the petri-dishes and the leaves removed. The larvae were then transferred onto fresh leaves using a camel hair brush.

The larvae were observed under a calibrated microscope at 12 hours interval for colour and size changes.

Record of any cuticle slought were kept at the same interval for any eventual moulting into the next instar. When activity like movement of the second larval instar were observed to reduce and the cutîcle started to slought, the larvae were trans-fered into the pupation cages.

The pupation cages were similar to the

oviposition once in size except for the darkened sides and the fine moist sand spread at the flask base a centimeter deep. Details like colour, size morphological and moults changes were equally observed under a microscrope from removed soil surfaces to expose the hiding pupae. Similarly, the soil surfaces were also observed twice a day for adult emergence. The adults were observed under microscope for size and colour variations with time in the rearing cages similar to that used for the larval development (Fig. 2). The number of living males were compared to female to assess the sex ratio in the Thrips nigropilosus. The living thrips were eventually compared for the adult longevity period. This study was conducted at 20°C and 70% relative humidity.

Datas for the instar sizes lengths (mm) and width (mm), their durations (days and hours) were eventually computed and their means and standard deviation (S.D ±) compared. Morphological descriptions of every instar were also summarized to facilitate later identifications.

Plate 1. The multiple temperature incubator where the thrips biology study was conducted.

Fig. 1 An oviposition cage

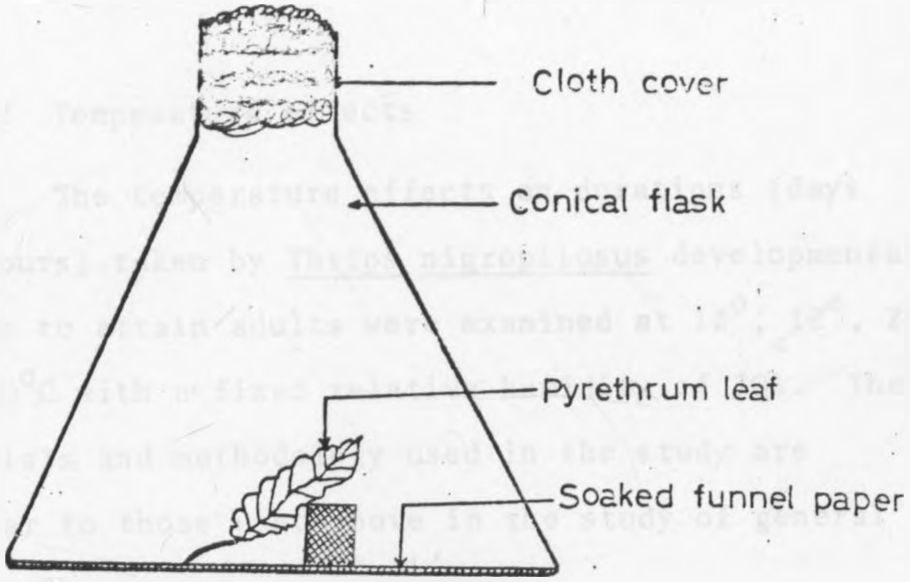
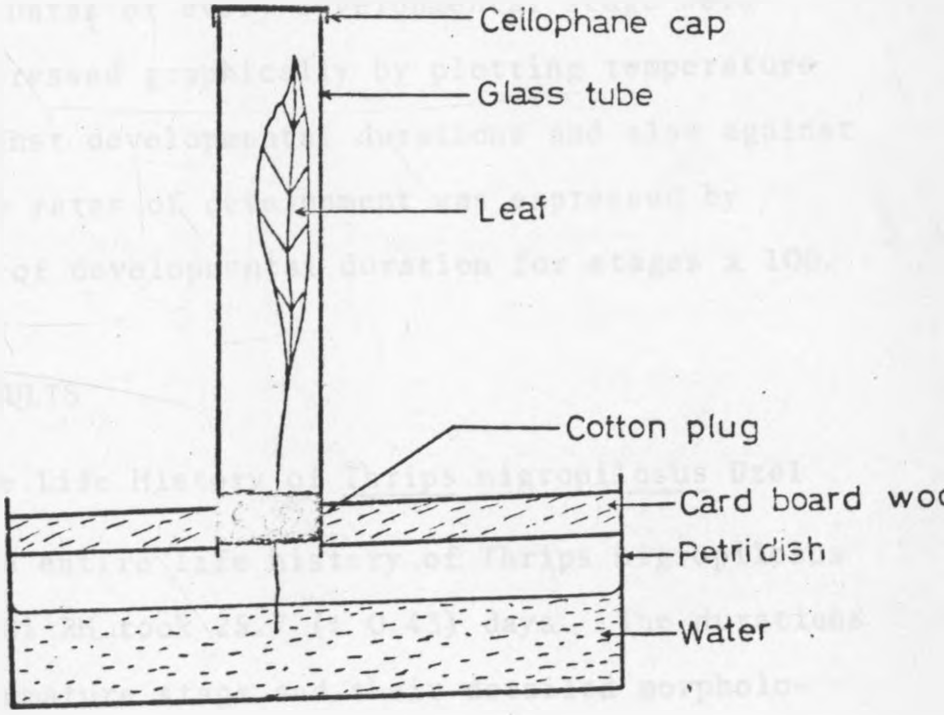


Fig. 2 A rearing cage



2.20.2 Temperature effects

The temperature effects on durations (days and hours) taken by Thrips nigropilosus developmental stages to attain adults were examined at 12°, 12°, 25° and 30°C with a fixed relative humidity of 70%. The materials and methodology used in the study are similar to those used above in the study of general life history of T. nigropilosus.

Using 25 first hatched larvae I for every temperature points under study, the mean time (days and hours) taken by every developmental stages were compared. Datas of every developmental stage were further expressed graphically by plotting temperature points against developmental durations and also against rates. The rates of development was expressed by reciprocal of developmental duration for stages x 100.

2.30 RESULTS

2.30.1 The Life History of Thrips nigropilosus Uzel

The entire life history of Thrips nigropilosus 20°C and 70% RH took 25.7 (± 0.43) days. The durations for each immature stage and their detailed morphological features at each moult are given below in order

to facilitate identity and provide a full account of this insect's metamorphic process.

2.30.1.1 The Egg

From the oviposition cage, T. nigropilosus females were observed to deposit their eggs singly in incisions made in the upper leaf surface by the ovipositors. From the leaves where the chlorophyll was removed, it was evident that some eggs, however, were only partially embedded with their long axis inclined at a shallow angle to the leaf surfaces.

Although it was not quite possible to identify the egg colour after the removal of chlorophyll as they were somehow bleached, the eggs were cylindrical, slightly kidney shaped (Fig. 3a). The shells or chorion of freshly laid eggs were smooth, delicate and pale white in colour. The egg average length and diameter was 0.25 (±0.09) mm and 0.14 (±0.10) mm respectively (Table I).

Both the egg shape and colour changed gradually during the incubation period to conical and yellow as the embryo developed.

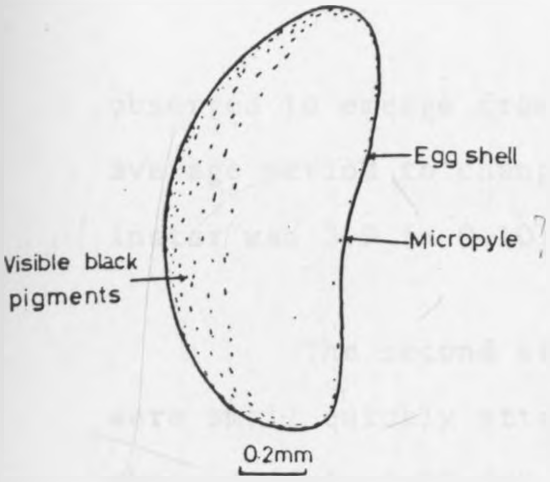
When the egg was near hatching black pigmented eyes were visible through the shell. At one end was clearly marked the funnel shaped micropyle used as a passage for the sperm at the time of fertilization. The incubation period for the eggs at 20°C and 70% RH was 7.7 (± 0.23) days.

2.30.1.2 Larval Instars

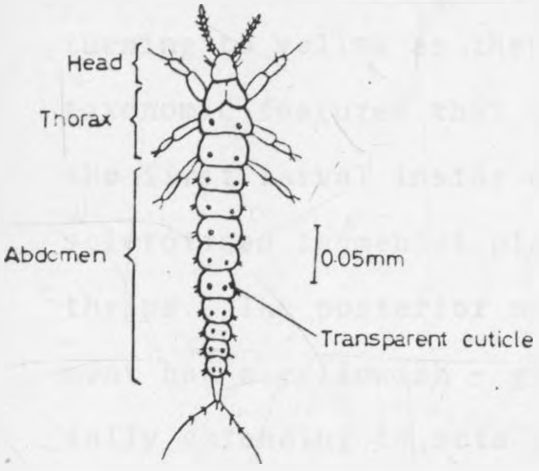
The first instar larva had distinct head, three thoracic and ten abdominal segments. They bore a pair of legs on each thoracic segments and thus resembled the adult forms except for the small size of 0.45 (±0.11) mm and 0.19 (±0.09) mm length and diameter respectively. The cuticle was almost transparent at hatching but soon developed pigment patches (Fig. 3b). The pigment which at first were yellowish after about 36 hours were fully selerotonized and became orange in colour as the individuals were about to change into the next instar.

By the third day the larvae had grown to about thrice their length at hatching. About this time they moved to a sheltered place on or near plant leaves in the cage to moult. Second stage larvae were

g 3a. An egg of T. nigropilosus 3-4 days old



g.3b. First instar larvae of T. nigropilosus at hatching.



g.3c. Second instar larvae of T. nigropilosus.

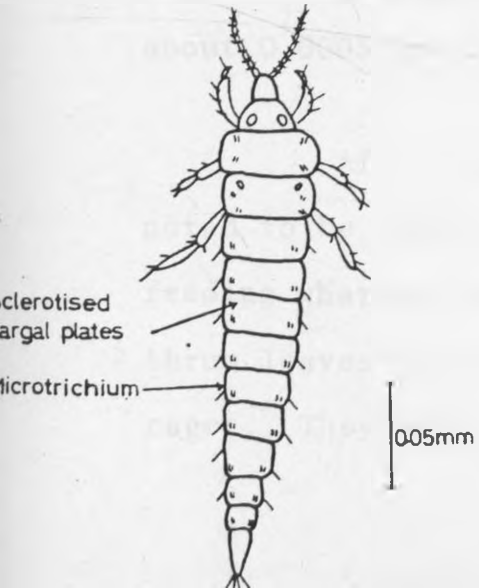


Fig 3d. Prepupa of T. nigropilosus.

