CROP PROTECTION PROGRAMME

Integrated Management of Fruit Flies (Diptera: Tephritidae) in India

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Final Technical Report

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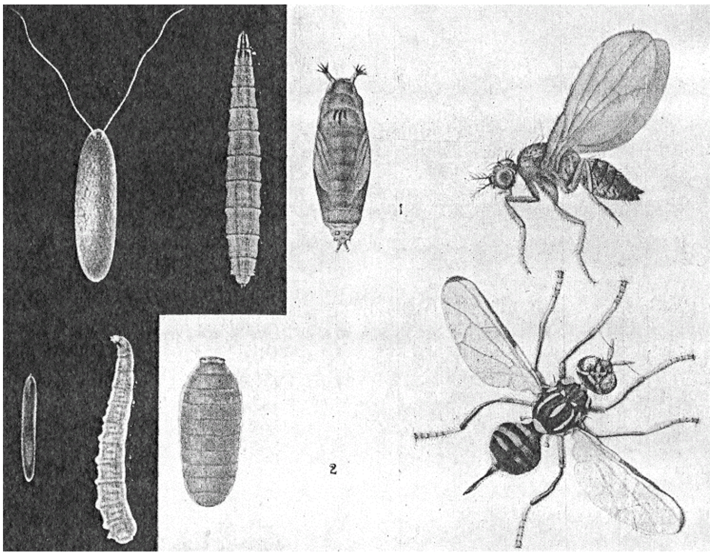

Indian Fruit Flies illustrated in Maxwell-Lefroy, H:
Indian Insect Life: A Manual of the Insects of the Plains, Tropical India
(Calcutta and Simla: Thacker, Spink, 1909).

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Executive Summary

Tephritid fruit flies cause serious damage to fruit and vegetables in South Asia and throughout much of the world.

This Project assessed the power and economic efficiency of IPM controls using minimum pesticide doses.

Flies affecting orchard fruit such as mangoes are attracted to the parapheromone lure methyl-eugenol, which is available from specialist suppliers as a food additive. Blocks soaked in lure and insecticide obtain good control of flies in mangoes, but the traps in use previously in India, either of soaked cotton wool, water or using extracts from Ocimum (Holy Basil), obtain levels of kill substantially inferior to soaked wooden blocks, which also have the key advantage of ease of disposition and not requiring weekly replacement. Lures may not provide full control in all cases, however, as when farms are small and pressure intense infestation is still substantial, and other controls need to be held in reserve.

Flies affecting cucurbit vegetables are attracted to cue-lure, which is much more expensive than methyl-eugenol and available only in small and weak preparations, so for small farmers these flies are most economically controlled by liquid baits mixed with insecticide, which attract a wide range of flies but require more frequent replacement than lure blocks. Studies concluded that the attraction of the same species of fly in different parts of the county to different baits was not consistent, with Southern flies tending to favour banana baits to jaggery baits, whereas North-Western flies tended to favour jaggery, with Eastern and Central flies in an indeterminate position. Weekly applications of baits can obtain control as good as cover sprays, and their ease allows them to be carried out more frequently, and locally-sourced baits of bananas or jaggery are as effective as imported and expensive protein hydrolysate baits.

Bait application and lure blocks do not obtain complete protection, and many farmers may find they may be profitably used together -when used in combination the two methods did not interfere with each other, and their effects in combination were multiplicative.

Both bait application and lure blocks benefited substantially from being used over areas of a whole village rather than a single farm, and village-level cooperative control offers great advantages. Cooperative control is most easily introduced where there are already in existence cooperatives or similar bodies around which groups of farmers organise, and which can provide a channel for the distribution of lures and advice on how to use them.

The Project has supported the establishment of a cooperative international association of fruit fly scientists and practitioners, the South Asia Fruit Fly Network, based on an open-access website (www.southasiafruitfly.net) and producing a regular *Newsletter* to spread word of developments in fruit fly management. The first issue of the *Newsletter*, accessible on the website, contains a summary description of the activities and achievements of the Project.

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The project staff would like to acknowledge the invaluable support provided by farmers, students and academic colleagues in the conduct of the tasks outlined in this report.

I. Project Activities

Activities were divided into a number of modules of research, which varied in the level of centralisation of control over the disparate group of research centres. For this reason, and to allow all write-ups to be prepared as future publications, in the conventional format of - Introduction - Materials and Methods - Results and Discussion - all activities and outputs are prepared as self-contained reports, which are presented in sequence. Each individual experiment, whether written up alone or as a synthesis with others, is introduced by a unique identifier code. The first part of this is numeric such as “03/03" which indicates the date of reporting and number of study, allowing reference to be made to the earlier presentation of the same experiments in previous Project Reports. The second part is three letters such as “MRR” to identify the original data file.

The questions addressed by each Output were also addressed in the Knowledge Review, conducted in Delhi and largely completed and reported in 2004, and each Output section begins with a summary of the relevant findings from the Knowledge Review.

1. Problem Definition

A. Key Informant Survey

The quantification of fly economic damage, and the allocation of damage to crops, geographical regions and fly species, was by means of a wide-ranging, quantitative “Key Informant Survey” which was conducted in a standardised manner in all research Centres.

B. Studies of Ecology and Abundance

At each Centre, specific and individual research activities studied particularly important aspects of the ecology and abundance of fruit flies.

C. Semi-Structured Interview (SSI) Survey

The SSI survey, conducted at all Centres, examined the economic and social factors underlying the cultivation of fruit fly host crops and the problems they encounter.

2. Farm-Level Fruit Fly Management

A. Experimental Studies of On-Farm Management of Fruit Flies

A programme of highly devolved field studies allowed each Centre to focus on aspects of local importance. Over 80 individual experimental studies were carried out. These were analysed and are presented as discrete experimental studies. Where possible, each experiment was conducted in two different areas, to provide a check on the reliability of results.

By contrast, a comprehensive programme of laboratory studies, centrally planned and directed among all Centres, assessed the usefulness of a wide variety of food baits, and ways in which these varied between localities and species. The methodologies and procedures used were standardised to allow the cross-comparison of results from different localities.

B. Semi-Structured Interview (SSI) Survey

The Semi-Structured Interview survey, conducted in a coordinated way, examined perceptions of farm-level fruit fly management

3. Village-Level Fruit Fly Management

A. Quantification of Returns to Farm-Level and Village-Level Management

A major study, highly demanding of resources and effort, quantified the relative economic returns to fruit fly management at farm and village level, at twelve locations (six using bait against melonflies, six using parapheromone against orchard flies) at the eight participating Centres. The use of this tightly centralised "meta-experiment" approach was a necessary way to address the need for very large plot sizes (by definition, for the quantified, replicated study of wide-area management) to allow each Centre to function as single replicate in a meaningfully replicated experiment.

B. Patterns of Extinction in Wide-Area MAT Control

A single study at a single Centre (Sardarkrushinagar, Gujarat) made use of a very large experimental mango plot to provide an unreplicated qualitative study of the spatial patterns of fruit fly intrusion into a protected square-kilometre area.

C. Semi-Structured Interview Survey

The SSI study, along with group discussions with villagers in participating experimental villages after the completion of experimental wide-area controls, examined the key features determining the social success or failure of village-level cooperative control.

4. Fruit Fly Management Plans

Analysis of the technical and socio-economic outputs of the Project allowed the identification of particular types of fruit fly host cultivation, and the production of targeted management plans, for action at both farm and village level, based on these.

5. The South Asia Fruit Fly Network

In an extension of its original Terms of Reference, the Project also provided technical and other support to the establishment of the South Asia Fruit Fly Network (SAFFN). Hosted initially by entomologists at Anand Agricultural University, Gujarat, this web-based network promotes communication and cooperation among fruit fly practitioners and analysts in the South Asian region. Support by the Project entailed funding of the initial start-up, training of technicians in web-site hosting and management, the drawing-up of the Network's operating principles and production of the initial editions of the SAFFN *Newsletter*.

II. Project Outputs

1. Problem Definition

Introduction

Table 1. Indian fruit production in annual millions of tonnes ('000 000MT) (FAO (2000).

Year	Mango	Citrus	Others
2000	12	3.19	23.37
1999	12	3.19	23.37
1998	12	3.19	23.37
1997	12	3.19	23.34
1996	12	3.17	22.17

Table 2. Production and value estimates for selected tree fruits in India for 1999. Production statistics are from Negi *et al.* (2000a). Price statistics are from Negi *et al.* (2000b), as wholesale prices, averaged over the major markets (Delhi, Mumbai, Kolkata, Chennai, Bangalore) weighted for tonnage marketed annually (except guava, estimated).

Value (1999)	Mango	Citrus	Guava	Sapota	Totals
Production ('000MT)	9782	3707	1801	668	15958
Price (Rs 000/MT)	12.7	13.8	9.5	10.1	
Value (Rs million)	124231	51156.6	17109.5	6746.8	199244

India is the world's largest tropical and subtropical fruit producer. Table 1 shows the production of citrus and mango over a sequence of years, and estimates of production and value. Official figures exist for some though not all of the hosts of fruit flies, and a summary of these is given in Table 2. India is the world's largest mango producer, with 65% of global production, and the mango export industry is a priority area.

Beyond cash value are further aspects of importance. Tree fruits are valuable sources of nutrition and vitamins at a time of growing awareness of their importance. Beyond the economic figures is the role of fruit fly hosts in rural nutrition, as borderline-subsistence poverty continues to decline in India. Fruit are also largely beneficial from environmental aspects, protecting soil from water, wind and tillage erosion. Several fly hosts are of great importance for the poor and vulnerable. The very crops for which production statistics do not exist are, because of their small-scale nature and small commercial potential, of greatest significance for the poorest farmers, and for small farmers, the greatest fly damage may be to cucurbits, attacked by *B. cucurbitae* and *Dacus ciliatus*. Anecdotal evidence suggests that many small subsistence growers of staple crops such as rice and cereals, in a potential position to move up to the cultivation of cucurbits for market, are prevented from doing so by pests, often mainly fruit flies, and so their control, particularly by cheap methods needing no access to capital goods such as sprayers, may offer significant improvements in living standards. Guava is called "the poor man's fruit" because of its poor keeping qualities and inability to ripen after harvest, which make it unsuitable for harvesting green to ripen in transit to market, and it is widely the preserve of small and local producers. It is an indication of its small and local scale of production that it is not considered a suitable crop for commercialisation. Jujube is also called "the poor man's fruit" in north Gujarat because of its tolerance of dry conditions, allowing it often to be the only productive plant which can be grown on what is often "waste ground". Sapota is widely grown in Gujarat, and in Karnataka is sometimes valued by smallholders even more than mango, because its production is high (up to 100-300kg/tree/year) and its fruiting season long (Bostock Wood and Wise, 1992).

Fruit flies are probably the most serious cause of pest losses to many tree fruits and most cucurbits. The melon fly has long been considered the most serious pest of cucurbits in Kerala (Dale *et al.*, 1966).

Fruit flies have been recorded as pests in India since the nineteenth century (Maxwell-Lefroy, 1905) and much is known about their incidence and distribution throughout South Asia (Kapoor, 1989, 1993; Kapoor *et al.*, 1976, 1977; Agarwal, 1984, 1985, 1987; Agarwal and Kapoor, 1985, 1986, 1988). Trap catches have been particularly widely studied and documented, and vary between zones, predominant hosts and fly species (Gupta *et al.*, 1992; Murthy and Regupathy, 1992; Mann, 1996; Patil *et al.*, 1996; Kumar *et al.*, 1997; Verghese, 1998; Agarwal and Kumar, 1999). However, while trap catches well indicate fluctuations of a single species in time such as seasonally or annually, they poorly represent actual infestation losses, due to the extreme differential susceptibility of different species to different lures, with some being attracted to none. Also, trap catches often correlate poorly with infestation level at field level (Nasir Uddin *et al.*, 2000b, Stonehouse *et al.*, in prep.), perhaps because lure traps attract males from great distances, as can be shown by trap catches in fields empty of hosts, implying attraction from outside the farm (Nasir Uddin *et al.*, 2000d). As a result, the relative role of various species in economic damage is less well understood than their geographical distribution.