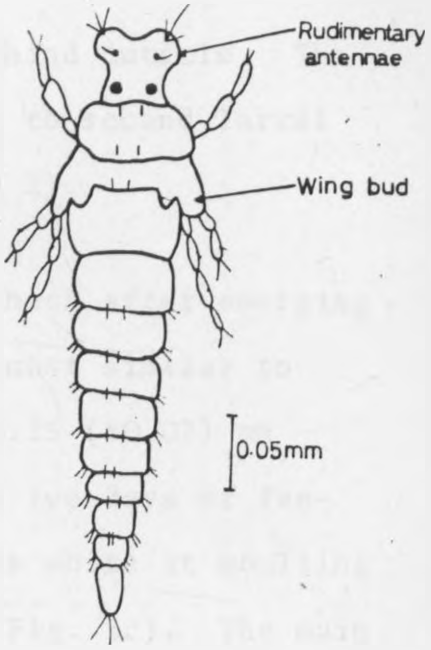
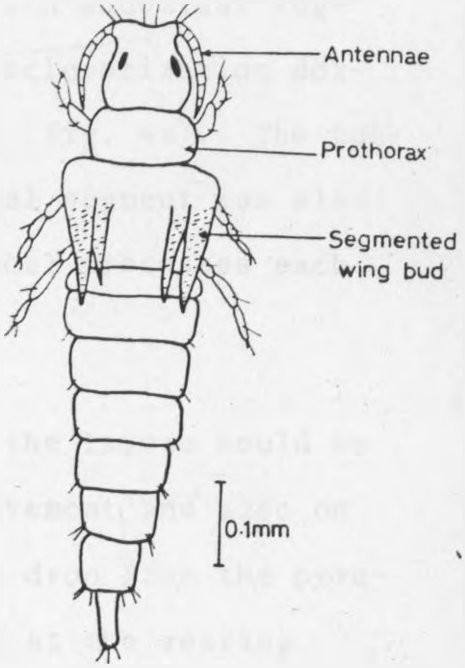


Fig.3e Pupa of T. nigropilosus.



observed to emerge from the left behind cuticle. The average period to change from first to second larval instar was 3.9 (± 0.10) days (Table 2).

The second stage larvae which after emerging were small quickly attained size almost similar to that of adult 0.90 (±0.04) mm and 0.25 (±0.02) mm length and width respectively after two days of feeding (Table I). The body colour was white at moulting turning to yellow as they matured (Fig. 3c). The main taxonomic features that distinguished the second from the first larval instar were the arrangements of the sclerotised segmental plates in the former as in adult thrips. The posterior margin of 9th abdominal segment had a yellowish - grey band sclerotization dorsally extending to seta insetions (Fig. 4a). The posterior third of the tenth abdominal segment was also yellowish-grey with about 20 conical processes each about 0.0005 mm in length.

After about seven days the larvae could be noted to be fairly inactive in movement and also on feeding whereby they were seen to drop from the pyrethrum leaves onto the cotton plug at the rearing cages. They were then transferred to the pupation

TABLE 1 Mean length and widths for eggs, instars and adults of T. nigropilosus reared at 20°C and 70% RH.

Developmental stages	Number of individuals (n)	Mean lengths (± S.D. (mm))	Mean width (± S.D. (mm)
Eggs	10	0.25 (0.09)	0.14 (0.10)
First instar larva	8	0.45 (0.11)	0.19 (0.09)
Second instar Larva	10	0.90 (0.04)	0.25 (0.02)
Prepupa	10	1.00 (0.11)	0.25 (0.10)
Pupa	8	1.10 (0.09)	0.40 (0.10)
Adult (female)	10	1.25 (0.04)	0.40 (0.15)
Adult (male)	3	1.10 (0.09)	0.40 (0.10)

cages, the larvae were seen to quickly penetrate into the sand to pupate. When the sand where they sunk were disturbed thereafter, the lining surrounding the larvae were seen to be coated with a thin transparent membrane which must have just been produced by pupating larvae. After two days the larvae were observed to have moulted and changed to prepupa leaving behind in the cocoon their old cuticles.

2.30.1.3 Prepupa

This was observed as an intermediate stage between the larva and the pupa. The individual differed from the second stage larvae by possessing wing buds and rudimentary antannae which appeared as short, straight sheaths infront of the head without distric segmentation (Fig. 3d). Since they remained within the soil cocoon these prepupa stages did not feed. They were similar in size as second larval stage (Table 1). The average prepupal stage duration was 3 days excluding the days for cocoon building (Table 2).

2.30.1.4 Pupa

There was no moulting process between the prepupae and pupal stages. The prepupa changed into

Fig.4a. Posterior end of T. nigropilosus female abdomen.

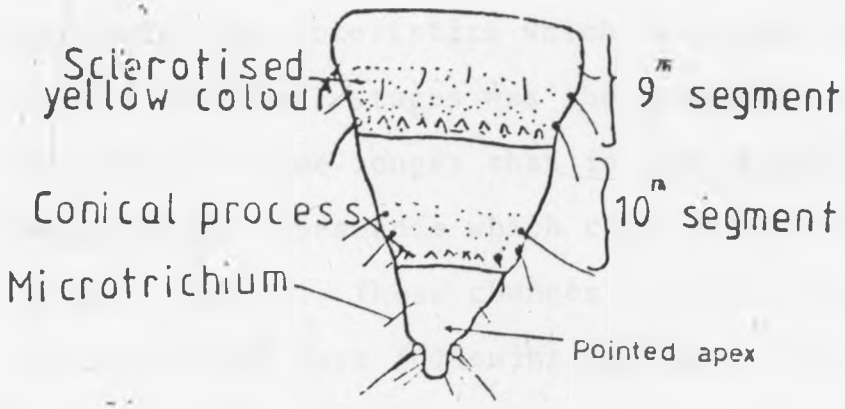


Fig.4b. Posterior end of T. nigropilosus male abdomen.

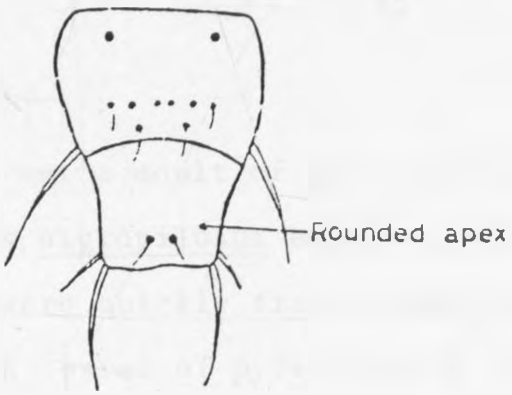
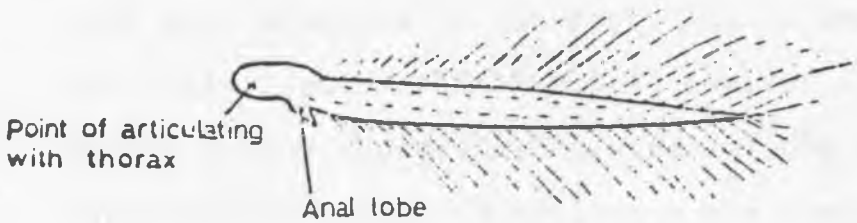


Fig.4c. A macropterous wing bud of T. nigropilosus.



pupa when the antennae grew longer than in the prepupa and turned backwards over the head to reach the first thoracic segment or prothorax (Fig. 3e). Other additional characteristics which determined the attainment of the pupal stages was the growth of the wing buds which became longer than in the prepupa, and the general body appearance which closely resembled that of adult thrips. These changes occured within an average of 3.5 days following the end of the prepupal duration (Table 2).

2.30.1.5 Adults

There was a moult of the pupa from which the adult Thrips nigropilosus emerged. The newly emerged adults were quickly transferred into rearing cages with fresh leaves of pyrethrum as their rearing medium. The sexes could easily be distinguished by size whereby the females were larger than the males; and also colouration whereby the females were brown with grey pigments on the head, thorax and abdomen and males lighter than females, however, the depth of the colour appeared to depend largely upon the time which had elapsed following the emergence of imago from the pupal stage. Finally, the shape of abdominal apex, whereby the female abdomen apex was

TABLE 2. Approximate durations (days and hours) of development stages of 25 T. nigropilosus reared at 20°C and 70% RH.

T. nigropilosus number	Incubation period of Eggs		Larva I		Larva II		Pupal		Total Time		Adult longevity	Sex
	d	h	d	h							d	
1	5	0	4	0	DEAD							
2	6	0	4	0	8		7	0	25	0	21	F
3	6	0	4	0	7	12	6	0	25	12	10	M
4	6	12	3	12	DEAD							
5	7	0	4	0	8	12	5	0	25	12	2	M
6	7	0	4	0	9	0	5	12	26	0	1	F
7	7	12	DEAD									
8	7	12	DEAD									
9	7	12	4	0	7	12	7	0	26	0	2	F
10	8	0	4	0	7	12	DEAD					
11	8	0	4	0	8	0	6	12	26	12	1	F
12	8	0	4	0	7	12	6	12	26	0	5	F
13	8	0	DEAD									
14	8	0	4	0	8	0	7	0	27	0	4	F
15	8	0	4	0	8	0	5	12	25	12	1	F
16	8	0	4	0	8	12	5	0	25	12	3	F
17	8	0	DEAD									
18	8	0	DEAD									
19	8	12	3	12	8	0	6	12	26	12	7	F
20	8	12	4	0	DEAD							
21	9	0	4	12	DEAD							
22	9	0	5	12	DEAD							
23	9	0	DEAD									
24	9	12	4	0	8	12	DEAD					F
25	10	0	3	12	8	12	7	0	29	0	19	F
n	25		19		14		12		12			
$\bar{X}$(S.D.)	7.7(0.23)		3.9(0.10)		7.9(0.12)		6.1(0.23)		25.7(0.43)			
Range	5-10		3.5-5.5		7.5-9.0		5.0-7.0		23.5-29.0		1-21	

Key d = days F = Female $\bar{x}$ = mean
h = hours M = Male SD = Standard Deviation

rounded (Fig. 4a) and male's flat (Fig. 4b).

Other morphological features noted on the adult included wing types exhibited by the thrips which were both micropterous (fully) and micropterous (reduced) wings each with a small posterior expansion and scale like at the base (Fig. 4c). The macropterous wings were commoner among the males than females. Secondly the sex ratio of females to males was 9:1 with adult longevity period lasting between 1 to 21 days under the laboratory conditions (Table 2).

2.30.2 The effect of temperatures on durations of thrips developmental stages

Fig. 5 shows the duration of developmental stages of Thrips nigropilosus and that the entire life history to be completed varied grately when the life cycle was studied at different temperatures. At 12^{o}, 20^{o}, 25^{o} and 30^{o}C the mean durations to complete development from eggs to adult was 50.1, 24.7, 18.4 and 14.2 days respectively. The relationship between temperature plotted against time of development produced a hyperbola line (A) indicating that there were differences between durations for the temperatures under study.

The rate of development of the thrips on

the other hand at different constant temperatures (12^{o}, 20^{o}, 25^{o} and 30^{o}C) were obtained by expressing the development time as a reciprocal x 100. For example, when the length of time to complete development by T. nigropilasus took 50 days at 12^{o}C; it completed 1/50 or 2% of the development each day. The results are expressed on the diagram fig. 5 by a straight line (B) indicating that within the temperature ranges, the rates of development for the eggs, larvae, pupae and (egg adult) were directly proportional to temperature; When the straight line for the rate of development was extrapolated it intersected the abscissa nearly at the 0^{o}C; except for pupa where the intersection was well below 0^{o}C.