Additional to the major pests are some minority species or those currently affecting only minority crops.

In Bihar *Bactrocera latifrons* is found in solanaceae such as *Solanum melongena* (Agarwal, 1984) and, though currently only abundant in wild, marginal and medicinal species, has been found in tomatoes (Rajendra Agricultural University, pers.comm.). *B. cucurbitae* is capable of infesting brinjal, as may be seen from several specimens in the National Insect Collection at the Pusa Institute in New Delhi, reared from brinjal in 1907. Similarly, the Gujarat Agricultural University Museum has *B. dorsalis* specimens reared from banana in 1969, which apparently persists, although not a commercial problem as they are killed before emergence by the heat treatment widely used to control banana ripening (Gijarat Agriculture University, pers. comm.). *Bactrocera correcta* has been found in grapes (Mani, 1992) and carambola fly in papaya (Rangona *et al*., 1997)

Table 3 shows losses to the two major pests of jujube in Gujarat. Bagle (1995-8) found that both pests may be controlled together, by two sprays of synthetic chemicals, in early October and 15 days later, alternating with neem sprays (neem alone is inadequate). This seems a case where switching fruit fly control away from cover sprays would serve little purpose, as the sprays have to be made anyway, to control the borer, and will continue to control flies at the same time, although other sources indicate that the fly and borer only rarely attack together and may be better controlled individually (Indian Institute of Horticultural Research, pers. comm.).

Table 3. Losses of jujube to fruit fly *Carpomyia vesuviana* and fruit borer *Meridarchis scyrodes* Meyr over three years in Gujarat (Bagle 1996-8). Percentage infestations are in samples taken after treatments; infestation percentages at harvest were similar to the samples for fruit flies but less for fruit borer.

Pest	*C. vesuviana*		*M. scyrodes*	
Control	None	Sprays	None	Sprays
1996	19	7	40	8
1997	15.1	6.4	13.5	5.2
1998	27	13	50	30
Mean	20.4	8.8	34.5	14.4

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A: Key Informant Survey

[KIS]: Key Informant Survey of Production, Value, Losses and Protection of Fruit Fly Hosts in India

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Introduction

The successful and cost-effective management of agricultural pests to a great extent relies on the possession of accurate information about the level of damage, its economic costs, among which crops and which areas the various levels of damage fall, and which pests are responsible for them. In a federal system such as India, the collection of information is often a responsibility of individual states, with the results that information is not available for all regions of the country and is most deficient in the poorest areas where agriculture is least developed and faces the greatest problems.

This study aimed to quantify the following aspects of the production, losses and protection of crops attacked by Tephritid fruit flies:-
1 - Production volume
2 - Losses to flies by hosts with crop protection
3 - Losses to flies by hosts without crop protection
4 - Value of losses

These values were divided up to obtain separate figures for
1 - Geographical regions of India
2 - Host fruits and vegetables
3 - Fruit fly species

Materials and Methods

Figures were discussed both with individuals in interviews and by means of a questionnaire circulated to as wide a body of respondents as possible.

Preliminary estimates were circulated, and all recipients requested to comment on them, and then revised estimated recirculated, so that the revised numbers were progressively improved.

The principle of this circulating request was that the estimates became gradually more accurate as more and more refining opinions are received and absorbed, using principles of
- Large-group estimation, relying on the trend by which a large group of individual estimates, even if of poor individual accuracy, tend to obtain values close to the actual figure.
- Bayesian algebra, in which successive estimates, subjective if need be, are used to refine and improve each other.
- Delphi consultations, in which opinions are circulated anonymously and discussed among a group.

The estimates sought from respondent were divided into three categories, on three different data sheets:-

1. Production and farm-gate value of major hosts nationwide as, host-by-host:
    a - Production volume for the whole of India per annum
    b - Overall average farm-gate price - the price received by the farmer in rupees/KG.

2. Production and fruit fly losses, host-by-host for each different agro-ecological zone:

2A - Relative levels of production of each host across zones, estimated by awarding a score of “100” to the zone with the greatest level of production of that host, and then others for the other zones as a percentage of that.
2B - Percentage losses to fruit flies, when hosts are not protected from them in any way.
2C - Percentage losses to fruit flies, when hosts are protected by local controls as currently in use.
2D - The percentage incidence of the local controls whose effect is assessed in 2C, as the percentage of production of that particular host which is protected against fruit flies at farm level (including protection from fruit flies provided by controls such as cover sprays which are not directed at them)

3. Prevalence in causing damage, relative to each other, of the various major fruit fly species, in the two broad categories of orchard fruit pests and cucurbit pests.

India was divided into the standard ecological zones used by ICAR:-
1. Himalayan Highlands West
    - Jammu & Kashmir
    - Himachal Pradesh
    - Uttaranchal
2. Punjab/Ganga Plain
    - Punjab
    - Haryana
    -Delhi
    - Uttar Pradesh
    - Bihar

3. Himalayan Highlands East
- North-Eastern States

4, Bengal Basin
- West Bengal
- Assam

5. Semi-Arid/Semi-Humid East
- Orissa
- Jarkhand
- Chhatisgarh
- Andra Pradesh

6. Semi-Arid West
- Rajasthan
- Gujarat
- Diu & Daman

7. West-Central/Lava Plateau
- Maharashtra
- Madya Pradesh

8. South
- Goa
- Karnataka
- Tamil Nadu
- Kerala

The full questionnaire and letter, including an outline map of the agroecological zones of India, is appended as Appendix 1 [File: iy5fkit].

Values were therefore obtained as:

Input values

Nationwide
- Production volume (V)
- Farm-gate price (P)

Per crop
- the fraction of national production in each zone, FV
- the fraction of production lost with protection by controls (LC)
- the fraction of production lost without protection by controls (LU)
- the fractional incidence of controls (C)

; %lossP, %lossUnp, %Pro
Losses were taken as of production before loss, so that if 20% is lost and production is 1000, the loss is 20% of 1000x(100/(100-20))=20% of 1000*(100/80) = 20% of 1250 = 250; if L is fraction lost and P production, lost production = LP/(1-P)

Calculated for each geographical area:-
- mean fractional loss LM = LU.(1-C) + LC.C
- volume of production lost with protection LVC = LC.V/(1-LV).C
- volume of production lost without protection LVU = LU.V(1-LU).(1-C)
- total volume of production lost LVT = LVC + LCU

Within each area, these were divided by species according to percentage estimates of losses by species (S):-
- fractional loss by species LS = S.LM
- volume lost by species VS = S.LVT

Volume loss estimates were converted to cash loss estimates by multiplication by nationwide farm-gate prices (i.e. prices were not estimated or applied separately by area).

The process omitted species of niche importance (e.g. *Carpomyia vesuviana* in jujube, *B. oleae* in olive, Moringa fly, *B. latifrons*)

Results

Table 1 shows the outcomes estimated for orchard fruit, and Table 2 those for cucurbit vegetables. For calculation in pounds, and exchange rate of £1=Rs80 was used.

Table 1. Estimates of the production and losses to fruit flies of orchard fruit in India. Columns indicate, by region, the total production in lakh metric tonnes and percentage of the national total, the percentages lost to fruit flies when controlled (Cnt) and uncontrolled (Unc), the percentage incidence of controls (%C), the weighted mean (Mn) of all losses among controlled and uncontrolled production, the calculated losses among protected and unprotected production in lack metric tonnes, the total of these, the percentage of losses attributable to the three main orchard fruit fly species (*Bactrocera dorsalis, zonata* and *correcta*), and the losses in lakh metric tonnes attributed to these three. In the final row are totals of metric tonne calculations, and means (weighted for production volumes) of percentage infestation values. Final figures are tonne estimates converted into cash values at estimated prices.

	Production		% lost				lakh MT loss			%losses by SP			lakh MT by SP		
Crop and region	% of total	lakh MT	Unc	Cnt	% C	Mn	unprot	prot	total	dorsalis	zonata	correcta	dorsalis	zonata	correcta
Mango															
Himalayan Highlands West	1.0	1.0	20	2	40	13	0.15	0.01	0.16	4	9	0	0.05	0.11	0.00
Punjab/Ganga Plain	50.8	50.3	6	2	70	3	0.96	0.72	1.68	1	2	0	0.68	0.98	0.02
Arid/Semi-Arid West	4.1	4.0	3	1	80	1	0.02	0.03	0.06	1	1	0	0.03	0.02	0.00
West-Central/Lava Plateau	12.7	12.6	3	1	80	1	0.08	0.10	0.18	1	0	0	0.10	0.06	0.02
South	17.8	17.6	25	3	50	14	2.93	0.27	3.20	10	1	3	2.29	0.23	0.69
Semi-Arid/Semi-Humid East	10.2	10.1	23	3	35	16	1.95	0.11	2.06	6	9	1	0.79	1.18	0.08
Bengal Basin	3.0	3.0	23	3	35	16	0.59	0.03	0.62	7	9	0	0.27	0.34	0.00
Himalayan Highlands East	0.5	0.5	10	3	30	8	0.04	0.00	0.04	3	5	0	0.02	0.02	0.00
Total (lakh MT) / Mean (%)		99.0	11	2	63	7	6.72	1.28	8.00	3	3	1	4.24	2.95	0.81
Value (Rs crore)		9900.0					672.30	127.82	800.13				423.75	295.50	80.88
Value (£ million)		12.4					0.84	0.16	1.00				0.53	0.37	0.10
Guava															
Punjab/Ganga Plain	61.0	11.0	12	3	0	12	1.50	0.00	1.50	5	7	0	0.61	0.87	0.02
Arid/Semi-Arid West	2.4	0.4	4	1	0	4	0.02	0.00	0.02	2	2	0	0.01	0.01	0.00
West-Central/Lava Plateau	6.1	1.1	10	2	0	10	0.12	0.00	0.12	6	3	1	0.07	0.04	0.01
South	6.1	1.1	10	2	0	10	0.12	0.00	0.12	7	1	2	0.09	0.01	0.03
Semi-Arid/Semi-Humid East	24.4	4.4	40	10	0	40	2.93	0.00	2.93	15	23	2	1.13	1.68	0.12
Total (lakh MT) / Mean (%)		18.0	18	5	0	18	4.69	0.00	4.69	8	10	1	1.90	2.61	0.17
Value (Rs crore)		1080.0					281.14	0.00	281.14				114.10	156.55	10.49
Value (£ million)		1.4					0.35	0.00	0.35				0.14	0.20	0.01

Jujube															
Punjab/Ganga Plain	19.4	0.3	12	3	5	12	0.04	0.00	0.04	5	7	0	0.02	0.02	0.00
Arid/Semi-Arid West	64.5	1.0	4	1	5	4	0.04	0.00	0.04	2	2	0	0.02	0.02	0.00
West-Central/Lava Plateau	12.9	0.2	10	2	5	10	0.02	0.00	0.02	5	3	1	0.01	0.01	0.00
Semi-Arid/Semi-Humid East	2.6	0.0	40	10	5	39	0.02	0.00	0.02	15	22	2	0.01	0.01	0.00
Bengal Basin	0.6	0.0	30	7	5	29	0.00	0.00	0.00	13	16	0	0.00	0.00	0.00
Total (lakh MT) / Mean (%)		1.5	7	2	5	7	0.12	0.00	0.13	4	3	0	0.06	0.06	0.00
Value (Rs crore)		90.0					7.49	0.08	7.57				3.66	3.68	0.22
Value (£ million)		0.1					0.01	0.00	0.01				0.00	0.00	0.00
Sapota															
Punjab/Ganga Plain	38.5	0.4	12	3	5	12	0.05	0.00	0.05	5	7	0	0.02	0.03	0.00
Arid/Semi-Arid West	38.5	0.4	4	1	5	4	0.02	0.00	0.02	2	2	0	0.01	0.01	0.00
West-Central/Lava Plateau	7.7	0.1	10	2	5	10	0.01	0.00	0.01	5	3	1	0.00	0.00	0.00
South	7.7	0.1	10	2	5	10	0.01	0.00	0.01	7	1	2	0.01	0.00	0.00
Semi-Arid/Semi-Humid East	7.7	0.1	40	10	5	39	0.05	0.00	0.05	15	22	2	0.02	0.03	0.00
Total (lakh MT) / Mean (%)		1.0	11	3	5	10	0.13	0.00	0.13	5	5	0	0.06	0.07	0.01
Value (Rs crore)		70.0					9.10	0.10	9.20				4.12	4.71	0.37
Value (£ million)		0.1					0.01	0.00	0.01				0.01	0.01	0.00
Phalsa															
Punjab/Ganga Plain	31.3	0.2	12	3	5	12	0.02	0.00	0.02	5	7	0	0.01	0.01	0.00
Arid/Semi-Arid West	31.3	0.2	4	1	5	4	0.01	0.00	0.01	2	2	0	0.00	0.00	0.00
West-Central/Lava Plateau	21.9	0.1	10	2	5	10	0.01	0.00	0.01	5	3	1	0.01	0.00	0.00
Semi-Arid/Semi-Humid East	12.5	0.1	40	10	5	39	0.04	0.00	0.04	15	22	2	0.02	0.02	0.00
Bengal Basin	3.1	0.0	30	7	5	29	0.01	0.00	0.01	13	16	0	0.00	0.00	0.00
Total (lakh MT) / Mean (%)		0.5	13	3	5	13	0.08	0.00	0.08	6	7	0	0.04	0.04	0.00
Value (Rs crore)		40.0					6.71	0.07	6.78				2.94	3.59	0.25
Value (£ million)		0.1					0.01	0.00	0.01				0.00	0.00	0.00

Peach															
Himalayan Highlands West	74.1	0.4	10	2	35	7	0.03	0.00	0.03	2	5	0	0.01	0.02	0.00
Punjab/Ganga Plain	11.1	0.1	12	3	35	9	0.00	0.00	0.01	4	5	0	0.00	0.00	0.00
Arid/Semi-Arid West	3.7	0.0	4	1	35	3	0.00	0.00	0.00	2	1	0	0.00	0.00	0.00
West-Central/Lava Plateau	3.7	0.0	10	2	35	7	0.00	0.00	0.00	4	2	1	0.00	0.00	0.00
Himalayan Highlands East	7.4	0.0	10	2	35	7	0.00	0.00	0.00	3	4	0	0.00	0.00	0.00
Total (lakh MT) / Mean (%)		0.5	10	2	35	7	0.04	0.00	0.04	2	5	0	0.01	0.03	0.00
Value (Rs crore)		45.0					3.26	0.33	3.59				1.18	2.40	0.02
Value (£ million)		0.1					0.01	0.01	0.01				0.00	0.00	0.00
Apricot															
Himalayan Highlands West	74.1	0.4	10	2	35	7	0.03	0.00	0.03	2	5	0	0.01	0.02	0.00
Punjab/Ganga Plain	11.1	0.1	12	3	35	9	0.00	0.00	0.01	4	5	0	0.00	0.00	0.00
Arid/Semi-Arid West	3.7	0.0	4	1	35	3	0.00	0.00	0.00	2	1	0	0.00	0.00	0.00
West-Central/Lava Plateau	3.7	0.0	10	2	35	7	0.00	0.00	0.00	4	2	1	0.00	0.00	0.00
Himalayan Highlands East	7.4	0.0	10	2	35	7	0.00	0.00	0.00	3	4	0	0.00	0.00	0.00
Total (lakh MT) / Mean (%)		0.5	0	0	0	0	0.04	0.00	0.04				1.18	2.40	0.02
Value (Rs crore)		45.0					3.26	0.33	3.59				0.00	0.00	0.00
Value (£ million)		0.1					0.01	0.01	0.01						

Table 2. Estimates of the production and losses to fruit flies of cucurbit vegetables in India, as in Table 1 but with the principle species the cucurbit species of *Bactrocera cucurbitae* and *tau* and *Dacus ciliatus*.

	Production		% lost				lakh MT loss			%losses by SP			lakh MT by SP		
	% of total	lakh MT	Unc	Cnt	%C	M n	unprot	prot	total	cucurbitae	tau	ciliatus	cucurbitae	tau	ciliatus
Cucumber															
Himalayan Highlands West	43.9	12.3	15	5	60	9	0.87	0.39	1.25	9	0	0	1.19	0.00	0.06
Punjab/Ganga Plain	26.3	7.4	20	7	60	12	0.74	0.33	1.07	11	0	1	0.97	0.00	0.10
Arid/Semi-Arid West	4.4	1.2	15	5	60	9	0.09	0.04	0.13	8	0	1	0.11	0.00	0.01
West-Central/Lava Plateau	21.9	6.1	20	7	60	12	0.61	0.28	0.89	11	0	1	0.80	0.00	0.10
South	1.3	0.4	30	10	75	15	0.04	0.03	0.07	13	0	2	0.06	0.00	0.01
Semi-Arid/Semi-Humid East	2.2	0.6	30	10	60	18	0.11	0.04	0.15	17	0	1	0.14	0.00	0.01
Total (lakh MT) / Mean (%)		28.0	18	6	60	11	2.45	1.11	3.56	10	0	1	3.28	0.00	0.28
Value (Rs crore)		5600.0					489.83	221.66	711.50				655.68	0.00	55.81
Value (£ million)		7.0					0.61	0.28	0.89				0.82	0.00	0.07
Muskmelon															
Punjab/Ganga Plain	22.7	6.8	20	7	60	12	0.68	0.31	0.99	11	0	1	0.90	0.00	0.09
Arid/Semi-Arid West	45.5	13.6	15	5	60	9	0.96	0.43	1.39	8	0	1	1.24	0.00	0.15
West-Central/Lava Plateau	22.7	6.8	20	7	60	12	0.68	0.31	0.99	11	0	1	0.88	0.00	0.11
South	4.5	1.4	30	10	75	15	0.15	0.11	0.26	13	0	2	0.23	0.00	0.03
Semi-Arid/Semi-Humid East	4.5	1.4	30	10	60	18	0.23	0.09	0.32	17	0	1	0.31	0.00	0.01
Total (lakh MT) / Mean (%)		30.0	19	6	61	11	2.71	1.25	3.96	10	0	1	3.57	0.00	0.39
Value (Rs crore)		1800.0					162.36	75.06	237.42				214.29	0.00	23.14
Value (£ million)		2.2					0.20	0.09	0.30				0.27	0.00	0.03
Watermelon															
Punjab/Ganga Plain	8.1	0.6	20	7	60	12	0.06	0.03	0.08	11	0	1	0.07	0.00	0.01
Arid/Semi-Arid West	8.1	0.6	15	5	60	9	0.04	0.02	0.06	8	0	1	0.05	0.00	0.01
West-Central/Lava Plateau	40.3	2.8	20	7	60	12	0.28	0.13	0.41	11	0	1	0.37	0.00	0.04
South	32.3	2.3	30	10	75	15	0.24	0.19	0.43	13	0	2	0.38	0.00	0.05
Semi-Arid/Semi-Humid East	4.0	0.3	30	10	60	18	0.05	0.02	0.07	17	0	1	0.06	0.00	0.00
Bengal Basin	4.0	0.3	20	7	60	12	0.03	0.01	0.04	12	1	0	0.04	0.00	0.00
Himalayan Highlands East	3.2	0.2	15	5	60	9	0.02	0.01	0.02	4	5	0	0.01	0.01	0.00
Total (lakh MT) / Mean (%)		7.0	23	8	65	13	0.71	0.40	1.11	12	0	1	0.99	0.01	0.11
Value (Rs crore)		245.0					24.96	13.92	38.87				34.64	0.52	3.72
Value (£ million)		0.3					0.03	0.02	0.05				0.04	0.00	0.00

Cooking melon															
South	100.0	2.0	30	10	70	16	0.26	0.16	0.41	14	0	2	0.37	0.00	0.04
Total (lakh MT) / Mean (%)		2.0	30	10	70	16	0.26	0.16	0.41	14	0	2	0.37	0.00	0.04
Value (Rs crore)		100.0					12.86	7.78	20.63				18.42	0.00	2.21
Value (£ million)		0.1					0.02	0.01	0.03				0.02	0.00	0.00
Pumpkin															
Punjab/Ganga Plain	4.4	0.4	20	7	40	15	0.07	0.01	0.08	13	0	1	0.07	0.00	0.01
Arid/Semi-Arid West	8.9	0.9	15	5	40	11	0.09	0.02	0.11	10	0	1	0.10	0.00	0.01
West-Central/Lava Plateau	6.7	0.7	20	7	40	15	0.10	0.02	0.12	13	0	2	0.11	0.00	0.01
South	17.8	1.8	30	10	60	18	0.30	0.12	0.42	16	0	2	0.38	0.00	0.05
Semi-Arid/Semi-Humid East	8.9	0.9	30	10	40	22	0.23	0.04	0.27	21	0	1	0.26	0.00	0.01
Bengal Basin	8.9	0.9	20	7	40	15	0.13	0.03	0.16	14	1	0	0.15	0.01	0.00
Himalayan Highlands East	44.4	4.4	15	5	40	11	0.47	0.09	0.56	5	6	0	0.25	0.31	0.00
Total (lakh MT) / Mean (%)		10.0	20	7	44	14	1.40	0.33	1.73	11	3	1	1.32	0.32	0.09
Value (Rs crore)		350.0					48.93	11.57	60.50				46.19	11.24	3.08
Value (£ million)		0.4					0.06	0.01	0.08				0.06	0.01	0.00
Bitter gourd															
Punjab/Ganga Plain	2.7	0.3	20	7	50	14	0.03	0.01	0.04	12	0	1	0.04	0.00	0.00
Arid/Semi-Arid West	2.7	0.3	15	5	50	10	0.02	0.01	0.03	9	0	1	0.03	0.00	0.00
West-Central/Lava Plateau	5.4	0.5	20	7	50	14	0.07	0.02	0.09	12	0	1	0.08	0.00	0.01
South	54.3	5.4	30	10	70	16	0.70	0.42	1.12	14	0	2	1.00	0.00	0.12
Semi-Arid/Semi-Humid East	21.7	2.2	30	10	50	20	0.47	0.12	0.59	19	0	1	0.56	0.00	0.02
Bengal Basin	6.5	0.7	20	7	50	14	0.08	0.02	0.11	13	1	0	0.10	0.01	0.00
Himalayan Highlands East	6.5	0.7	15	5	50	10	0.06	0.02	0.07	4	6	0	0.03	0.04	0.00
Total (lakh MT) / Mean (%)		10.0	27	9	61	16	1.43	0.62	2.05	14	0	1	1.85	0.05	0.16
Value (Rs crore)		1500.0					214.43	93.45	307.88				276.97	6.98	23.93
Value (£ million)		1.9					0.27	0.12	0.38				0.35	0.01	0.03