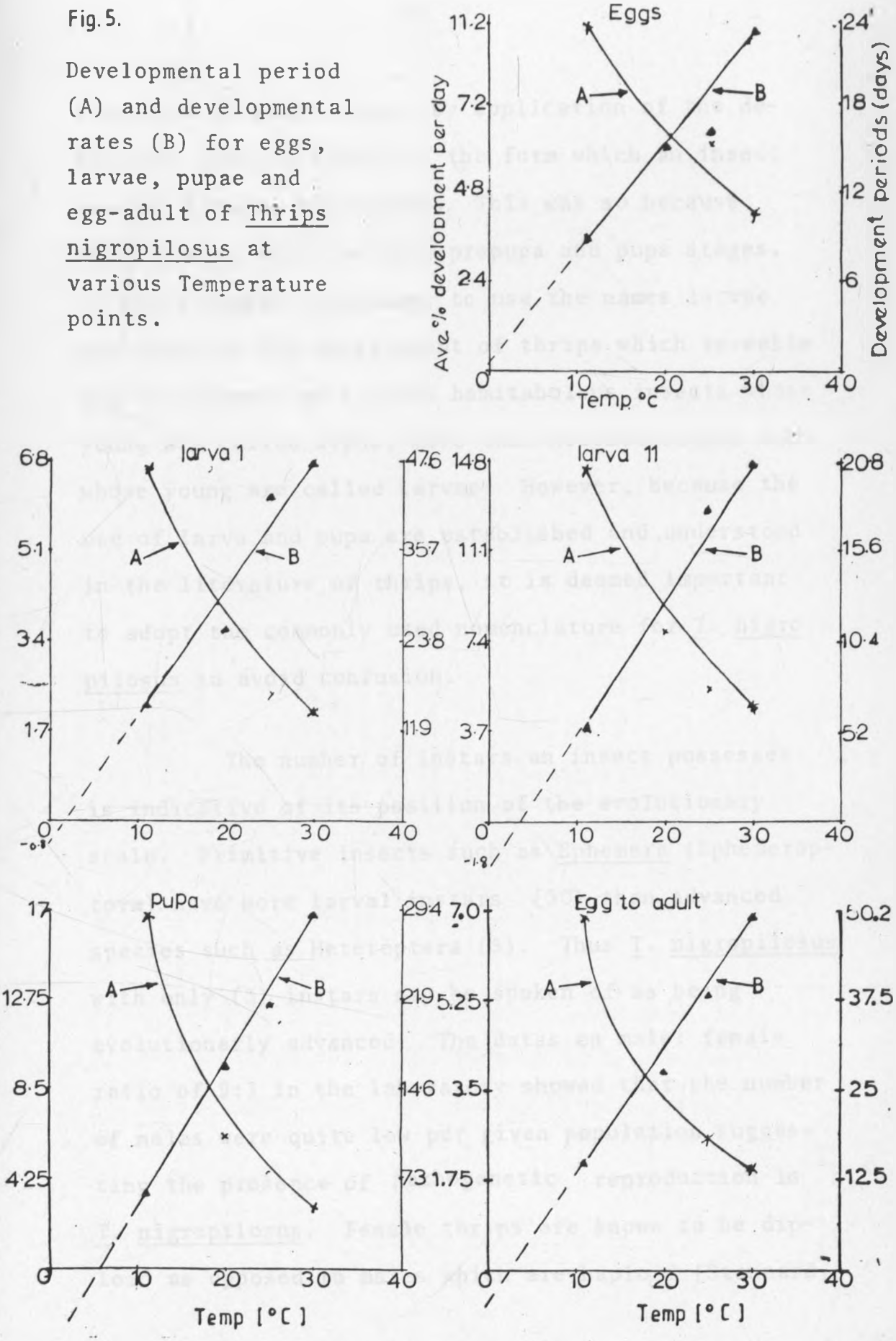
2.40 DISCUSSION AND CONCLUSION

2.40.1 The life History

The life history of Thrips nigropilosus like any other insect was divided into a series of stages. There were a total of four stages between egg and adult, namely two feeding larvae known as first and second larval stages; and two non-feeding stages, prepupa and pupa. Although the life history studies of T. nigropilosus revealed the four stages, there were only

Fig. 5.

Developmental period (A) and developmental rates (B) for eggs, larvae, pupae and egg-adult of Thrips nigropilosus at various Temperature points.



3 instars to adult stage, by application of the defination that an instar is the form which an insect assumes between the moults. This was so because there was no moult between prepupa and pupa stages. It would appear a misnomer to use the names larvae and pupae to the development of thrips which resemble the development of typical hemitabolous insects whose young are called nyphs, more than holometabolous ones whose young are called larvae. However, because the use of larva and pupa are established and understood in the literature of thrips, it is deemed important to adopt the commonly used nomenclature for T. nigro pilosus to avoid confusion.

The number of instars an insect possesses is indicative of its position of the evolutionary scale. Primitive insects such as Ephemera (Ephemeroptera) have more larval instars (30) than advanced species such as Heteroptera (5). Thus T. nigropilosus with only (3) instars may be spoken of as being evolutionarly advanced. The datas on male: female ratio of 9:1 in the laboratory showed that the number of males were quite low per given population suggesting the presence of pathogenetic reproduction in T. nigropilosus. Female thrips are known to be diploid as opposed to males which are haploid (Stannard,

1968). O'Neill (1960) noted that males are the product of unfertilized eggs, similarly he explained the reason for pathogenetic reproduction and scarcity of males to be a factor of introduced species because pathenogenetic forms are more easily spread than sexual forms. Morison (1957) on the other hand explained that pathogenetic reproduction is a factor of temperature with fewer males occuring where it is warmer. The low ratio can only partly be explained by the fact that T. nigropilosus was introduced into Kenya late 1950's (Bullock, 1961) hence the reason for pathenogenicity. Finally, the adult longevity period of about 21 days for T. nigropilosus under this study is similar to that found by Harris et al (1936) on T. tabaci at 30°C and Seshadri (1953) on Trichinothrips brevicaps at 22°C. Given however, that embryogenesis development is faster for the first 10 days than the later (Gawaad et al., 1970), the T. nigropilosus is in a better position to effectively produce lots of eggs, hence, increase its population in warmer conditions of 20°C and 70% RH with the longevity period running to 21 days.

From the study it is evident that the weakest point of the Thrips nigropilosus life history like any other thrips is when their development is at

the larvae II stage tending towards pupae. Since the pupation occurs in soil, if a persistent chemical spray would be directed at the soil surface e.g. organochlorines the pest would be killed at the larval stage as they descend to pupate and when they ascend from the pupal into adult stages. Using this method the possible natural enemies of thrips i.e. predators and pathogens on the pyrethrum leaves and flowers would remain unharmed hence resulting into an effective mean of an integrated pest control on the thrips and other pests on pyrethrum.

2.40.2 Effect of temperature on development durations

There has been many studies on the duration of different stages and life history of a number of thrips species at constant temperatures. The shortest time required to complete the life cycle for Taeniothrips gladioli M. is about 10 days at 30°C (Herr, 1934). Since instars are exothemic their development is bound to be very sensitive to temperature changes in an environment. The rate of development of T. nigropilosus under study temperature did increase with rising temperature. This rate is bound to be affected by the cooler and warmer extremes as the

extrapolated lines show Fig. 5. Davidson (1944) in his study of the relationship between temperature and development of the thysanoptera found out that temperature beyond 30°C would be lethal to their development. In the present study temperatures below 0° and above 30°C seems to be lethal to the development of T. nigropilosus at the eggs, and larval stages but not for the pupae which could endure the lower extreme temperatures. This phenomena on pupae can be explained by the fact that they could be more resistant to the extreme temperature than the eggs and larvae. Secondly the variation from the normal on pupae could have arisen from the fact that datas on pupae about durations to achieve their development were obtained through difficulty by scratching the sand surfaces and a bit of guess work about the prepupal to pupae thus making them less precise as those of larva and eggs. These measurements however, would illustrate the dependancy of rate of development in T. nigropilosus on temperature for the complete life history.

The significance of these studies on the effect of temperatures on development would be diminished in the field because the relationship between temperature and rate of development would be less well defined since temperature and other components

of weather fluctuate. For example, harmful high or low temperature may occur and impair subsequent development at a place which had favourable temperatures for developments. However, for this species T. nigropilosus which may be, do not aestivate, the rate of development at temperature which fluctuates daily within a suitable range would probably be similar to the rate at equivalent constant temperatures in that range. This was found to be true for T. tabaci which developed from egg to adult in 11.2 days at a constant temperature of 30°C (Harris et al., 1936) and in 13.9 days at fluctuating temperature with a mean of 30°.8C (Lall et al., 1968). The significance of this phenomenon to the pest status of T. nigropilosus on pyrethrum grown in a wide ecological zones as Kenya has yet to be investigated, however, going by the fact that rate of development is affected much by temperature in its life history the same will determine the number of generations produced each year, hence the importance of the pest on pyrethrum.

CHAPTER 3 ECOLOGICAL STUDIES OF PYRETHRUM THRIPS

Three aspects of studies were undertaken in established Pyrethrum fields at the Pyrethrum Research Sub-station, Limuru situated about 40 km west of Nairobi. The altitude is 2,350 m above sea level and the centre coordinates are $01^{o}7'S$ and $36^{o}30'E$. The research sub-station is a part of a large area of gently undulating Abardare Ranges with well drained, very deep red loam soils. The experiments were conducted in both the long and short rain seasons of late 1982 and 1983. The studies undertaken on Thrips tabaci and Thrips nigropilosus, (the major thrips on pyrethrum) included: the influence of weather factors on the occurance of thrips on crop; Preferences of pyrethrum cultivars by the thrips species; and alternative host plants for the Pyrethrum thrips. The information obtained from these studies are important to enable us understand the ecological requirements of the thrips for the implementations of the intergrated pest management (IPM) programmes.

The experimental plots were both measuring one hectare each into which were established pyrethrum plants at (60 x 30) cm spacing. The plants were

fertilized, weeded at four intervals and given all the agronomic requirements as recommended by Mwakha (1974), Chandra, (1981) and Rao et al., (1982).

3.10 THE INFLUENCE OF WEATHER FACTORS ON THE OCCURANCE OF THRIPS IN PYRETHRUM

3.10.1 INTRODUCTION

The rate of any animal population during the breeding season and the eventual size of a population of say thrips in an area depends partly on the number of thrips breeding in the area and partly on the number entering and leaving it. Population built up of thrips in an area is also a factor of seasonal fluctuation. Population changes are usually least in species that do not disperse far and in regions where the weather throughout the year is equable.

Many overlapping generations develop with suitable weather for very rapid breeding and the limits between generations becomes obsecured resulting into much greater increase in number as was observed for Thrips tabaci (Sakimara 1939, Carlson 1964). Seasonal incidences or occurance of thrips in field is a record of their seasonal history. Some insects,

for example, armyworms may occur at certain times as outbreaks and then disappear completely or remain in very low population level. The study reported here were initiated to provide information on the pyrethrum thrips, (T. tabaci and T. nigropilosus) population in relation to seasonal weather changes (temperature, rainfall and relative humidity). The information obtained would be used to determine when and whether a pest control programme is necessary for the pyrethrum thrips with a given climatic trend.

3.10.2 MATERIALS AND METHODS

The experiment was conducted at the Pyrethrum Research Sub-station, Limuru, described above. Pyrethrum plant of clone 4331 was established on one hectare plot continuously under the crop. At the middle of this field were marked out a plot (21 x 30) m. The pest populations were assessed from the marked plot. The crop was planted on 15th December 1981 and received the agronomic requirements as mentioned above. The plants were in complete bloom with flowers from May, 1982.

The larvae and adult numbers of T. tabaci and T. nigropilosus and datas on daily weather factors were obtained for the pyrethrum field on the 15th of

each month starting from June 1982 to February 1983 when the crops were cut - back to rejuvinate for the next season. Five leaves and a flower were randomly sampled by picking from one plant skipping five plants in a row to realise fifty leaves and ten flowers into 4 wide-necked jars covered with screw tops. This sampling was repeated five times again skipping 7 rows to take the next sample. The samples were immediately transferred into the laboratory, then washed to recover the thrips.

The recovery process involved filling the jars with methylated spirit and shaking vigorously as was adopted by Bullock (1965). The jars were then allowed to stand for two minutes before the plant tissues were removed one at a time shaking the excess liquid back into the jars. The plant parts were washed twice to ensure maximum recovery of thrips. The resultant mixture were tipped into glass petri-dishes and thrips counting performed under a binocular microscope for total number of Thrips tabaci and T. nigropilosus together (see 1.30 above). The prevailing weather conditions, rainfall, temperature and relative humidity) during the trial were obtained monthly from a meteorological weather station about 0.5 km from the trial site within the Research Station. The weather datas were the means of the rainfall,

temperature and relative humidity.