Small gourd															
Punjab/Ganga Plain	9.4	0.8	10	4	50	7	0.04	0.02	0.06	6	0	1	0.05	0.00	0.01
Arid/Semi-Arid West	3.1	0.3	8	3	50	6	0.01	0.00	0.01	5	0	1	0.01	0.00	0.00
West-Central/Lava Plateau	6.3	0.5	10	4	50	7	0.03	0.01	0.04	6	0	1	0.03	0.00	0.00
South	31.3	2.5	15	5	70	8	0.13	0.09	0.22	7	0	1	0.20	0.00	0.02
Semi-Arid/Semi-Humid East	25.0	2.0	15	5	50	10	0.18	0.05	0.23	10	0	0	0.22	0.00	0.01
Bengal Basin	6.3	0.5	10	4	50	7	0.03	0.01	0.04	7	0	0	0.04	0.00	0.00
Himalayan Highlands East	18.8	1.5	8	3	50	6	0.07	0.02	0.09	2	3	0	0.04	0.05	0.00
Total (lakh MT) / Mean (%)		8.0	12	4	56	8	0.48	0.21	0.69	7	1	0	0.60	0.05	0.04
Value (Rs crore)		1200.0					72.32	31.24	103.56				89.36	7.64	6.56
Value (£ million)		1.5					0.09	0.04	0.13				0.11	0.01	0.01
Ridge gourd															
Punjab/Ganga Plain	7.4	0.6	7	2	50	5	0.02	0.01	0.03	4	0	0	0.03	0.00	0.00
Arid/Semi-Arid West	3.7	0.3	5	2	50	4	0.01	0.00	0.01	3	0	0	0.01	0.00	0.00
West-Central/Lava Plateau	11.1	0.9	7	2	50	5	0.03	0.01	0.04	4	0	0	0.04	0.00	0.00
South	14.8	1.2	10	3	70	5	0.04	0.03	0.07	5	0	1	0.06	0.00	0.01
Semi-Arid/Semi-Humid East	37.0	3.0	10	3	50	7	0.16	0.05	0.21	6	0	0	0.20	0.00	0.01
Bengal Basin	3.7	0.3	7	2	50	5	0.01	0.00	0.01	4	0	0	0.01	0.00	0.00
Himalayan Highlands East	22.2	1.8	5	2	50	4	0.05	0.02	0.06	2	2	0	0.03	0.04	0.00
Total (lakh MT) / Mean (%)		8.0	8	3	53	5	0.33	0.11	0.44	4	0	0	0.38	0.04	0.02
Value (Rs crore)		400.0					16.28	5.54	21.82				18.81	1.84	1.17
Value (£ million)		0.5					0.02	0.01	0.03				0.02	0.00	0.00
Bottle gourd															
Punjab/Ganga Plain	12.0	0.4	20	7	50	14	0.05	0.02	0.07	12	0	1	0.06	0.00	0.01
Arid/Semi-Arid West	0.0	0.0	15	5	50	10	0.00	0.00	0.00	9	0	1	0.00	0.00	0.00
West-Central/Lava Plateau	40.0	1.4	20	7	50	14	0.18	0.05	0.23	12	0	1	0.20	0.00	0.02
South	4.0	0.1	30	10	70	16	0.02	0.01	0.03	14	0	2	0.03	0.00	0.00
Semi-Arid/Semi-Humid East	36.0	1.3	30	10	50	20	0.27	0.07	0.34	19	0	1	0.33	0.00	0.01
Bengal Basin	4.0	0.1	20	7	50	14	0.02	0.01	0.02	13	1	0	0.02	0.00	0.00
Himalayan Highlands East	4.0	0.1	15	5	50	10	0.01	0.00	0.02	4	6	0	0.01	0.01	0.00
Total (lakh MT) / Mean (%)		3.5	24	8	51	16	0.55	0.16	0.70	14	0	1	0.65	0.01	0.05
Value (Rs crore)		175.0					27.27	7.92	35.18				32.35	0.50	2.34
Value (£ million)		0.2					0.03	0.01	0.04				0.04	0.00	0.00

Snake gourd															
Punjab/Ganga Plain	4.0	0.2	20	7	50	14	0.03	0.01	0.03	12	0	1	0.03	0.00	0.00
Arid/Semi-Arid West	2.0	0.1	15	5	50	10	0.01	0.00	0.01	9	0	1	0.01	0.00	0.00
West-Central/Lava Plateau	2.0	0.1	20	7	50	14	0.01	0.00	0.02	12	0	1	0.01	0.00	0.00
South	32.0	1.6	30	10	70	16	0.21	0.12	0.33	14	0	2	0.29	0.00	0.04
Semi-Arid/Semi-Humid East	40.0	2.0	30	10	50	20	0.43	0.11	0.54	19	0	1	0.52	0.00	0.02
Bengal Basin	8.0	0.4	20	7	50	14	0.05	0.02	0.07	13	1	0	0.06	0.00	0.00
Himalayan Highlands East	12.0	0.6	15	5	50	10	0.05	0.02	0.07	4	6	0	0.03	0.04	0.00
Total (lakh MT) / Mean (%)		5.0	27	9	56	16	0.78	0.28	1.06	15	1	1	0.96	0.04	0.06
Value (Rs crore)		375.0					58.77	21.02	79.79				72.04	3.10	4.65
Value (£ million)		0.5					0.07	0.03	0.10				0.09	0.00	0.01
Sponge gourd															
Punjab/Ganga Plain	5.0	0.1	20	7	50	14	0.02	0.00	0.02	12	0	1	0.02	0.00	0.00
Arid/Semi-Arid West	5.0	0.1	15	5	50	10	0.01	0.00	0.01	9	0	1	0.01	0.00	0.00
West-Central/Lava Plateau	10.0	0.3	20	7	50	14	0.03	0.01	0.04	12	0	1	0.04	0.00	0.00
South	10.0	0.3	30	10	70	16	0.03	0.02	0.05	14	0	2	0.05	0.00	0.01
Semi-Arid/Semi-Humid East	50.0	1.3	30	10	50	20	0.27	0.07	0.34	19	0	1	0.32	0.00	0.01
Bengal Basin	10.0	0.3	20	7	50	14	0.03	0.01	0.04	13	1	0	0.04	0.00	0.00
Himalayan Highlands East	10.0	0.3	15	5	50	10	0.02	0.01	0.03	4	6	0	0.01	0.02	0.00
Total (lakh MT) / Mean (%)		2.5	25	9	52	16	0.41	0.12	0.53	15	1	1	0.49	0.02	0.03
Value (Rs crore)		125.0					20.56	6.11	26.67				24.47	0.89	1.31
Value (£ million)		0.2					0.03	0.01	0.03				0.03	0.00	0.00
Chayot/Chao-Chao															
South	47.6	1.0	30	10	70	16	0.12	0.07	0.20	14	0	2	0.18	0.00	0.02
Semi-Arid/Semi-Humid East	19.0	0.4	30	10	50	20	0.08	0.02	0.10	19	0	1	0.10	0.00	0.00
Bengal Basin	0.0	0.0	20	7	50	14	0.00	0.00	0.00	13	1	0	0.00	0.00	0.00
Himalayan Highlands East	33.3	0.7	15	5	50	10	0.06	0.02	0.08	4	6	0	0.03	0.04	0.00
Total (lakh MT) / Mean (%)		2.0	25	8	60	15	0.26	0.11	0.38	12	2	1	0.31	0.04	0.03
Value (Rs crore)		100.0					13.15	5.64	18.78				15.41	2.12	1.25
Value (£ million)		0.1					0.02	0.01	0.02				0.02	0.00	0.00

Ash gourd																
Punjab/Ganga Plain	30.0	3.0	20	7	50	14	0.38	0.11	0.49	12	0	1	0.44	0.00	0.04
Arid/Semi-Arid West	1.4	0.1	15	5	50	10	0.01	0.00	0.02	9	0	1	0.01	0.00	0.00
West-Central/Lava Plateau	11.4	1.1	20	7	50	14	0.14	0.04	0.19	12	0	1	0.17	0.00	0.02
South	11.4	1.1	30	10	70	16	0.15	0.09	0.24	14	0	2	0.21	0.00	0.03
Semi-Arid/Semi-Humid East	11.4	1.1	30	10	50	20	0.24	0.06	0.31	19	0	1	0.30	0.00	0.01
Bengal Basin	17.1	1.7	20	7	50	14	0.21	0.06	0.28	13	1	0	0.27	0.01	0.00
Himalayan Highlands East	17.1	1.7	15	5	50	10	0.15	0.05	0.20	4	6	0	0.09	0.11	0.00
Total (lakh MT) / Mean (%)		10.0	21	7	52	14	1.29	0.42	1.71	12	1	1	1.48	0.12	0.10
Value (Rs crore)		500.0					64.39	21.08	85.48				74.20	6.12	5.16
Value (£ million)		0.6					0.08	0.03	0.11				0.09	0.01	0.01
Sweet gourd																
Bengal Basin	50.0	1.0	20	7	50	14	0.13	0.04	0.16	13	1	0	0.15	0.01	0.00
Himalayan Highlands East	50.0	1.0	15	5	50	10	0.09	0.03	0.11	4	6	0	0.05	0.06	0.00
Total (lakh MT) / Mean (%)		2.0	18	6	50	12	0.21	0.06	0.28	9	3	0	0.21	0.07	0.00
Value (Rs crore)		200.0					21.32	6.40	27.72				20.58	7.14	0.00
Value (£ million)		0.3					0.03	0.01	0.03				0.03	0.01	0.00

Table 3. Summaries of values from Tables 1 and 2, with cash losses in crore rupees.