The obtained datas were finally expressed as the number of thrips per plant and averages of the weather factors were computed. Comparisons between the weather factors and thrips number were then graphically displayed in a diagram.

3.10.3 RESULTS

The influence the weather factors (temperature rainfall and relative humidity) has on the mean number of thrips per pyrethrum plant are expressed in Fig. 6. The highest number of thrips per plant were noted in the months of June 1982 and January 1983. Low rainfall however, were recorded in the months of March, April, May, November and December 1982 and February 1983. Mean temperatures per month were obtained from the average of daily wet and dry temperatures. It is only in the months of September and January 1983 that the mean monthly temperatures went above $10^{o}C$, otherwise the temperatures over the experiment period in Limuru remained between $8.5^{o}C$ to $9.9^{o}C$. Similarly, relative humidity over the period was about 55 - 60% RH. The influence the weather factors had on the thrips population, thus can only be attributed to rainfall variations and not

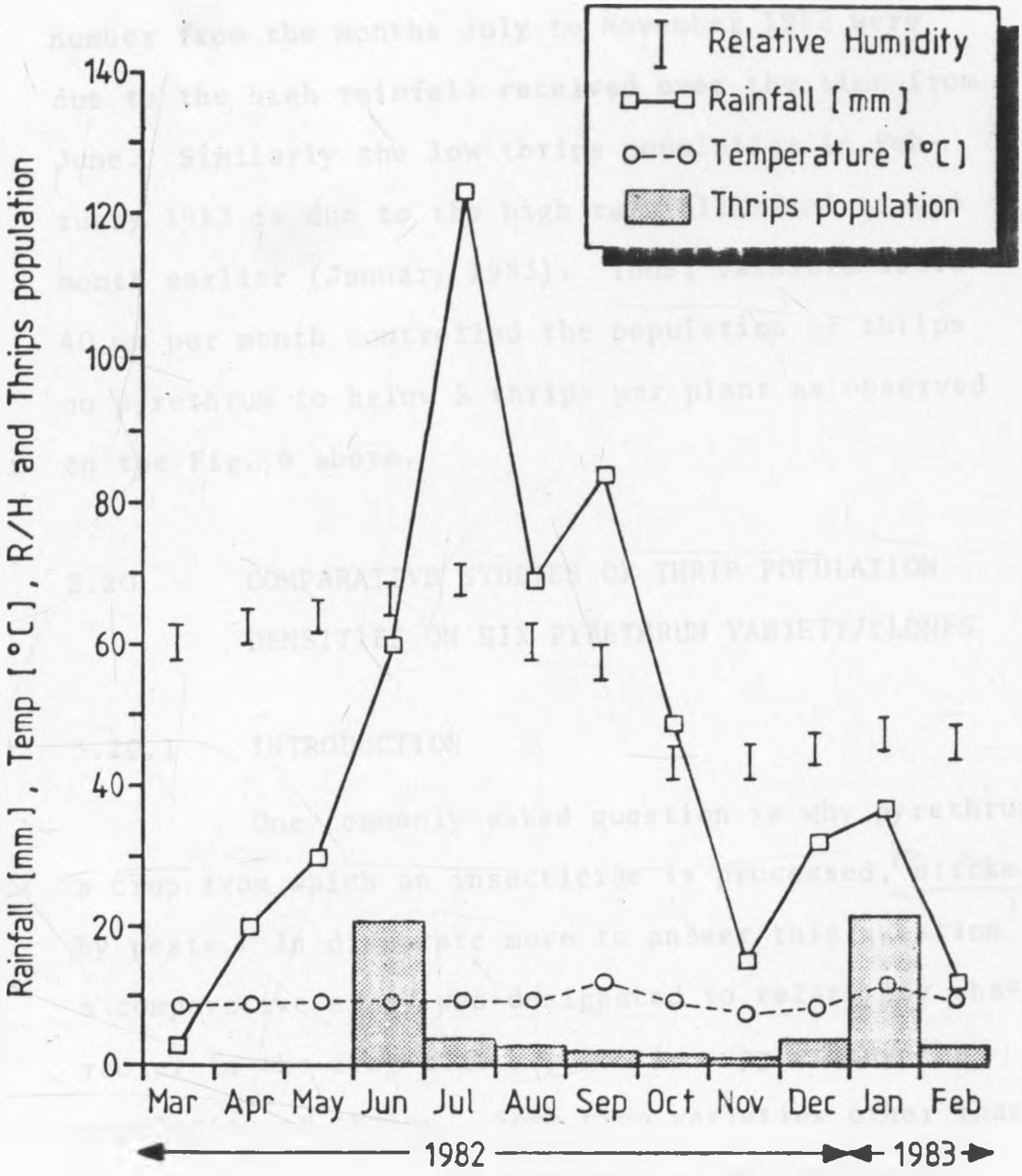


Fig. 6. Rainfall (mm) temperature (^{o}C), Relative Humudity (%) and thrips population curves over one year period.

temperatures or relative humidity. The low thrips number from the months July to November 1982 were due to the high rainfall received over the time from June. Similarly the low thrips population in February 1983 is due to the high rainfall received one month earlier (January 1983). Thus, rainfall above 40 mm per month controlled the population of thrips on pyrethrum to below 5 thrips per plant as observed on the Fig. 6 above.

3.20 COMPARATIVE STUDIES OF THRIP POPULATION DENSITIES ON SIX PYRETHRUM VARIETY/CLONES

3.20.1 INTRODUCTION

One commonly asked question is why pyrethrum, a crop from which an insecticide is processed, is attcked by pests. In disperate move to answer this question a comparative study was designated to relate any character in the crop that may act in suppressing the population of thrips. Some crop varieties other than pyrethrum are known to have natural mechanisms to limit insect pest population build-ups on them. This host plant resistance to insects was first recorded in grapes against grape fly, Phylloxera vitifolial (Fitch) in Europe in the 1870's. However, the use of insecticides slowed the development of this

technique as a means of reducing insect pest populations attacking crops. But development of resistance to insecticides by pests have recently renewed and accelerated interest in research on insect resistant crop varieties

The present study aims at assessing any significant differences of the thrips populations on the commonly grown pyrethrum clones/varieties. Since pest population on a crop species is a measure to the crops suitability as food or for oviposition, it is assumed that the pyrethrum clone/variety with less thrips number may have a mechanism in it to resist their attack. Two species of thrips, (Thrips tabaci and Thrips nigropilous) attack pyrethrum in the field. This ecological study also aims at enlightening any interaction between these thrips species to the pyrethrum clones/varieties. Thirdly, the two thrips attack heavily the flowers and leaves, and so using the pyrethrum clones/variety, the study aims at establishing the parts of the crop heaviest attacked by the thrips to give in sight to the thrips niches.

3.20.1 MATERIALS AND METHODS

The experiment to investigate thrips population densities on the pyrethrum clones/varieties

was conducted at the Pyrethrum Research Sub-station, Limuru. Six commercially grown pyrethrum clones/ varieties were planted on 13th September, 1981 on a one hectare field, with all agronomic requirements given, except they were not sprayed with any insecticide(Plate 2).

The six pyrethrum clones/variety used in this experiment were: clones 4331, SB/66/107, MO/70/ 1013, O/64/219, Ma/63/1889 and variety P4. Their characters and history are summarised on Table 3 below. At the centre of the field were marked plots each measuring 4.5 m x 2 m laid down using randomised block design with three replications (Plate 2). The clones were planted from splits and the variety from seedlings raised in a nursery.

The thrips number per clone or variety; in the leaves and flowers; and their interaction per crop were assessed for the two species Thrips tabaci and T. nigropilosus separately. The thrips number were assessed per plot for the fifty randomly picked leaves and 10 flowers put into different bottle jars. Collections were made from 15th December, 1981 to 15th December, 1982 flowering season. The plant parts were later washed in the laboratory and thrips number counted under a binocular microscope.

Plate 2. Intercropped pyrethrum cultivars at Limuru Agricultural sub-station

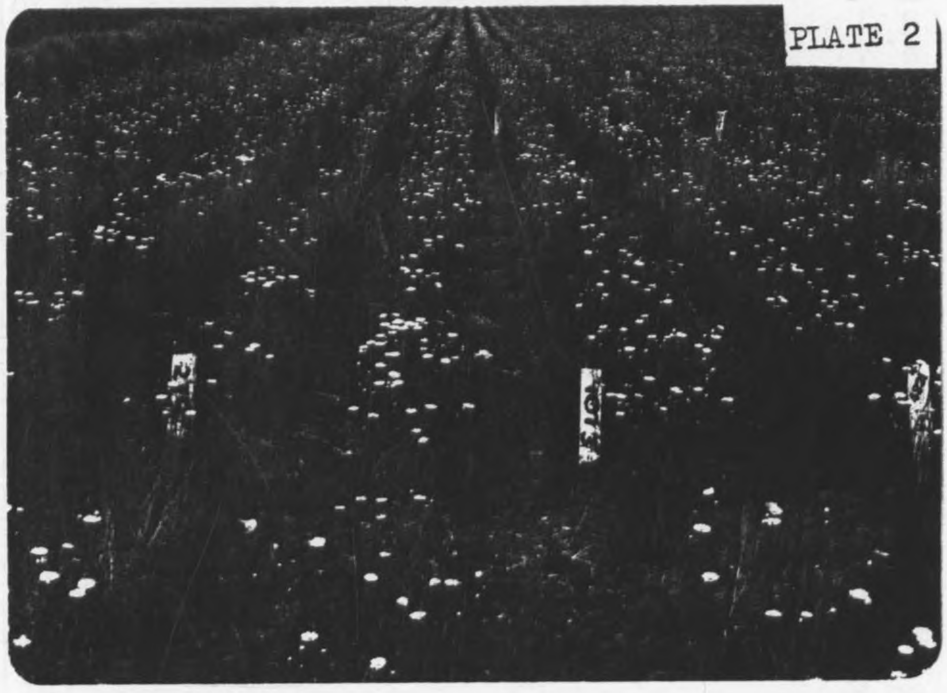


TABLE 3 History and major characters of Pyrethrum clones/variety used in the thrips population studies

Clones/variety and source	Years of Origin	Pyrethrum content	Yields Kg/ha.	Flower number/ plant	Flower sizes (cm. (±S.D)	Leaves colour and Average number
Clone 4331	1964	1.6	1200	38.0 ± 13.0	3.975 ±0.399	Whitish Green
					Haploid	
Clone SB/66/107	1976	1.7	500	17 ± 8.6	5.00± 0.328	Green
					Triploid	Averagely many leaves
Clone Mo/70/1013	1979	1.9	1100-1200	39.5 ± 7.4	3.980±0.431	Green
					Haploid	Many tiny leaves
Clone O/64/219	1972	1.8	600-800	35.1 ± 2.3	3.677±0.342	Greyish green
					Haploid	many closely packed leaves
Clone Mo/63/1889	1966	1.6	500-700	30 ± 4.1	4.091±0.299	Deep Green
					Haploid	Averagely very many broad leaves
Variety P4	1970	2.0	600-800	32.5 ± 7.6	3.120±0.449	Green and Whitish
(From polycrops clones 3093, 4743 and Mo/62/428)					Mixed Haploid Triploid	Many leaves

Source = Annual Report Min. of Agriculture & Livestock Development, Nairobi, Kenya.

Datas on the mean number of T. tabaci and T. nigropilosus were finally transformed using Natural Log (x + 2) and analysis of variance and means associated with significant source of variation separated by Least Standard Deviation test.

3.20.3 RESULTS

Tables 4 (a) and (b) shows that mean number of thrips per plant varied from one pyrethrum clone/ variety to the other. The lowest number of thrips per plant were recorded on clone MO/70/1013 and the highest on clone 4331. Comparatively clones SB/66/107, O/64/219 and Ma/63/1889 had high mean number of thrips per plant significantly different (P = 0.05) from variety P4 which had low thrips number.

When interaction between the thrips in leaves or flowers were assessed for the pyrethrum clones/variety still clone MO/70/1013 haboured least thrips in flowers. In leaves on the other hand variety P4 and clone MO/70/1013 had the least thrips number compared to clone Ma/63/1889 that was leading. Means of thrips per pyrethrum clone/variety in flowers were generally higher than in leaves.

Interaction between the thrips species

TABLE 4 (a) Pest - cultivars population densities

Pyrethrum clone/ variety	Thrips population/ cultivar	Thrips species interaction with cultivar		Thrips species in leave of flowers interaction with cultivar	
		T. tabaci	T. nigropilosus	Flowers	Leaves
Clone 4331	2.8397 b	3.1909	2.4884	3.7609d	1.9185 bc
" 5B/66/107	2.5613 a	2.8392	2.2834	3.4060c	1.71651 b
" Mo/70/1013	1.9072 a	2.1590	1.6554	2.4097a	1.4047 a
" O/64/219	2.6002 b	3.0864	2.1140	3.3175c	1.8830 bc
" Ma/63/1889	2.5563 a	2.8102	2.3025	2.8953b	2.2174 c
Variety P4	2.2025 a	2.6632	1.7418	3.0774b	1.3276 a
	Significance differences	Not significantly different		Significant difference	
	LSD 5% = 0.3151			LSD 5% = 0.4464	

TABLE 4(b) Two way table for the thrips ecological niches

	Flowers	Leaves
T. tabaci	4.5497 d	1.0332 a
T. nigropilosus	1.7392 b	2.4560 c

LSD % = 0.2578

Means with one or more letters in common along the same column do not differ significantly at the 5% probability level according to LSD.

(T. tabaci and T. nigropilosus) to the pyrethrum clones/variety were also assessed and there were no significant difference. However, for every crop under study means of T. tabaci was higher than for T. nigropilosus. The high infestation of T. tabaci on pyrethrum quantified the overall thrips population per cultivar.

Table (2b) gives further information about the interaction between thrips species to the crop positions (leaves or flowers). T. tabaci occured more in flower and T. nigropilosus almost exclusively in leaves.

3.30 ALTERNATIVE PLANT HOSTS FOR PYRETHRUM THRIPS

3.30.1 INTRODUCTION

Whereas Thrips tabaci Lind. were first recorded on Pyrethrum in Kenya in 1930's (Harris, 1943). T. nigropilosus was reported much later on the crop in 1950's (Bullock, 1961). Since their reporting, however, the two species of thrips have been reported as important to the extent that only occassional sprays reduce their numbers in the pyrethrum fields (Anonymous, '80-83). Whereas the reason for this

frequent rise in the thrips population in the field could be due to population built up over time, it is believed that part of it could be due to the availability of alternative host plants which acts as the source of infestation when pyrethrum enjoys good weather. The aim of this study thus, was to access any alternative hosts plant. Such information would serve as a guide to recommendations on cultural practices to suppress the thrips.

Availability of alternative host for feeding to a large extent determines the population of a given pest. Species with limited hosts are more localized than those with more. Insects generally can be grouped into three categories on their association with specific kind of host plant. The first group includes the feeders that exercise choice depending largely on availability abundance, texture of foliage, succulence etc. They range over a wide variety of plants and such insects are known as polyphagous. The second group, the insects that restricts their feeding to a small number of usually similar plants and are termed oligophagous. Members of the most highly specific series form, the third group and are referred to as monophagous.

The present study intends to enlighten on the feeding choices of the two species of thrips to help explain any reason for their populations on the crop in the field.

3.30.2 MATERIALS AND METHODS

Studies on the alternative hosts of the pyrethrum thrips were conducted at the Pyrethrum Research Sub-station, Limuru between 20th October, 1981 and 20th July, 1982. All available trees, shrubs, herbs and weeds were randomly sampled and the thrips extracted in the laboratory.

Fifty leaves of various plants were sampled into bottle jars from within the pyrethrum fields and 100 m radius from the pyrethrum plantations in the research sub-station on the 20th of every month. Similar sampling was performed in a different bottle jar picking 10 flowers using Southwood's (1866) washing method as adopted by Ota (1968) by using 51% ethanol. The leaves and flowers were washed twice before and after dissection to ensure maximum recovery of thrips. Thrips counting was done under binocular microscope. Thrips number were thereafter compared for various plants assessing the means for the number of times the plant was sampled for the thrips. The plant parts

(leaves and flowers) infected were noted and the thrips (T. tabaci or T. nigropilosus) noted per plant. Only those plants with thrips are recorded below.

3.30.3 RESULTS

Table 5 shows that the plant families attacked by the two species of thrips were: Allianceae, Gramineae, Luguminaceae, Compositae, Cruciferae, Caryophyllaceae, Amaranthaceae, Oxalidaceae, Rubiaceae and Commelinaceae. All these plant species haboured Thrips tabaci, sometimes at low population.

Thrips nigropilosus on the other hand were only reported mostly on Compositae and Gramineae, and a few were however spotted on Leguminaceae and Commelinaceae. Compared to Thrips tabaci, Thrips nigropilosus occupied much fewer alternative host plant families. There were 1788 T. tabaci on those alternative hosts compared to only 209 T. nigropilosus in sampled over the period.

Twenty seven host plants were found to harbour the thrips. Apart from a few neighbouring plantation crops like onion, oats and wheat, all the other vegetations were basically weeds which are commonly seen in the pyrethrum fields. Some of these

TABLE 5 Alternative hosts - Thrips population

Host plant	Family	Parts infected	Thrips species	Population number
1. Onion (Allium cepa)	Alliaceae	Leaves	T. tabaci	1031
2. Tobacco (Nicotiana tabacum)	Solanaceae	Leaves & Flowers	T. tabaci	41
3. Kikuyu Grass (Panicetum cleandestum Chiov.)	Gramineae	Leaves	T. tabaci	311
4. Oats (Avena spp.)	Gramineae	Flowers	T. tabaci	80
5. Alfalfa (Medicago sativa)	Leguminosae	Leaves & Flowers	T. tabaci T. nigropilosus	5 13
6. Wheat (Triticum satinum)	Gramineae	Leaves	T. nigropilosus	66
7. Chrysanthemum spp.	Compositae	Leaves & Flowers	T. tabaci T. nigropilosus	44 23
8. Star grass (Cynodondactulos spp.)	Gramineae	Leaves	T. tabaci	3
9. Blue couch (Digitaria scelarum Choiv)	Gramineae	Leaves	T. tabaci	9
10. Black jack (Bidens pilosa L.)	Compositae	Flowers	T. tabaci T. nigropilosus	10 12
11. Love grass (Steralia media L.)	Gramineae	Leaves	T. tabaci	
12. Rape (Brassica napus L.)	Cruciferae	Leaves & Flowers	T. tabaci	14
13. Strapwon (Corrigiola littoralis L.)	Caryophyllaceae	Leaves & Flowers	T. tabaci	6
14. Nutgrass (Cyperus rotundus L.)	Cyperaceae	Leaves & Flowers	T. tabaci	4
15. Spurrey (Spargula arvensis L.)	Caryophyllaceae	Leaves & Flowers	T. tabaci	22
16. Pigweed (Amaranthus hybridust L.)	Amaranthaceae	Leaves & Flowers	T. tabaci	34
17. Oxalis (Oxalis latifolia Sond.)	Oxalidaceae	Leaves	T. tabaci T. nigropilosus	15 19
18. Macdonaldi gallant soldier (Galinsova parviflora Car.)	Compositae	Leaves	T. tabaci T. nigropilosus	25 16
19. Mexican marigold (Tagetes monuta L.)	Compositae	Leaves & Flowers	T. tabaci T. nigropilosus	35 18
20. (Erucastrum arabicum Fischio Mey.)	Cruciferae	Flowers	T. tabaci	6
21. Goose grass (Galium sporium L.)	Rubiaceae	Leaves & Flowers	T. tabaci	13
22. Wild finger-millet (Eleusina indica L.)	Gramineae	Leaves & Flowers	T. tabaci T. nigropilosus	12 7
23. Spiny sow-thistle (Sonchus asper Hill.)	Compositae	Leaves	T. tabaci	26
24. Capsela bursa-pastoris Medic.)	Cruciferae	Leaves	T. tabaci	7
25. Eragrostis tenusfolia Stand	Gramineae	Leaves	T. tabaci T. nigropilosus	10 11
26. Wandering jew (Commelina banghalensus L.)	Commelineae	Leaves &	T. tabaci T. nigropilosus	5 7
27. Fleabane (Conza bonariens Cronq.)	Compositae	Leaves & Flowers	T. tabaci	

weeds are seasonal and others biannual to perennual.

Whether all these alternative hosts were ideal for the thrips is hard to tell. Lowly recorded figures as 2 T. tabaci or Brassica napus could be as a result of these thrips reaching the plants accidentally spread by wind from their ideal host plants. That being the case then about 3/4 of those plants observed for the thrips population harbouring about 10 thrips and more species could be considered to be suitable alternative hosts. Since T. tabaci had more host plant it can be called a polyphagous species and T. nigropilosus with limited hosts oligophagous.

3.40. DISCUSSIONS AND CONCLUSION

3.40.1 Influence of Weather Factors

About 40 mm of rainall per month reduced thrips population per given month. Rainfall over the experimentation time, however, was much lower than normally is the case. The effect of the rainfall on the population of thrips were not reflective on the diagram till the following month. This partly could be due to the methodology used in the study that gave the averages of weather factor when in actual sense the thrips number observed from 15th date of one month

to the following month.

The results on the rainfall influences is supported by the finding of Harris et al. (1936) who stated that the washed thrips by rainfall were killed, hence was the reason for the low population he observed after two days of driving rain.

When rainfall pattern was continuously lower than 30 mm per month for 2 to 3 months i.e. March - May (1982) and November - December (1982), thrips population quickly increased to achieve an economic threshold. It is believed this increase in population was partly a factor of reproduction among the thrips which Harding (1961) found to increase with warm, sunny, dry season.

With low rainfall thus, the thrips population continue to increase till drought causes plants to wither and food to become scarce. The only remedy to this high population built up therefore would be to control the population using a chemical spray. Chemical sprays could economically be embarked on after 3 months of continuous drought or with little rainfall below 30 mm per month to achieve the desired thrips population per plant of below economic threshold. This explains

Bullock's (1961) observation that the thrips on Pyrethrum reduce flowering during the drought.

3.40.2 Comparative Studies of Pyrethrum Thrips Densities on Pyrethrum Clones/variety

Pest population hence its attractiveness to a crop is one measure of the crops resistance to attack. Thrips can be attracted to a pyrethrum clone or variety to feed, oviposit or hide from extreme weather stresses. The data in section 3.20.3 showed that the six Pyrethrum clones/variety differed in their preference by Thrips tabaci and T. nigropilosus. Clone Mo/70/1013 with many medium flower sizes many tiny leaves and high pyrethrin content (1.9%); and variety P4 with almost same characters as Mo/70/1013 and Pyrethrin content of 2.0% Table 3 were the least attacked by thrips. The remaining clones sharing common character of lower pyrethrin content and many leaves, more so clone Ma/63/1889 with quite broad leaves and many flowers except for SB/66/107 which compensated the low flower number by the large size (5.00 + 0.328 mm) generally harboured more thrips per plant. This clonal and varietal differences in preferences by Thrips tabaci and T. nigropilosus may be due to environmental factors. This was suggested by other workers like Van

Emden (1978) and Khamala et al. (1981) who showed that although resistance is genetically controlled, it is also modified in expression by the environment through various effects on the insects.