Fruit	lakh MT	Rs Crore	% losses unp	prot	% prot	Mn	lakh MT loss unprot	prot	total	Rs Crore unprot	prot	total	% loss/SP Bd	Bz	Bcr	lakh MT by SP B.d.	B.z.	B.cr.	Rs Crore B.d.	B.z.	B.cr.
Mango	99.0	9900	11	2	63	7	6.72	1.28	8.00	672.3	127.8	800.1	3	3	1	4.24	2.95	0.81	423.7	295.5	80.9
Guava	18.0	1080	18	5	0	18	4.69	0.00	4.69	281.1	0.0	281.1	8	10	1	1.90	2.61	0.17	114.1	156.5	10.5
Jujube	1.5	90	7	2	5	7	0.12	0.00	0.13	7.5	0.1	7.6	4	3	0	0.06	0.06	0.00	3.7	3.7	0.2
Sapota	1.0	70	11	3	5	10	0.13	0.00	0.13	9.1	0.1	9.2	5	5	0	0.06	0.07	0.01	4.1	4.7	0.4
Phalsa	0.5	40	13	3	5	13	0.08	0.00	0.08	6.7	0.1	6.8	6	7	0	0.04	0.04	0.00	2.9	3.6	0.3
Peach	0.5	45	10	2	35	7	0.04	0.00	0.04	3.3	0.3	3.6	2	5	0	0.01	0.03	0.00	1.2	2.4	0.0
Apricot	0.5	45	0	0	0	0	0.04	0.00	0.04	3.3	0.3	3.6	2	5	0	1.18	2.40	0.02	0.0	0.0	0.0
Sum/Mean	121.0	11270	12	2	55	6	11.8	1.3	13.1	983.3	128.7	1112.0	4	3	1	7.5	8.2	1.0	549.8	466.4	92.2

Cucurbits	lakh MT	Rs Crore	unp	prot	% prot	Mn	lkMTloss unprot	prot	total	RsCrore unprot	prot	total	%loss/SP Bcu	Bt.	Dc	lakhMT by SP B.cu.	B.t.	D.c.	B.cu.	B.t.	D.c.
Cucumber	28.0	5600	18	6	60	11	2.45	1.11	3.56	489.8	221.7	711.5	10	0	1	3.28	0.00	0.28	655.7	0.0	55.8
Muskmelon	30.0	1800	19	6	61	11	2.71	1.25	3.96	162.4	75.1	237.4	10	0	1	3.57	0.00	0.39	214.3	0.0	23.1
Watermelon	7.0	245	23	8	65	13	0.71	0.40	1.11	25.0	13.9	38.9	12	0	1	0.99	0.01	0.11	34.6	0.5	3.7
Cooking melon	2.0	10	30	10	70	16	0.26	0.16	0.41	12.9	7.8	20.6	14	0	2	0.37	0.00	0.04	18.4	0.0	2.2
Pumpkin	10.0	350	20	7	44	14	1.40	0.33	1.73	48.9	11.6	60.5	11	3	1	1.32	0.32	0.09	46.2	11.2	3.1
Bitter gourd	10.0	1500	27	9	61	16	1.43	0.62	2.05	214.4	93.5	307.9	14	0	1	1.85	0.05	0.16	277.0	7.0	23.9
Small gourd	8.0	1200	12	4	56	8	0.48	0.21	0.69	72.3	31.2	103.6	7	1	0	0.60	0.05	0.04	89.4	7.6	6.6
Ridge gourd	8.0	400	8	3	53	5	0.33	0.11	0.44	16.3	5.5	21.8	4	0	0	0.38	0.04	0.02	18.8	1.8	1.2
Bottle gourd	3.5	175	24	8	51	16	0.55	0.16	0.70	27.3	7.9	35.2	14	0	1	0.65	0.01	0.05	32.3	0.5	2.3
Snake gourd	5.0	375	27	9	56	16	0.78	0.28	1.06	58.8	21.0	79.8	15	1	1	0.96	0.04	0.06	72.0	3.1	4.7
Sponge gourd	2.5	125	25	9	52	16	0.41	0.12	0.53	20.6	6.1	26.7	15	1	1	0.49	0.02	0.03	24.5	0.9	1.3
Chayot	2.0	100	25	8	60	15	0.26	0.11	0.38	13.1	5.6	18.8	12	2	1	0.31	0.04	0.03	15.4	2.1	1.3
Ash gourd	10.0	500	21	7	52	14	1.29	0.42	1.71	64.4	21.1	85.5	12	1	1	1.48	0.12	0.10	74.2	6.1	5.2
Sweet gourd	2.0	200	18	6	50	12	0.21	0.06	0.28	21.3	6.4	27.7	9	3	0	0.21	0.07	0.00	20.6	7.1	0.0
Sum/Mean	128.0	12670	19	7	59	12	13.3	5.3	18.6	1247.4	528.4	1775.8	10	0	1	16.4	0.8	1.4	1593.4	48.1	134.3

Table 4. Summary, as in Table 3, with cash values in millions of UK pounds.

							lakh MT loss			Million £			% loss/SP			lakh MT by SP			Million £		
	lakh MT	Million £	unp	prot	%pr	mn	unprot	prot	total	unprot	prot	total	Bd	Bz	Bcr	B.d.	B.z.	B.cr.	B.d.	B.z.	B.cr.
Mango	99.0	12.37	11	2	63	7	6.72	1.28	8.00	0.84	0.16	1.00	3	3	1	4.24	2.95	0.81	0.53	0.37	0.10
Guava	18.0	1.35	18	5	0	18	4.69	0.00	4.69	0.35	0.00	0.35	8	10	1	1.90	2.61	0.17	0.14	0.20	0.01
Jujube	1.5	0.11	7	2	5	7	0.12	0.00	0.13	0.01	0.00	0.01	4	3	0	0.06	0.06	0.00	0.00	0.00	0.00
Sapota	1.0	0.09	11	3	5	10	0.13	0.00	0.13	0.01	0.00	0.01	5	5	0	0.06	0.07	0.01	0.01	0.01	0.00
Phalsa	0.5	0.05	13	3	5	13	0.08	0.00	0.08	0.01	0.00	0.01	6	7	0	0.04	0.04	0.00	0.00	0.00	0.00
Peach	0.5	0.06	10	2	35	7	0.04	0.00	0.04	0.00	0.00	0.00	2	5	0	0.01	0.03	0.00	0.00	0.00	0.00
Apricot	0.5	0.06	0	0	0	0	0.04	0.00	0.04	0.00	0.00	0.00	2	5	0	1.18	2.40	0.02	0.00	0.00	0.00
Sum/Mean	121	14.09	12	2	55	6	11.82	1.29	13.11	1.23	0.16	1.39	4	3	1	7.48	8.16	1.02	0.69	0.58	0.12

							lkMTloss			Mill£			%loss/SP			lakhMT by SP			Million £		
	lakh MT	Million £	unp	prot	%pr	mn	unprot	prot	total	unprot	prot	total	Bcu	Bt	Dc	B.cu.	B.t.	D.c.	B.cu.	B.t.	D.c.
Cucumber	28.0	7.00	18	6	60	11	2.45	1.11	3.56	0.61	0.28	0.89	10	0	1	3.28	0.00	0.28	0.82	0.00	0.07
Muskmelon	30.0	2.25	19	6	61	11	2.71	1.25	3.96	0.20	0.09	0.30	10	0	1	3.57	0.00	0.39	0.27	0.00	0.03
Watermelon	7.0	0.31	23	8	65	13	0.71	0.40	1.11	0.03	0.02	0.05	12	0	1	0.99	0.01	0.11	0.04	0.00	0.00
Cooking melon	2.0	0.13	30	10	70	16	0.26	0.16	0.41	0.02	0.01	0.03	14	0	2	0.37	0.00	0.04	0.02	0.00	0.00
Pumpkin	10.0	0.44	20	7	44	14	1.40	0.33	1.73	0.06	0.01	0.08	11	3	1	1.32	0.32	0.09	0.06	0.01	0.00
Bitter gourd	10.0	1.88	27	9	61	16	1.43	0.62	2.05	0.27	0.12	0.38	14	0	1	1.85	0.05	0.16	0.35	0.01	0.03
Small gourd	8.0	1.50	12	4	56	8	0.48	0.21	0.69	0.09	0.04	0.13	7	1	0	0.60	0.05	0.04	0.11	0.01	0.01
Ridge gourd	8.0	0.50	8	3	53	5	0.33	0.11	0.44	0.02	0.01	0.03	4	0	0	0.38	0.04	0.02	0.02	0.00	0.00
Bottle gourd	3.5	0.22	24	8	51	16	0.55	0.16	0.70	0.03	0.01	0.04	14	0	1	0.65	0.01	0.05	0.04	0.00	0.00
Snake gourd	5.0	0.47	27	9	56	16	0.78	0.28	1.06	0.07	0.03	0.10	15	1	1	0.96	0.04	0.06	0.09	0.00	0.01
Sponge gourd	2.5	0.16	25	9	52	16	0.41	0.12	0.53	0.03	0.01	0.03	15	1	1	0.49	0.02	0.03	0.03	0.00	0.00
Chayot	2.0	0.12	25	8	60	15	0.26	0.11	0.38	0.02	0.01	0.02	12	2	1	0.31	0.04	0.03	0.02	0.00	0.00
Ash gourd	10.0	0.63	21	7	52	14	1.29	0.42	1.71	0.08	0.03	0.11	12	1	1	1.48	0.12	0.10	0.09	0.01	0.01
Sweet gourd	2.0	0.25	18	6	50	12	0.21	0.06	0.28	0.03	0.01	0.03	9	3	0	0.21	0.07	0.00	0.03	0.01	0.00
Sum/Mean	128	15.84	19	7	59	12	13.26	5.34	18.61	1.56	0.66	2.22	10	0	1	16.44	0.78	1.39	1.99	0.06	0.17

B. Studies of Ecology and Abundance

Introduction

Over the past century, many studes have examined the ecological basis for the abundance, distribution and management of fruit flies. Many studies have examined the basic biology of the key species such as *Bactrocera dorsalis* (Kumar and Agarwal, 1998c), *B. zonata* (Rana *et al*., 1992; Rahman *et al*., 1993) and *B. cucurbitae* (Koul and Bhagat, 1994a&b) including often finding a high correlation of abundance with temperature, allowing estimates to be made of relative abundance in various zones and seasons (Patel and Patel, 1995, 1996, 1998; Agarwal and Kumar, 1999). Temperature and diet effects have also been examined for *Carpomyia vesuviana* (Dashad *et al*., 1999a; Sangwan and Lakra, 1992) and *Gitona* (Murthy and Regupathy, 1992). Shukla and Prasad (1985) found that the key determinants of fly abundance were (1) host availability (2) median temperature and (3) relative humidity. Similar studies have allowed the development of ecological models, allowing accuracy in prediction of up to 74% for the judicious deployment of controls (Verghese, 1998).

The study of the developmental biology, ecology and host preferences of fly species has shed light on their propensity to cause damage to different crops. Infestation rates, and therefore crop losses, as introduction risks as well as field estimates, may be illuminated by comparative assays of the success of species in hosts, such as in speed of development or percentage survival, when reared in the laboratory. For example, *Dacus ciliatus* in Gujarat is most severe in little gourd (GAU, pers.comm.) and in laboratory choice experiments it also preferred little gourd to, in order, cucumber and bitter, bottle, smooth and ridge gourds (Patel and Patel, 1998c); it also developed in little gourd faster than five other cucurbits (Patel 1994). Similarly, Gupta and Verma (1995) found that melon fly both had lower survival and slower development on sponge gourd than on bitter gourd and cucumber. Table II.1 shows some “growth indices” for laboratory cultures in India.

Table 1. Growth indices (percentage survival from first larva to adult, divided by the number of days elapsed for the same development) for various *Bactrocera* fruit flies on various hosts (*dorsalis* data from Kumar and Agarwal 1998b; *zonata* data from Rahman *et al.*, 1993; *cucurbitae* data from Agarwal and Yazdani, 1991).

		Bactrocera	
Host	*Dorsalis*	*Zonata*	*cucurbitae*
Mango	4.54	6.54	
Orange	3.42	4.46	
Papaya	4.84		
Guava	3.58		
Sapota		4.70	
Smooth gourd		5.28	6.33
Long melon			6.48
Cucumber			6.74
Bottle gourd			4.79
Bitter gourd			5.96
Pointed gourd			6.51

The validity of such exercises depends on several assumptions such as the general association between percentage survival and life-cycle duration for a given species on a range of hosts. Although the studies cited above suggest an association, Table II.2 suggests a poor such correlation between four varieties of mango. Laboratory studies seem to give coherent pointers to field attack severity, but the association cannot be taken as perfect.

Table 2. Rank ordering of four mango varieties in five parameters affecting life cycle of *B. dorsalis* (Kalia and Srivastava, 1992a,b).