The tiny leaves on clone Mo/70/1013 and variety P4 could have created a less conducive environments for the thrips for hiding and oviposition hence the reason for the low thrips populations. Clones Ma/63/1889 on the other hand has fewer thrips in their flowers than leaves, and this is presumably explained by the presence of many broad leaves which afforded their protection from harsh environmental changes. The morphological compositae nature of pyrethrum flowers provided protection for the thrips. Although clone SB/66/107 had only a few flowers per given plant, their flowers were quite huge and provided the conducive environment for the thrips, hence the reason for the high thrips numbers in flowers than leaves.

A number of studies have shown that crops varieties are genetically resistant to pests hence harbours fewer pests than susceptible varieties (Shelton et al., 1983, Khamala et al. 1981). The present study shows that Pyrethrum clones/variety with higher Pyrethrin content for clone Mo/70/1013

and variety P4 with pyrethrin content about 2% harboured fewer thrips than those with low pyrethrin content. Pyrethrin content is a genetical factor in pyrethrum crop. Going by this example one could come to a conclusion that high pyrethrin content in a pyrethrum crop would qualify it to be resistant to the thrips. However, the inadequacy of datas presented here makes it impossible to conclude that pyrethrin content is the genetic factor responsible for the variation in thrips population on different pyrethrum cultivars.

The use of thrips resistant pyrethrum clones/variety may fall into two categories: firstly as an adjunct to other control measures and secondly, as a principal control method. Resistance as an adjunct to other control measures would involve careful coordination with other control measures on one hand and improvement programme on the other. Insect resistant cultivars combined with minimum insecticide application as a nucleus of an intergrated pest management system, have always given much higher yields (Raheja, 1976; Taylor, 1976; Shelton et al., 1983).

Insect resistance as a principal method of pest control could prove, especially valuable where

the unit value on margin of profit of pyrethrum is small and the average acreage large. It would be of great value by replacing insecticides as this would be a great step forward for small scale farmers who cannot afford insecticides and insecticides application machinery. Development of plant resistance would also reduce insecticide resistant strains to thrips. There would be no extra cost to the farmers once they obtain resistant pyrethrum clone/variety and it is available to him thereafter.

3.40.3.3 Alternative Plant Hosts for Pyrethrin Thrips

Thrips tabaci was reported on all the sampled plant families in the Pyrethrum Research Substation, Limuru and this confirmed strongly that it is a polyphogous thrips species even in the present conditions at Limuru with many shrubs and wild growths around the pyrethrum farms.

Thrips nigropilosus on the other hand restricted its feeding to Compositae, the family of Pyrethrum and to Gramineae. With such restriction in the food choice T. nigropilosus would belong to the Oligophagous group of insect pests.

The total number of T. nigropilosus observed on alternative hosts were 209 compared to 1788 of Thrips tabaci. Such a low population confirms the problem T. nigropilosus has to increase in importance on the Kenya fields since first reported (Bullock, 1961). Pests with limited hosts are disadvantaged to have a limited gene flow resulting in the low numbers. Similar sentiments were suggested by Ananthakrishnan (1979) on other species of Thrips. Using crops least suitable to T. nigropilosus for their feeding during Pyrethrum off season, this pests population can be discouraged a great deal to achieve the goal of an intergrated pest management.

The pyrethrum thrips were noted on plantation crops (onion, oats and wheat) and also on weeds. To a large extent, the majority of the alternative hosts were weeds. The weeds thus, acts as alternative hosts during Pyrethrum off-season and it is advisable to enlighten the pyrethrum farmers of the dangers of keeping weeds in the pyrethrum field. Frequent weeding should be advocated and when spraying the crops against thrips, the sprays ought to be directed also to the weeds to avoid the thrips escaped.

CHAPTER 4 EFFECTS OF THRIPS ON PYRETHRUM DEVELOPMENT AND YIELD

4.10 INTRODUCTION

Pyrethrum plants has as the major pests the thrips and nematodes (Bullock, 1963). The thrips attack and feed on the plant leaves and flowers which become brown, crinkly and silvery in appearance. The pyrethrum flower yields since early 1980's compared to previous years have been noted to reduce thus lowering establishments of popular clones like 4331 Ks/75/64 and Ks/71/6. (Anonymous 1985-6). It is believed that the pyrethrum thrips play a big role in lowering the stated flower production. The thrips populations on the pyrethrum crop that renders reduction in yields and so would warrant control is not established as yet.

An attempt is made in the following study to determine the thrips status on pyrethrum by assessing their influence on the flower bud development and yield losses using flower numbers and weights as the parameters on the crop infested by varying thrips populations. A great deal of money can be spent upon uneconomic pest control measures which may bear little relationship to the increased

yields realised after control.

4.20 MATERIALS AND METHODS

Studies on pest status were conducted in a green house at the Faculty of Agriculture, University of Nairobi. Pyrethrum clone 4331 were established in large flower pots of 40 cm diameter and 20 cm deep on 5th September, 1981 and received the required agronomic husbandry. For uniformity of the plants, they were constantly trimmed upto flowering stage. First harvest were taken on 4th May 1982 prior to exposure to different treatments.

The plants were exposed to four treatments of varying thrips populations. The potted plants were arranged in the green house into plots with three replications to fit a completely randomised design. The thrips populations included 0 (no thrips), 10, 100 and 500 thrips per plant confined on the pyrethrum plants by cloth cages (Plate 3). The treatments thus were as follows:-

Treatment numbers	Thrips population/plant
1	0
2	10
3	100
4	500

The damages done on the pyrethrum plants were assessed by counting the blasted dead flower buds, open flower numbers and by evaluating the dry flower weights per treatment.

4.20.1 Dead flower buds - their numbers were determined after picking them on the harvesting dates and their numbers compared for the treatments.

4.20.2 Flower numbers - were assessed for harvestable flowers with fully opened petals at harvest by counting per plot and their numbers compared for the treatments.

4.20.3 Dry flower weights - the counted flowers at harvest were picked then dried by putting in an oven 80°C for 2 hours and that at 50°C for 2 days and lastly at room temperature and reweighed after 2 days. The average weights of the last readings gave the dry flower weights which were compared for the treatments over the experimentation period.

The datas on the mean flower bud and open flower numbers and that of dry flower weights were finally transformed using square root $x + \frac{1}{2}$ and analysis of variance (ANOVA) done.

Plate 3. Caged Pyrethrum plants in Greenhouse for the pest economic importance studies

4.30 RESULTS

Results on the thrips status on pyrethrum are summarized on tables 6.7 and 8 below.

4.30.1 Thrips effect on flower buds development

The data given in table 6 showed that plots exposed to thrips attack experienced a definite pattern of flower buds deaths from the second and third harvest (25th May, 1982) with heavily infested plants (500 thrips/plant) recording many bud deaths firstly, then the high death peak shifting to plants with 100 thrips per plant in the fourth harvest (7.2203). Lastly, the peak eventually shifted to the plants with 10 thrips per plant at the fifth (6.5678) and sixth (5.2835) harvests.

The attained bud death were noted to subside after attaining the highest peak. Treatment with 500 thrips per plant attained first followed by 100 thrips per plant then 10 thrips per plants. Control plots (0 thrips/plant) were, however, observed to maintain almost a uniform death number over the experimentation period. The dying flower buds were observed to first bronze, then gets blasted before opening into harvestable flowers (Plate 4).

TABLE 6 The effect of Pyrethrum thrips on dead flower buds. Note: Transformation used is $\sqrt{x + \frac{1}{2}}$.

Treatment	4-5-82	25-5-82	8-6-82	29-6-82	13-7-82	3-8-82
1	2.3462b	2.6389a	3.1565a	2.6389a	3.1565a	2.1213a
2	2.1213a	2.6389a	3.1565a	5.3227c	6.5878d	5.2835d
3	2.3462b	4.0305b	4.3869b	7.2203d	5.2168c	3.4407b
4	2.1213a	5.0330c	8.7580c	3.5129b	4.3869b	4.1590c

LSD 5% Interaction (Dates x Treatments) = 0.5532

Dates = 0.2760

Treatments = 0.2258

Means with one or more letters in common along the same column do not differ significantly at the 5% probability level according to LSD.

Plate 4. Dead and blasted flower buds and vegetative growth, the result of the thrips damage.

TABLE 7 The effect of Pyrethrum thrips on flower number produced. Note: Transformation used is $\sqrt{x + \frac{1}{2}}$

Treatments	4-5-82	25-5-82	8-6-82	25-6-82	13-7-82	3-8-82
1	6.4410a	6.1134b	5.0330c	5.5732c	4.5707c	3.6751b
2	6.5416a	7.0160d	5.3227d	4.6766b	3.1565b	2.1213a
3	6.5516a	6.7655c	4.1590a	2.1213a	2.1213a	2.1213a
4	6.7433a	6.7971a	4.3869b	2.1213a	3.1565b	2.1213a

LSD 5% Interaction = 0.4942
Dates = 0.2471
Treatments = 0.2017

Means with one or more letters in common along the same column do not differ significantly at the 5% probability level according to LSD.

TABLE 8 The effects of Pyrethrum thrips on dry flower weights (g) Note: Transformation used is $\sqrt{x + \frac{1}{2}}$

Treatments	4-5-86	25-5-82	8-6-82	29-6-82	13-7-82	3-8-82
1	3.0483b	2.6878b	2.5712d	2.6744c	2.3538c	2.3287b
2	3.0518c	2.9653d	2.4231c	2.5628b	2.2302b	2.1213a
3	3.0218a	2.8013c	2.3846b	2.1213a	2.1213a	2.1213a
4	3.0580d	2.6096a	2.3347a	2.1213a	2.2037b	2.1213a

LSD %: Interaction (Dates x Treatments) = 0.0860

Dates = 0.0430

Treatments = 0.0351

Means with one or more letters in common along the same column do not differ significantly at the 5%. Probability level according to LSD.

4.30.2 Thrips effect on harvestable flower numbers

Plots with highest thrips populations (500) per plant had fewer flower from the second harvest and those with 100 thrips per plant experienced similar low flower numbers from the third harvest and the same phenomenon were observed on plants with 10 thrips per plants from the fourth harvest statistically significant at (5%) level table 7.

Over the experimentation period, flower number yields showed that even for the the control treatment their counts continued to decline significantly (at 5% probability level) Table 7, with the flower number reducing to almost half at the sixth harvest. This reduction in flower numbers, however, was faster noted on plots exposed to high thrips (500) number after 2 months than low thrips number (10) 4 months compared to control.

4.30.3 Thrips effect on flower weights

Plants exposed to high thrips number 500/ plant quickly had low flower weights (2.6096 g) as from the second harvest, and those exposed to 100 thrips/plant experienced the same (2.3846 g) from the third harvest onwards. The plants with 10 thrips per

plant, however, experienced the significant yield differences (2.5628 g) from the fourth harvest compared to control table 8. The control plots maintained a harvest to the end of the experiment. Observations of pyrethrum flowers exposed to the thrips showed that they were spiralled at the petals, generally partly opened and smaller than those from the control plots plate 5.