Variety	Bangalora	Malika	Dashehari	Amrapali
Oviposition preference	1	2	3	4
Number of oviposition punctures	1	2	3	4
Number of eggs per puncture	1	2	3	4
Life cycle speed	3	1	4	2
Percentage survival	1	2=	2=	4
Early attack in field	-	1	-	2

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~03/48[SRR]: Patterns of Infestation of Agricultural Hosts by Fruit Flies in North Gujarat

Patel, RK, Chowdhury, FK, Joshi, B

Abstract

Fruit flies infesting different cucurbit hosts in the early part of the growing season near Palanpur were assessed by sampling fruit and rearing out *Bactrocera* fruit flies in the months of March, April and May (N=1). *B. zonata* predominated in all hosts and was found in cucumber, watermelon, pumpkin and ridge and bitter gourds; *B. dorsalis* was found in pumpkin and ridge and bitter gourds; *B. cucurbitae* was found only in ridge and bitter gourds, and only in May, indicating that the “orchard flies” *zonata* and *dorsalis* may build up populations earlier, and *cucurbitae* slightly later.

Introduction

Like many areas, North Gujarat is host to a range of different fly species which may differentially affect different hosts at different times of year. This study examined patterns of infestation among a range of hosts in 2003.

Materials and Methods

The prevalence of different fruit fly species among different hosts in North Gujarat was examined by the collection of hosts and their removal to the laboratory for the rearing and identification of flies. Data were gathered as numbers of flies reared from fruit identified in the field as infested and collected opportunistically, and not forming formal replicates.

Results and Discussion

The numbers of flies in different species, hosts and months are given in Table 1. There were significant differences among hosts and flies, with *B. zonata* alone infesting cucumbers and watermelons, *zonata* and *dorsalis* pumpkin, and all three species ridge and bitter gourds. There was an indication, not susceptible to statistical analysis, that the “orchard flies” *zonata* and *dorsalis* may build up populations earlier, and *cucurbitae* slightly later. These data may under-indicate the prevalence of *B. cucurbitae*, which is known to infest pumpkin in North Gujarat (as is indicated by the effectiveness of cue-lure MAT for their protection).

Table 1. Numbers of fruit flies of different species reared from opportunistically-collected infested hosts in North Gujarat in 2003. Distribution differed significantly between fly and host species (χ^2=36.4433[8]* {*P*<0.0001}).**

2003	*Bactrocera*	Cucumber	Water-melon	Pumpkin	Ridge gourd	Bitter gourd	Month totals
March	*zonata*	10	-	-	-	-	10
	dorsalis	0	-	-	-	-	0
	cucurbitae	0	-	-	-	-	0
April	*zonata*	10	7	11	9	-	37
	dorsalis	0	0	6	6	-	12
	cucurbitae	0	0	0	0	-	0
May	*zonata*	9	-	-	0	14	25
	dorsalis	0	-	-	0	6	6
	cucurbitae	0	-	-	8	3	11
Host totals	*zonata*	29	7	11	9	14	70
	dorsalis	0	0	6	6	6	18
	cucurbitae	0	0	0	8	3	11

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~03/47[ACY]: Trap Catches of Fruit Flies in Different Crop Environments in Central Gujarat

Jhala, RC, Sisodya, D

Abstract

In order to study the rhythms of adult fruit fly abundance in different crop environments, traps containing both methyl-eugenol (for orchard flies) and cue-lure (for melonflies) were deployed through the year, emptied weekly, in farm stands of orchard hosts (mango, guava, sapota) and cucurbits (mostly bottle and small gourds) near Anand (N=1). Peaks in orchard fly populations appeared earlier than those in melonflies. In most cases, each fly type (*cucurbitae* and orchard flies) peaked first in their presumed preferred habitat (respectively cucurbits and orchards) and then in their presumed non-preferred (vice-versa): this may indicate that local fly populations in preferred host habitats build up and/or host fruit pass their production peak and are saturated, and then flies venture further afield into non-preferred habitats.

Introduction

Fruit flies are caught in parapheromone traps for both research and on-farm monitoring purposes. This experiment aimed to evaluate seasonal fluctuations of traps in different environments and, in particular, differences in seasonal rhythms between melon flies (*B. cucurbitae*) and orchard fruit flies (*B. dorsalis* and *B. zonata*) in cucurbit fields and orchards.

Materials and Methods

One-litre bottle fly traps were loaded with 5x5cm square straw-board blocks, dropped with five drops of methyl-eugenol, five drops of cue-lure and five drops of DDVP, this charge being replenished at 15-day intervals. Traps were hung in orchards of tree fruit (mango, guava and sapota) and fields of cucurbits (mostly bottle gourd and small gourd) near Anand, and emptied at weekly intervals, the fly catch sorted into melonflies and orchard flies.

Results and Discussion

Table 1 shows the catches of melonflies and other tephritids over the season, as a composite calendar year composed of data from two years. Melonfly was prevalent in cucurbit fields in numbers significantly larger than those of orchard fruit flies, but in orchards melonfly was present in numbers relatively less smaller than those of orchard flies. Peaks in orchard fly populations appeared earlier than those in melonflies. In most but not quite all cases, each fly type (*cucurbitae* and orchard flies) peaked first in their presumed preferred habitat (respectively cucurbits and orchards) and then in their presumed non-preferred (vice-versa): this may indicate that local fly populations in preferred host habitats build up and/or host fruit pass their production peak and are saturated, and then flies venture further afield into non-preferred host habitats.

Table 1 (overleaf). Catches of (*Bactrocera cucurbitae*) and other, orchard fruit tephritids (mostly *B. dorsalis* and *B. zonata*). "#" indicates replenishment of the soaked-block charge. "!" indicates the peak for each species in particular environments.

Date	Melon flies				Orchard flies			
	Mango	Guava	Sapota	Cucurbits	Mango	Guava	Sapota	Cucurbits
06-Jan-2003	13	15	9	81	21	78	14	9
13-Jan-2003#	12	16	7	75	24	73	16	7
20-Jan-2003	10	26	9	70	23	60	20	14
27-Jan-2003#	8	20	8	62	17	44	17	12
03-Feb-2003	10	7	5	54	24	32	12	6
10-Feb-2003#	12	13	12	44	25	30	24	6
17-Feb-2003	7	8	17	41	14	21	44	11
24-Feb-2003#	16	12	21	32	33	20	53	8
03-Mar-2003	24	10	15	42	46	25	63	10
10-Mar-2003#	13	12	12	52	42	22	58	9
17-Mar-2003	12	11	6	58	44	19	62	12
24-Mar-2003#	15	12	8	49	42	8	57	8
31-Mar-2003	11	7	12	43	45	10	49	10
07-Apr-2003#	12	10	10	46	43	12	45	11
14-Apr-2003	13	8	7	48	59	11	40	10
21-Apr-2003#	12	7	10	51	105	14	39	12
28-Apr-2003	8	8	8	48	195	17	37	13
05-May-2003#	10	5	11	54	212	19	40	9
12-May-2003	8	4	7	46	235	19	39	2
19-May-2003#	7	5	7	55	**517!**	22	42	10
26-May-2003	8	3	4	48	324	18	36	7
02-Jun-2003#	5	6	6	39	248	17	31	5
09-Jun-2003	4	2	8	42	234	16	30	3
16-Jun-2003#	6	4	4	57	205	12	28	4
23-Jun-2003	12	10	12	88	201	17	17	10
30-Jun-2003#	10	12	8	84	156	16	30	8
07-Jul-2003	21	18	18	98	149	32	35	14
14-Jul-2003#	17	12	12	108	138	30	48	10
21-Jul-2003	21	18	21	180	100	32	**109!**	21
22-Jul-2002#	17	16	14	214	112	**110!**	71	33
29-Jul-2002	6	11	13	217	29	22	39	52
05-Aug-2002#	15	32	20	254	64	35	84	**65!**
12-Aug-2002	**91!**	33	29	**429!**	21	10	9	23
19-Aug-2002#	55	27	42	195	10	12	23	14
26-Aug-2002	51	**77!**	73	183	8	23	17	19
02-Sep-2002#	49	48	**74!**	92	5	5	4	2
09-Sep-2002	41	51	61	88	4	4	4	3
16-Sep-2002#	36	38	19	53	7	2	5	3
23-Sep-2002	38	42	25	41	6	7	11	1
30-Sep-2002#	32	43	17	30	4	6	7	4
07-Oct-2002	30	46	18	21	5	2	2	4
14-Oct-2002#	34	50	27	12	7	5	21	3
21-Oct-2002	36	47	30	19	10	12	17	7
28-Oct-2002#	19	18	11	12	18	30	15	10
04-Nov-2002	23	27	13	21	10	48	10	2
11-Nov-2002#	31	33	14	35	14	57	14	3
18-Nov-2002	18	27	11	50	8	69	9	3
25-Nov-2002#	8	29	13	50	29	63	12	9
02-Dec-2002	14	21	15	54	22	67	21	16
09-Dec-2002#	12	21	10	71	19	78	18	17
30-Dec-1899	13	29	14	99	20	96	20	13
23-Dec-2002#	6	13	3	76	20	87	9	11
30-Dec-2002	11	14	8	85	23	82	11	13

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~03/40[ARR];04/21[ARQ];04/03[ACH]: Infestation of Cucurbits by *Bactrocera cucurbitae* and *Dacus ciliatus* in Central Gujarat

Sisodya, D, Jhala, RC, Stonehouse, JM

Abstract

A programme of rearing-out from five types of gourd, collected opportunistically from fields around Anand in 2003, found a significant difference (P<0.001) among hosts favoured relative to each other, *Dacus ciliatus* favouring bitter and little gourds, and *Bactrocera cucurbitae* bottle and smooth gourds. Relative infestation of hosts over time also differed significantly (P<0.001) between the two species. In little gourd, infestation by *B. cucurbitae* was highest between September and January, and lowest between June and August; that by *D. ciliatus* was highest between March and April, and lowest between July and December. In bitter gourd, infestation by *B. cucurbitae* was highest between July and August, and lowest between April and May; that by *D. ciliatus* was highest in April and lowest in September. These results imply niche separation between the two species. Preferences were also assessed in the laboratory, by releases of equal numbers of pairs of male and female adults of each species in cages in the laboratory with a range of six potential host species, both alone as each species by itself, and as each accompanied by the other, to detect interspecific competition as possible adjustments in laying preferences in the company of the other species. Neither species modified the frequency of its reproductive selections in the presence of the other. The two species differed significantly in the hosts in which reproduction took place, with *B. cucurbitae* favouring smooth gourd, ridge gourd and cucumber, with bitter and bottle gourds intermediate and little gourd least favoured, and *D. ciliatus* favouring little gourd, with bottle gourd not selected at all and the other species intermediate. Preferences between the two species differed significantly (χ^2=39.1389[4]*** {P<0.0001}).

Introduction

The Dacine fruit flies *Bactrocera cucurbitae* and *Dacus ciliatus* both infest a variety of gourds in central Gujarat, and the ways in which their niches are separated are not fully understood. These experiments aimed to quantify the incidence of the two species and examine differences in their distribution patterns between host species and in time.

1. Infestation of different cucurbits

Materials and Methods

Cucurbit fruit, identifiable as infested with fruit flies, were collected from fields in November, 2003. Five fruits each of little gourd, bitter gourd, smooth gourd, ridge gourd and bottle gourd were kept individually in bowls with soil at the bottom, and pupae emerging were collected and kept in plastic vials for adult emergence, which were identified as to species

Results

Table 1 shows the numbers of flies collected. Both species infected the majority of fruit species, but that the relative distribution of the two among different host species differed. *D. ciliatus* favoured little and ridge gourds, and *B. cucurbitae* smooth and ridge gourds; relative to each other *D.c.* favoured bitter and little gourds, and *B.c.* bottle and smooth gourds.