4.40 DISCUSSIONS

4.40.1 Dead buds

The data presented on the number of dead flower buds showed a definite pattern of death with flower buds exposed to higher pest populations dying at a larger number earlier than low pest populations. This is believed to be as the result of the effects done by the thrips to the vegetative development of pyrethrum by directly injuring the plant tissues and sacking the plant sap lowering their vigour. This injury eventually made the plants to shrivel, the buds getting blasted not developing into to full flowering, hence, are the counted dead flower buds. This phenomenon was quickly observed on pyrethrum plants exposed to 500 thrips per plant after one and a half months of thrips exposure. The trend changed

Plate 5. Thrips effects on flower shapes.

5a. Small flower size

5b. Partly opened flower due to thrips injury

5c. Spiralled flower petals asymptom of thrips attack

5d. A healthy open flower

to plants treated with 100 thrips per plant after two months of exposure and then to 10 thrips per plant after 2½ to 3 months of the pest exposure to the crop.

Similarly, it was observed that after the crops in a treatment attained their highest flower death peaks enumerated above, the recorded flower deaths thereafter were noted to be much lower than for those exposed but have not achieved their peaks. This can be explained by the fact that the thrips blasted the buds that would give rise to developing terminal buds that would yield more buds. The injury of the buds, hence, brings a total crop dormancy and if the injury continue the crop can die back resulting into the crops total death.

It is important that the thrips population should be controlled before the injury stage as is quickly noted for populations of 100 to 500 thrips per plant. A low population of 10 thrips per plant as can be seen in the study is dangerous to the crop if left uncontrolled for two and more months. A pesticide application at two months interval is deemed important and economical for lowly infested plants as 10 thrips per plant to keep the thrips population at a threshold level.

4.40.2 Flower numbers

Pyrethrum is grown for its flowers from which are extracted useful insecticides called pyrethrin. The present study shows that the flower number were faster reduced in plots exposed to higher thrips (500) followed by 100 thrips per plant then lastly to 10 thrips per plant Table 7. This drastic reduction in flower numbers is believed to be the result of the injury done to the opening flowers directly arresting their development into open flowers.

Pyrethrum plants are known to economically produce open flowers for 9 months in a year after which they are cut back (dormant) to rejuvinate for next season (Njokah, 1979). Harvesting time of this experiment were fitted at the peak of flower production, hence any noted reduction in flower number as for plants with higher thrips number is basically due to treatment. Physiologically, the opening flower buds develops to harvestable stage after about one to one and a half months depending on temperature (Kroll, 1966). This explains the small difference obtained on Table 7 for second harvest compared to third and fourth harvests when the influences of the treatments were clearly marked. Flowers counted at the second harvest are believed to had opened when the treatments

were first administered and harvests thereafter clearly reflects the influence the high thrips number (100-500) per plant had on flower numbers. The opening flowers developments were arrested and hence is the reason for the differences. The results above further explains that the damage rendered by even as low a population as 10 thrips per plant, with time became severe after two to three months partly could be, to the fact that the injury inflicted by the low population (10) continued to be repeated on the crop tissue and this over time becoming severe.

Lastly, the noted reduction in flower numbers even for control plots with time can only be explained by the fact that pyrethrum plants naturally undergoes dormancy after 9 months of continuous flower production per given season and so all these plants were tending towards their dormancy for this season, hence the reduction in flower number even for the control. This reduction however was more manifested in plots with thrips than the control, hence the need for a pyrethrum farmer to be aware of the effect of thrips on his crop, i.e. bringing early dormancy on a crop from which he could have

harvested for a longer time.

4.40.3 Flower weights

Pyrethrum farmers are paid on the outcome of their produce i.e. dry weights and the quality of their pyrethrum content (%). The flower weight, thus is an important measure for the financial income. Anything that would affect the flower weights as is observed with the thrip at high numbers (100-500) per plant should be controlled. Even at low thrips number of 10 per plant, they become important after two months on the crop, so they should be controlled before their injury level is realised.

The spiralled, partly opened and smaller flowers could not compete adequately with healthy open flowers mainly got from the control plots on the dry flower weights. This partly could be due to the fact that thrips could have done direct injury to the flower petals and sepals tearing them apart which then reduces the flower sizes hence flower weights compared to the control.

4.50 CONCLUSION

The present study clearly shows the

importance of thrips as a pest of pyrethrum plant in a green house condition a fact which had not been assessed previously. Pyrethrum thrips (Thrips tabaci and T. nigropilosus) are economically important pests at high populations of above 100 thrips per plant causing a considerable injury to crop. They cause drastic death to the flower buds arresting also their vegetative development and when left uncontrolled for a month or so would cause the crops death. Secondly thrips at high population (100/plant) reduces the flower numbers quickly rendering the crop less productive and then the crop goes to dormancy earlier than usual. And lastly, high thrips populations of 100 and more per plant, reduces the flower weights hence lower income to the farmer compared to the control.

The study also reveals that thrips at low populations and in the present study 10 per plant became economically important under the green house condition after two months of continuous exposure to the crops. Thrips on pyrethrum like on any other crop should be effectively controlled before acquiring their economic injury level. At high populations of over 100 thrips per plant, they ought to be chemically or otherwise controlled immediately. At low number

their cummulative effect could be put under control at the threshold level.

Assuming the conditions in the field, would remain static as in our present study, pest populations could be controlled to below 10 thrips per pyrethrum plant using chemical spray at two months interval.

LITERATURE CITED

ANANTHAKRISHNAN, T.N. (1979). Biosystematic of Thysanoptera. Ann. Rev. Entomol. 24: 159-83.

ANDISON, H. (1953). Fruit, ornamental and green house insects in coastal area. proc. 7th Pactic Congr. 4: 132.

ANDREWARTHA, H.G. (1934). Thrips investigation. 5. On the effects of soil moisture on the viability of the pupal stages of Thrips imaginis Bagnall. J. Coun. Scient. Ind. Res. Aus. 7: 239-244.

ANONYMOUS (1980-6). Min. of Agriculture Annual Reports (not published), Nairobi, Kenya.

ANONYMOUS (1985-6). Reports of J.J. Anyango (1985). Proceedings International Society for Horticultural Science. 12th African Horticultural Symposium, Nairobi, Kenya. J.J. Anyango (1986). Proceedings International Conference on Tropical Entomology, Nairobi, Kenya. (Abstract only).

BAILEY, S.F. (1932). A method employed in rearing thrips. J. Econ. Ent. 25: 1194-1196.

_____(1940). The distribution of injuries thrips in the United States. J. Econ. Ent. 33: 133-6.

_____(1957). The thrips of California. Part I. Suborder Terebrantia. Bull Calif. Insect Surv. 4: 143-220.

BECKLEY, V.A. (1938). Pyrethrum in Kenya. Bull Imp. Inst. Lond. 26: 31-44.

BREWER, J.G. (1973). Microhistological examination of the secretary tissue in pyrethrum flowers. Pyre Post 12(1): 17-22.

BULLOCK, J.A. (1961). The pests of pyrethrum in Kenya. Py. Post 6: (2): 22-24.

_____(1963a). Thysanoptera associated with pyrethrum and control of Thrips tabaci Lind. Trop. Agric. Trin. 40: 329-335.

_____(1963b). The occurrence, sampling and control of Tetranychus ludeni Zacher. (Acarino - Tetranychidae) on pyrethrum. East Afric. Agric. and Forest. Journal.30: 8-10.

_____(1965). The assessment of populations of Thrips nigropilosus Uzel.on pyrethrum. Ann. Appl. Biol. 55: 1-12.

BUSVINE, J.R. (1960). Resistance to pyrethrum. Bull WHO, 22: 592-593.

CARLSON, E.C. (1964). Effect of flower thrips on onion seed plants and a study of their control. J. Econ. Ent. 57: 735-741.

CASIDA, J.E. (1973). Pyrethrum: the natural insecticide Ed. by Casida, J.E. New York Academic Pr. 1973 pp 81.

CHANDRA, V. (1981). Nutrient requirement, for some medicinal and aromatic plant, Biological Memoirs (Lucknow) (1981) 6(1): 81-06.

DAIKER, K.C. (1985). Tomato pests in South Africa, their potential damage and their control. Tech. Comm. Hort. Sc. Series. Dept. of Agric. Res. of South Africa.

DAVIDSON, J. (1944). On the relationship between temperature and the role of development of insects at constant temperature. J. Anim. Ecol. 13: 26-38.

DEV, H.N. (1964). Preliminary studies on the biology of the Assam thrips Scirtothrips dorsalis Hood on Tea Indian J. Ent. 26: 184-194.

EMDEN, H.G. van (1978). Ecological information necessary for pest management in grain legumes. In "Pest of Grain Legumes Ecology and Control" edited by Singh S.R., van Emden, H.G. and Taylor, T.A. New York Academic Press, 287-307.

HARDING, J.A. (1961). Effect of migration, temperature and precipitation on thrips infestation in South Texas J. econ. Ent. 54: 77-79.

HARRIS (1945). Annual Report of Entomological Rep. Dep. Agric. Tanganyika. Reported in Rev. Appl. Ent. 33: 85.

HARRIS, H.M.; DRAKE, C.J. and TATE, H.D. (1936). Observations of onion thrips. Towa Coll. J. Sci. 10: 155-172.

HEAD, S.W. (1967). A study of the insecticidal constituents of Chrysanthesum cinariefolium. Their composition in different pyrethrum clones Py. Post. 9(2).

HEALEY, V. (1964). The density and distribution of the species of Aptinothrips (Thysanoptera) in the grass in a woodland. Entomologists 97: 258-263.

HERR, E.A. (1934). The gladioles thrips, Taeniothrips gladioli M. & S. Bull Ohio. Agric. Exp. Stn. 537.

Hibbs, C. (1962). Onion thrips (Thrips tabaci Lind.) biology. Ann ent. Soc. Amer. 55: 512-515.

GADDUM, E.W. (1949). Annual Report of the Agricultural Officer (Pyrethrum services) Ref. Dept. Agric. Kenya, 1947, 155-160.

GAWAAD, A.A.A. and ELSHAZLI, A.Y. (1970). Studies of T. tabaci Lind. VI. New stage in the life cycle. J. agric. Res. 60: 645-686.

GHABN, A.A.E. (1948). Contribution to the knowledge of the biology of T. tabaci in Egypt (Thysanoptera) Bull. Soc. Fouad. I. Ent. 32: 123-174.

GLYNNE JONES, G.D. (1960). Studies on the photolysis of pyrethrum. Ann. App. Biol. 48 (2): 352-362.

_____ (1973). World Production of Pyrethrum. Py. Post 12 (1): 23-25.

GRADIANGER, C.B. (1936-45a). Pyrethrum flowers Supplement to 2nd ed. pp. 400-404. McLaughlin Gormley King. Minneapolis Minnesota.

_____(1936-1945b). Pyrethrum flowers, Supplement to 2nd ed. pp. 394 McLaughlin Gomley King. Minneapolis, Minnesota.

GRAND HALE, D.N.; PATIL, A.S.; AWATE, B.G.; NAIL, L.M. (1984). Evaluation of certain insecticides for control of onion thrips in Maharashtra. J. of Maharastra Agric. Universities 9(1): 104-105.

KHAMALA, C.P.M.; NGANGA, P.P. (1981). Resistance of cowpea varieties to the legume bud thrip Megalurothrips sjostedti (Trybom) (Thysanoptera: Thripidae) in Kenya. Kenya J. of Sc. & Tech (B) (1981) 2:3-7.

KNOWLSON, J.S. (1942). Pyrethrum general preference order M-179. Fed. Regist. 7: 4479.

KROLL, U. (1966). Cultivation of Pyrethrum in Kenya pp 1-16 Pub. Py. Board of Kenya. Nakuru.

LALL, S.B. and SINGH, L.M. (1968). Biology and Control of the onion thrips in India. J. Econ. Ent. 61: 676-679.