Table 1. Numbers of adults of *Bactrocera cucurbitae* (*B.c.*) and of *Dacus ciliatus* (*D.c.*) emerging from five infested fruit of different cucurbit hosts collected from gourd fields near Anand, November 2003, and the ratio of *D.c.* to *B.c.* as a percentage. The distribution of the two species differed significantly among different hosts (χ^2>18.5[4]* {P<0.001}).**

Gourd	*B.c.*	*D.c.*	% Ratio *D/B*
Bitter	7	36	514
Little	41	58	141
Ridge	150	46	31
Smooth	343	37	11
Bottle	86	0	0

2. Cycle over time

Materials and Methods

Twenty-five infested gourds collected from randomly-selected fields every fortnight in 2003 and 2004 were brought to the laboratory and kept in galvanised cages with soil at the bottom; emerged pupae were collected and kept in vials for adult emergence; adults were identified and recorded by species.

Results

Table 2 shows the numbers of each species identified each fortnight. The patterns of fluctuations differed between the two species. In little gourd, infestation by *B. cucurbitae* was highest between September and January, and lowest between June and August; that by *D. ciliatus* was highest between March and April, and lowest between July and December. In bitter gourd, infestation by *B. cucurbitae* was highest between July and August, and lowest between April and May; that by *D. ciliatus* was highest in April and lowest in September.

Table 2. Numbers of adults of *Bactrocera cucurbitae* (*B.c.*) and of *Dacus ciliatus* (*D.c.*) emerging from 25 infested gourd fruit collected fortnightly from fields near Anand, with for each the months of population maxima and minima. Distribution patterns over time differed significantly for the two species in all cases (all *P*<0.001).

	Little gourd				Bitter gourd	
	2002-3		2004		2004	
	B.c.	*D.c.*	*B.c*	*D.c*	*B.c*	*D.c*
November	-	-	-	-	-	-
	100	85	-	-	-	-
December	99	86	-	-	-	-
	78	37	-	-	-	-
January	58	62	47	31	-	-
	22	55	42	52	-	-
February	21	72	11	72	-	-
	84	69	18	82	-	-
March	10	23	24	108	-	-
	54	22	22	90	-	-
April	53	125	19	85	8	24
	24	149	22	74	11	26
May	12	84	24	87	12	23
	9	41	19	90	9	21
June	0	38	23	83	18	15
	0	8	10	76	22	18
July	14	6	8	53	34	15
	8	2	12	44	88	11
August	12	0	5	38	51	9
	25	12	18	31	38	5
September	22	20	19	29	27	0
	26	24	21	24	18	0
October	25	19	24	27	14	0
	18	42	23	26	-	-
November	15	24	21	25	-	-
	18	25	24	22	-	-
December	8	22	18	20	-	-
	-	-	-	-	-	-
Maximum	September-November	April	January	March	July-August	April
Minimum	June	July-August	July-August	December	April-May	September
χ^2	52.6197*** [25]		48.2679*** [22]		32.9095*** [12]	

3. Choices in the laboratory

Materials and Methods

This laboratory study aimed (a) to compare oviposition and reproductive success by each species in a range of potential gourd hosts and (b) to see whether these were, by either species, modified in the presence of the other as an indication of interspecific competitive displacement. Adult fruit flies of the two species, reared in the laboratory from stock gathered in the field near Anand, were released into cages containing six species of gourd - smooth, ridge, bitter, bottle and bitter gourds and cucumber - and their oviposition and reproductive success in each was represented by the number of emerged adult offspring emerging from pupae from each fruit after oviposition was allowed to take place. Three unreplicated exposures took place, each of a release of ten male and ten female flies in an arena containing one of each of the six hosts species under study: one of was of *B. cucurbitae*, one of *D.*

ciliatus and one of a 50:50 mixture of the two. After 48 hours of exposure for oviposition, adults reared out from each host were identified, counted and tabulated.

Results

Table3 gives the numbers of adults emerged from each of the six host species after exposure to four fly species blends - *cucurbitae*-alone, *ciliatus*-alone, *cucurbitae*-in-the-presence-of-*ciliatus*, and *ciliatus*-in-the-presence-of-*cucurbitae*.

Table 3. Numbers of adult flies emerging from each of six different gourd fruits after exposure to oviposition by *B. cucurbitae* alone, *D. ciliatus* alone, and each in the presence of the other.

	B. cucurbitae		*D. ciliatus*	
Totals	alone	with other	alone	with other
Smooth gourd	27	28	9	9
Ridge gourd	22	26	8	9
Cucumber	18	13	9	12
Bitter gourd	10	15	8	9
Bottle gourd	9	25	0	0
Little gourd	4	2	13	13

Initial analysis was for each species separately to see if relative success in different hosts differed in the presence of the other, but for neither species was this the case (for *cucurbitae* χ^2=5.2921[4]ns {*P*=0.2586}; for *ciliatus* χ^2=0.4985[4]ns {*P*=0.9737} - both with the two least populated categories pooled for statistical reliability). Subsequent analysis was of species preference by each, which differed significantly (using values for each species alone, and pooling the two least populated categories for each - bottle and little gourds - χ^2=39.1359[4]*** {*P*<0.0001}).

Discussion

Bactrocera cucurbitae and *Dacus ciliatus* differed in their distribution among different host species and in their infestation fluctuations over time in little gourd, implying niche separation between the two species. The two species differed significantly in their preference for, and reproductive success in, different host species, but by this methodology no competitive displacement could be demonstrated.

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~03/34[GRR]: Patterns of Infestation of Agricultural Hosts by Fruit Flies in Southern Gujarat

Patel, ZP, Jagadale, VS

Abstract

Mango infestation increased throughout the season from 28 to 82% from May to June, and was not different between different zones. Gourd infestation increased throughout the season from 22 to 88% from October to December; infestation started on the earlier-developing little gourd before the later-developing bitter gourd.

Introduction

Like many areas in India, South Gujarat is host to separate guilds of fruit flies affecting cucurbits such as gourds on the one hand and orchard fruit such as mangoes on the other. This study examined patterns of infestation among two types of hosts in 2003. The research location is situated at 21^{o}N, 73^{o}E and 7.6MASL. The climate is characterised by moderate summers and winters, and heavy rainfall (1500 to 1800mm). Mango, sapota, banana, sugarcane, paddy and vegetables are the major crops grown.

Materials and Methods

The prevalence of different fruit fly species among gourds and mangoes in South Gujarat was examined by the determination of percentage infestation in samples of fruit selected at random (but opportunistically, not forming formal replicates) in 2003.

Results and Discussion

Tables 1 and 2 give the mean percentage infestation of two sorts of gourd and mangoes in four localities over fortnightly sampling visits through the respective growing seasons. Infestation increased steadily over each season, but types and localities did not differ greatly in infestation levels.

Table 1. Percentage infestation of gourds of two varieties in Southern Gujarat in 2003, from the inspection of 200 fruit.

Week	October III	November I	November III	December I	December III	Row means
Bitter gourd	-	33.5	45.0	62.0	87.5	57.0
Little gourd	21.5	33.5	51.5	72.0	-	44.6
Column means	21.5	33.5	48.3	67.0	87.5	

Table 2. Percentage infestation of mangoes in three localities in Southern Gujarat in 2003, from the inspection of 120 fruit. There were no significant associations between months and localities (contingency test χ^2=1.6177[4]ns {*P*=0.8056}).

Week	May I	May III	June I	Row means
Kacholi	30	53	75	53
Desad	40	65	82	62
Gandevi	28	62	82	57
Column means	33	60	79	

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~03/19[RRR]: Infestation of Hosts by Tephritid Species in Central Kerala

Thomas, J, Vidya, CV

Abstract

An opportunistic, presence/absence sampling survey of rearing out of fruit flies from field-gathered hosts around Thrissur found only *Bactrocera dorsalis* in mango and guava, and mostly *B. cucurbitae* in bitter gourd, but some *dorsalis* in bitter gourd and some *B. zonata* in little gourd, indicating that infestation of cucurbits by “orchard” fly species is possible.

Introduction, Materials and Methods

In 2003 a sample of host fruit, both cucurbits and orchard fruit, were opportunistically gathered in farm fields around Thrissur. Sampling was not systematic or fully-randomised, and more a qualitative presence/absence than a quantitative survey. Flies emerging as adults were identified as to species.

Results and Discussion

The percentage compositions of emerging adults from each host are given in Table 1. This indicates that both *B. dorsalis* and *zonata* can and do infest cucurbit hosts in Kerala.

Table 1. Tephritid species emerging reared out from infested fruit gathered from farm fields in Central Kerala in 2003. Sample sizes varied from one to twenty. Given are numbers of adult flies emerging as percentages of the total.

Bactrocera	*dorsalis*	*cucurbitae*	*zonata*
Mango	100	0	0
Guava	100	0	0
Little gourd	0	0	100
Bitter gourd	2	98	0

*****

~03/22[MRR]: Patterns of Distribution and Infestation among the Fruit Fly Guild of Southern Kerala

Jiji, T, Napoleon, A, Nair, B

Abstract

A rearing-out programme from field-collected fruit found, for the first time in Kerala, *Bactrocera cucurbitae* in *Coccinia indica* and *B. dorsalis* in guava. A survey of field-collected mangoes found percentage infestation varied between 11 (in *Varikka*) and 44 (in *Bangalora*), but this difference was not significant (*P*=0.1293; N=3). In the laboratory, life cycle stages among various local species and hosts varied from 3 to 4 days for the egg, 8 to 11 for the larva 7 to 13 for the pupa.

Introduction, Materials and Methods

A programme of collecting opportunistically-sampled hosts and potential hosts of fruit flies was conducted around Thiruvananthapuram in order to establish the infestation and distribution of different species. Additionally, in the laboratory, fly species were reared to establish the development times under local conditions.

Results and Discussion

1. Species Records
In 2003 host rearing in Southern Kerala identified two tephritid species in previously-unreported hosts in the locality:
A - New host record: *Bactrocera cucurbitae* (Coquillett) infesting *Coccinia indica* (Trivandrum; Lab rearing)
B - New host record: *B. dorsalis* (Hendel) infesting guava (Trivandrum; Lab rearing)

2. Percentage Infestation of Mango Varieties
Table 1 summarises percentage infestation of local mango varieties by sampling fruit from different varieties in three complete randomised blocks.

Table 1. Means and standard deviations (<SD>; N=3) of the percentage infestation of four mango varieties in Southern Kerala. Differences were not significant (ANOVA *F*=2.4636[4,8]ns {*P*=0.1293}).

Mulgoa	Bangalora	Banganapalli	Neelum	Varikka
24.3	44.1	17.4	19.8	11.1
<17.0>	<7.5>	<15.1>	<20.9>	<12.7>

3. Duration of Life Cycle Stages

Table 2 summarises laboratory assessments of the duration in days of the developmental stages of local pest tephritids on local hosts.

Table 2. Duration in days of certain stages of local *Bactrocera* species on local hosts under local conditions in Southern Kerala.

Bactrocera:	Egg	Larva	Pupa	Adult
- *cucurbitae* in cucumber	3	10	8	25
- *cucurbitae* in coccinia	4	11	7	25
- *dorsalis* in "Neelum" mango	-	-	10.5	16.5
- *dorsalis* in "Bangalora" mango	-	8.4	12.75	20.3

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~05/02[VRR]: Infestation of Gourds by Melon Fruit Fly in Varanasi

Satpathy, S, Swamy, S, Rai, S, Stonehouse, JM, Verghese, A, Mumford, JD

Abstract

In the IIVR research station outside Varanasi samples were taken weekly of catches of *Bactrocera cucurbitae* in cue-lure traps and also of the volume and infestation of two local hosts, cucumber and melon. Overall, the fly population, as infestation and flies caught on the wing, increased even while production of the main local host, cucumbers, fell, though this was not statistically significant. There was not, as found elsewhere, a correlation between an increase in the infestation of fruit and a decrease in the mass of individual uninfested fruit (positive association; *P*=0.2590).