LEWIS, T. (1962). The effects of temperature and relative humidity on mortality in Liniothrips cerealium Holiday (Thysanoptera) overwintering in back. Ann. app. Biol. 50: 313-326.

_____(1973). Thrips, the biology, ecology and economic importance. London, Academic Pr. (1973) pp. 81.

MALONE, J.C. and BROWN, N.C. (1968). Toxicity of various grades of Pyrethrum to laboratory animals. Py. Post 9 (3): 3-8.

MORISON, G.D. (1949). Thysanoptera in London area London. Nat. 59: 1-36.

MORISON, G.D. (1957). A review of British glass house Thysanoptera. Trans. R. Ent. Soc. Lond. 109: 467-520.

MOTE, U.N.; SONONE, H.N. (1977). Relative susceptibility of different varieties of onion (Allium cepa) to thrips (Thrips tabaci Lind.) J. of Maharashtra Agric. Univ. 2(2): 152-155.

MUTURI, S.N. (1976). Constraints of pyrethrum production, Min. of Agriculture, Nairobi.

MWAKHA, E. (1974). Effects of weeding frequency on establishment of pyrethrum in Kenya. Py. Post 12(3): 98-102.

NASH, R. (1954). Studies of synergistic effect of piperonyl butoxide and isobutylundecyleneamide on Pyrethrins and ellethrins. Ann. Appl. Biol. 4(4): 652-663.

NJOKAH, J.J. (1979). Effects of fertilizers and plant density on products of Pyrethrum clonal nurseries. M.Sc. Thesis, Nairobi University.

NJOROGE, I.N. (1975). Annual Report. Senior pyrethrum Officer, Min. of Agriculture, Nairobi.

O'NEILL, K. (1960). Identification of the newly introduced phlaeothripid Haplothrips clarisetis Priesner (Thysanoptera). Ann. ent. Soc. Am. 53: 507-510.

OTA, A.K. (1968). Comparison of three methods of extracting the flower thrips from rose flowers. J. Econ. Ent. 61: 1754-5

PICKFORD, R.J.J. (1983). A selective method of thrips control on cucumber. Bull (SROP) 6(3): 177-180.

PRIESNER, H. (1928). Thysanoptera europes Wien. pp. 343-568. (1949). 'Genera Thysanopterorum'. Bull Soc. fouad Ent. 33: 31-157.

_____(1964). A monograph of the Thysanoptera of the Egyptian deserts. Publs. Inst. Desert. Egypta. (1964) 3: 549 pp.

RAHEJA, A.K. (1976). Assessment of losses caused by pests on cowpeas in Northern Nigeria PANS (Pest Artic News Summ.) 22/(2): 229-233.

RAO, B.R.R.; SINGH, S.P. (1982). Spacing and nitrogen studies in Pyrethrum (Chrysanthemum cinerariefolium) J. of Agric. Sc. UK. 99/2): 457-459.

SAKIMURA, K. (1939). On the host plants of some Hawaiian thrips. Proc. Hawaii Ent. Soc. 10: 251.

_____(1947). Thrips in relation to gall forming and plant disease transmission. A review Proc. Hawaii Ent. Soc. 13: 59-96.

SESHADRI, A.R. (1963). Observations on Trichronthrips brevicaps (Bagnall), a little known predatory thrips from South India. India J. Agric. Soc. 23: 27-39.

SHELTON, A.M. (1982). Plant injury and contamination by onion thrips in Sauerkrani Report - New York Agric. Expt. Station No. 45: 6-8.

SHELTON, A; ANDALORO, J. (1983). Management of Insect Pests in Processing Cabbage in New York State, USA. In 10th International Congress of Plant Protection (1983) (Vol. 3).

SOUTHWOOD, T.R.E. (1966). Ecological Methods with Reference to the study of Insect Population London: Methuen and Co. Ltd. 391 pp.

SPEYER, E.R. (1935). Some common species of the genus thrips (Thysanoptera). Ann. Appl. Biol. 21: 120-52.

STANNARD, L.J. (1969). The thrips or Thysanoptera of Illinois. Bull III. St. nat Hist. Sur. 29: 215-552.

SYLVESTER, N.K. and WEAVING, A.J.S. (1967). Pyrethrin as an insect repellent, Part II: A study of the persistence of Pyrethrins films, when applied in three

types of formulation, as an insect repellents to human skin. Py. Post 9(2): 8-14.

TAYLOR, W.E. (1976). Co-ordinated minimum insecticide trial: Yield performance of insect resistant cowpeas cultivars from IITA compared with Sierra Leone cultivars. Tropical Grain Legume Bulletin 7.

WACHS, H. (1947). Synergists insecticides. Science 105: 530-31.

WARD, L.K. (1966). The biology of Thysanoptera Ph.D. Thesis, London University.

WILKINSON, H. (1939). Entomological section. Annual Report. Rep. Dep. Agric. Kenya 1937, 86-101.

APPENDICES

THRIPS NIGROPILOSUS BIOLOGY STUDIES

TABLE 1 - Durations of Life Stages at 12°C

	Egg (incubation period)		Larval 1		Larval II		Pupa		Total
	d	h	d	h	d	h	d	h	
1.	8	12	7	0	12	12	18	0	46.0
2.	9	0	DEAD						
3.	9	0	8	0	13	12	DEAD		
4.	9	12	DEAD						
5.	9	12	7	0	DEAD				
6.	9	12	DEAD						
7.	10	0	6	12	15	12	16	12	48.5
8.	10	0	6	0	DEAD				
9.	10	12	8	0	DEAD				
10.	10	12	6	0	15	12	17	0	49.0
11.	10	12	7	0	13	12	DEAD		
12.	11	00	7	0	16	12	18	0	52.5
13.	11	00	DEAD						
14.	11	00	6	0	14	0	18	0	49.0
15.	11	00	6	0	DEAD				
16.	11	12	6	12	DEAD				
17.	12	12	DEAD						
18.	12	0	6	0	18	0	16	12	52.5
19.	12	12	6	0	16	12	16	0	51.0
20.	12	12	DEAD						
21.	12	12	DEAD						
22.	13	0	7	12	14	0	16	0	50.5
23.	13	0	7	0	15	12	17	0	52.5
24.	13	12	DEAD						
25.	14	0	6	0	14	0	16	12	50.5
n	25		17		12		10		
$\bar{X}$	11.1		6.7		14.9		17.0		40.2
S.D.±	0.3		0.17		0.46		0.25		0.67

TABLE 2 - Duration of life stages at 20°C

	Egg incubation period)		Larval I		Larval II		Pupa		TOTAL
1.	5	12	4	0	7	12	6	0	23.0
2.	5	12	4	12	7	0	6	12	23.5
3.	5	12	DEAD						
4.	6	0	3	0	DEAD				
5.	6	0	4	12	8	0	6	0	24.5
6.	6	0	5	0	7	0	5	0	23.0
7.	6	0	4	0	8	12	6	12	25.0
8.	6	0	4	12	8	0	5	12	24.0
9.	6	12	4	0	9	0	6	0	25.5
10.	6	12	DEAD						
11.	6	12	4	0	7	0	DEAD		
12.	6	12	4	0	8	0	6	0	24.5
13.	6	12	4	12	7	0	6	12	24.5
14.	6	12	3	0	DEAD				
15.	7	0	4	0	DEAD				
16.	7	0	4	0	8	0	6	0	25.0
17.	7	0	4	0	7	0	6	12	24.5
18.	7	0	4	12	7	12	6	12	25.5
19.	7	0	3	0	9	0	6	0	25.0
20.	7	0	4	12	8	0	6	12	26.0
21.	7	0	4	0	7	12	6	12	26.0
22.	7	0	DEAD						
23.	7	12	3	0	8	0	6	12	25.0
24.	7	12	4	0	7	0	6	0	24.5
25.	7	12	3	12	8	12	6	12	26.0
n			25		22		19		18	
$\bar{X}$			6.6		4.0		7.8		6.2	24.7
S.D.±			0.12		0.12		0.15		0.10	0.22

TABLE 3 - Durations of life stages at 25°C

	Egg (incubation period)		Larval I		Larval II		Pupa		Total
1.	5	12	2	0	5	12	4	12	17.5
2.	5	12	DEAD						
3.	5	12	2	12	5	0	4	0	17.0
4.	6	0	2	0	5	0	4	0	17.0
5.	6	0	DEAD						
6.	6	0	2	0	6	0	5	12	19.5
7.	6	0	2	0	DEAD				
8.	6	0	DEAD						
9.	6	0	2	0	7	0	5	0	20.0
10.	6	0	DEAD						
11.	6	0	2	12	5	0	4	12	18.0
12.	6	0	2	0	5	0	DEAD		
13.	6	0	2	12	5	12	5	0	19.0
14.	6	0	DEAD						
15.	6	0	DEAD						
16.	6	0	2	12	5	12	5	0	19.0
17.	6	0	2	12	6	0	4	0	18.5
18.	6	0	2	0	DEAD				
19.	6	12	3	0	DEAD				
20.	6	12	2	12	DEAD				
21.	6	12	2	12	4	12	5	0	18.5
22.	6	12	2	0	DEAD				
23.	6	12	2	12	5	12	DEAD		
24.	6	12	2	0	DEAD				
25.	6	12	2	0	5	12	5	0	19.0
n	25		19		13		11		
$\bar{x}$	6.1		2.3		5.5		4.7		18.5
S.D.	0.06		0.07		0.17		0.17		0.30

TABLE 4 - Duration of life stages at 30°C

	Eggs (incubation period)		Larval I		Larval II		Pupa		Total
1.	3	12	DEAD						
2.	4	0	2	0	5	0	3	12	14.5
3.	4	0	2	12	4	0	3	12	14.0
4.	4	0	DEAD						
5.	4	0	1	12	6	12	DEAD		
6.	4	0	2	12	DEAD				
7.	4	0	DEAD						
8.	4	0	2	0	3	12	4	0	13.5
9.	4	0	DEAD						
10.	4	0	2	12	5	12	3	0	14.5
11.	4	0	2	0	DEAD				
12.	4	0	2	12	5	12	3	0	15.0
13.	4	0	DEAD						
14.	4	0	DEAD						
15.	4	0	2	0	DEAD				
16.	4	0	1	12	DEAD				
17.	4	0	DEAD						
18.	4	12	DEAD						
19.	4	12	DEAD						
20.	4	12	2	12	DEAD				
21.	4	12	DEAD						
22.	4	12	DEAD						
23.	4	12	2	0	4	0	3	12	14.0
24.	4	12	DEAD						
25.	4	12	1	12	4	12	3	0	14.0
n	25		13		8		7		
$\bar{X}$	4.2		2.1		4.8		3.4		14.2
S.D.	0.06		0.11		0.35		0.14		0.18

TABLE 5 Pest-clones Relationships

ANOVA TABLE

Source of variation	d.f	Sums of squares	Mean ss	F
Pest species	1	8.666880	8.666880	57.98019**
Treatment applied	5	6.645694	1.329139	8.891751**
Flowers/leaves	1	35.272860	35.272860	235.970431**
F/L interaction pest species	1	80.645212	80.645212	539.505031**
Pest species interaction treatment	5	0.658335	0.131667	0.880834 N.S
F/L Interaction treatment	5	3.241799	0.648360	4.337436**
C/L Intra treatment interaction pest species	5	1.431237	0.286247	1.914952 N.S
All treatment (24%)	23	136.562018	5.937479	39.720892
Error	48	7.175059	0.14948	-
Total	71	143.737077	-	-

C.V = $S/\bar{X}$ x 100
= 15.82%

** Significant at 1% N.S Significant at 5%

* Significant at 5%