Introduction, Materials and Methods

In the IIVR research station outside Varanasi samples were taken weekly of catches of *Bactrocera cucurbitae* in cue-lure traps (N=3) and also of the volume and infestation of two local hosts, cucumber and melon.

Results and Discussion

Table 1. The development of the production and infestation of two hosts outside Varanasi between April and May, 2005. Given for each date are, where available, the trap catch by cue-lure (the preceding week), production volume, percentage infestation and, for cucumbers, the mean mass in g of an individual uninfested fruit. Below each is the slope, standard error of slope and statistical significance of the progress of each value over time.

	Trap catch	Cucumbers			Melons	
Date (2005)	(week before)	Production volume	Percent infestation	g/fruit uninfested	Production volume	Percent infestation
20 April	15	150	26	145	-	-
27 April	28	131	37	202	-	-
02 May	76	94	11	153	-	-
11 May	789	60	47	181	33	10
17 May	144	-	-	-	29	10
25 May	110	-	-	-	35	17
Slope	6.62	-4.47	0.69	1.02	0.18	0.52
<SD>	<10.81>	<0.51>	<1.14>	<1.96>	<0.40>	<0.25>
t	0.6125	8.6767	0.6078	0.5195	0.4415	2.1170
[df]	[5]	[3]	[3]	[3]	[2]	[2]
{P}	{0.5670}	{0.0032}	{0.5862}	{0.6393}	{0.7020}	{0.1685}

Table 1 shows the progress over the sampling period of the production and infestation levels of two host fruits. There were no clear trends over the sampling period apart from the decreasing volume of cucumbers harvested. Fly populations (as revealed by cue-lure trapping) and infestation of both melons and cucumbers increased, but these were patchy and non-significant. Overall, the fly population, as infestation and flies caught on the wing, increased even while production of the main local host, cucumbers, fell, though this was not statistically significant. There was not, as found elsewhere, a correlation between an increase in the infestation of fruit and a decrease in the mass of individual uninfested fruit, which may indicate smaller masses of fruit brought forward by the vine to replace losses (this association was positive and non-significant (t=1.3889[3]ns {P=0.2590}).

C. Semi-Structured Intervies (SSI) Survey

The SSI survey full interview texts are appended as Appendix 6 [File: iy5fssi].

Gourd Cultivation

Cucurbit gourds are favoured as a cash crop, particularly by relative small and marginal growers, as the market is generally perceived as good and increasing. Gourd consumption is rising with general expansion of middle-class incomes, and increasing awareness of their dietary and medical benefits. Their keeping and transportation are not superior to those of other vegetables such as brinjal or cauliflower.

A particular advantage of gourds is their relatively long harvesting period. This obtains higher and more prolonged yields, and also some protection against risk, of potential fluctuations in both yields and prices - if there is an episodic problem with harvesting, such as low production or prices, the long season holds out the hope of more production becoming available later.

One of the critical factors deciding the cultivation of gourds is the availability of water. Water availability is required throughout the harvesting season, so gourds respond well to the availability of irrigation and their cultivation tends to cluster around wells and riverbanks.

Perhaps surprisingly in a relatively populous country, Indian farmers often suffer from acute shortages of labour. Gourds are seen as relatively undemanding of labour as their needs for weeding are less than for some crops. Labour availability is often a decisive factor in production.

The availability of stakes and wires for the construction of pandals is a major preoccupation of gourd growers. Gourd cultivation requires capital to allow these to be purchased.

Fruit flies are not always the most serious problem for gourd growers, and a relative lack of pest problems is one of gourds’ favoured qualities.

Mango and Orchard Fruit Cultivation

The great majority of mango cultivation takes place where mangoes have “always been grown” and there are few instances of small farmers installing mango trees where there were none before. Fruit flies are not the main concern of the majority of mango growers, and the other pests of mango feature prominently. However, as production develops the problems of fruit flies become more serious, visible and expensive, and so a concern with fruit fly control is typically a specific concern of the more innovative and ambitious “leader farmers”.

Guava is cultivated almost exclusively in low-technology environments, with no investment at all in pest management. Farmers are often unaware of the extent of fruit fly losses.

2. Farm-Level Fruit Fly Management

Introduction

Farmer responses to fly pests may comprise nothing, cover sprays, bait sprays, lures, or some form of Integrated Pest Management (IPM). Many different control options have been evaluated and/or recommended, ranging from cover sprays to cultural controls such as fallen-fruit collection to locally-derived lures and baits such as basil, fruit juice, ammonia, jaggery and molasses, often fermented. Overall, India with its traditions of non-violence and harmony with nature has favoured agriculture with conceptual characteristics such as *Swadeshi* (indigenous), *Swaavalambi* (self-reliant) and *Savayava* (organic) (anon., 1999). Synthetic chemicals are generally frowned on, many NGOs fostering organic farming, with a growing urban market for organic produce. This provides a promising base for the development of minimum-pollution IPM with minimal cover pesticide use.

Insecticide

As cover sprays and as ingredients in other controls, there are many lethal elements used against fruit flies, including synthetic chemicals, neem, other botanicals and pathogens.

Cover sprays, while considered by IPM practitioners the last resort, can and do control flies when applied in a position to do so, controlling *Carpomyia vesuviana* on jujube (Lakra *et al*., 1991; Bagle, 1992; Saravaiya *et al*., 1998; Dashad *et al*., 1999b), moringa fly (Logiswaran, 1993), *Bactrocera dorsalis* on guava (Mann, 1996) and *Bactrocera cucurbitae* on bitter gourd (Reddy, 1997). Other studies have concluded that cover sprays obtain only poor control of *B. cucurbitae* (National Centre for IPM, pers.comm.).

Bait sprays have requirements not necessarily the same as for cover sprays. Shukla *et al.* (1984) found cover sprays of deltamethrin reduced mango loss from 28.725% (untreated) to 2.875% (with fenthion) and 1.814% (with the more expensive deltamethrin). In using bait sprays against melon fly, Dale and Nair (1966) found that of the six insecticides evaluated all obtained 100% mortality on the first day after application, and none more than 20% after ten days, but that some were superior at intermediate times - at day three malation obtained over 80%, dipterex and parathion about 70%, and sevin, BHC and DDT all less than 60%. In Pakistan, Farooq (unpub.) found dipterex best for cover spray control of melon fly, attributing this to a slight attractant property, while studies in India found that in bait sprays, while better than cypermethrin (which is slightly repellent) dipterex was less effective than dichlorphos because the former, as stomach-acting, is slower in lethal infect than the contact-action of the latter (Indian Institute of Horticultural Research, pers. comm.).

Botanical and non-conventional pesticides are widely favoured by farmers and consumers, as (often) cheap or home-cultivable, less damaging to the environment and health of people and domestic and beneficial organisms, and increasingly allowing certifiably “organic” cultivation with a large price premium in discerning markets. A survey of organic bait and lure controls, largely from unpublished sources, recommends tobacco and pyrethrum as lethal components (Stoll, 2000). Neem is widely used and recommended in India - the plant grows easily along hedgerows and its properties are widely known by farmers and extended by NGOs and extensionists. It has been successfully used against pests of Cruciferae (Krishna Moorthy *et al*., 1998, 2000), Jassids and other sucking pests attacking the early stages of bitter gourd (Soman *et al*., 1999) and produced successful fruit fly protection in guava, jujube and cucurbits, as shown in Table II.4. It may not be a panacea, however. A farmer in Bihar reported a small-scale student trial where neem control was inferior to that of synthetic chemicals, and an apparent fertiliser effect deleteriously stimulated weed growth in neem-treated plots. It has also been reported that neem’s disagreeable smell may discourage consumers - though perhaps not seriously when set against synthetic chemicals and their need for preharvest intervals, which are of growing concern among Indian consumers and farmers. Table 1 also shows a less successful trial outcome. The different outcomes of these trials offer many interpretations, perhaps because the fly species and neem plant part and preparation may make considerable differences.

Table 1. Percentage infestation of cucumbers by *Bactocera cucurbitae* with different cover treatments (data from provisional experiments by IIHR) and of little gourd by *Dacus ciliatus* with different cover treatments (Patel, 1994, mean of two seasons' data).

B cucurbitae on cucumber		*D ciliatus* on little gourd	
Insecticide	Infestation	Insecticide	Infestation
None	53	None	13
Neem cake[1]	6	Fenthion 0.05	4
Neem kernel extract[2]	9	Carbaryl 0.2	4
Pon cake[3]	21	Endosulfan 0.07	8
Carbaryl	21	Monocrotofos 0.04	9
Nuvacron	21	Dichlorvos 0.05	7
Dimacron	23	Deltamethrin 0.001	7
Metacid	24	Triazophos 0.04	9
		Neemark[4] 0.3	11

1 - Dry neem cake after crushing for the extraction of oil, crumbled into the soil around the base of plants and covered with soil.
2 - 75g of crushed kernel, soaked overnight in 1l water and filtered.
3 - Extract of *Pongamia glabra*, a local insecticidal plant.
4 - Commercial neem extract

Much farm-level fruit fly control depends on the attraction of flies to baits and lures, and another question is whether neem, which has a slight repellent as well as insecticidal effect, may work as the killing ingredient in these, or may repel flies and thus undermine attraction and mortality. Table II.5 shows how on at least one fruit fly its effect as an oviposition deterrent is greater than as an insecticide. At first glance it would therefore appear unsuitable, but this has never been actually tested, and if neem can be used in attractant preparations this may offer the possibility of all-home-made controls.

Table 2. Effect of neem (Nimbecidine 0.03%) on different life table parameters of the Moringa fruit fly, *Gitona distigma* Meigon (Diptera: Drosopholidae), in comparison with no treatment, and percentage reduction attributable to neem (Ragumoorthi and Rao, 1998).

Parameter	Neem	Nothing	% reduction
Fecundity (Eggs/female)	50.25	62.75	19.92
Oviposition (Eggs/female)	15.33	54.67	71.96
Eggs hatching (%)	57.25	69.75	17.92
Larval survival (%)	81.25	89.00	8.71
Adult emergence (%)	71.25	85.50	16.67
Adult longevity (days)	11.00	23.30	52.79

A further option may be the use of pathogens as insecticides. Sinha and Saxena (1999) found that culture filtrates of *Rhizoctonia solani*, *Trichoderma viride* and *Gliocladium virens* adversely affected the oviposition and development of *Bactrocera cucurbitae*.

Soil applications for fly control have also been evaluated. Dale *et al.* (1966) found aldrin and heptachlor killed 100% of melon fly pupae after one day, and 20-40% after 42 days, although all others tested killed only 90% at day one and one after 42. Soil applications, however, seem unlikely to be an economically viable tool, unless also benefiting from hitting another pest at the same time. They also may require economies of scale, as areas cleared by larval or pupal control are prone to reinvasion from outside (see below).

Bait

A wide variety of different bait preparations has been recommended and/or used in India over many years, including protein hydrolysate (Gupta and Verma, 1982; also used against fruit-sucking moths in Uttar Pradesh), brewer's yeast (Singh, 1997; available in Indian shops as "active dried yeast"), jaggery, molasses, toddy and fruit juice and pulp. A widespread continuing recommendation (e.g. Srinavasan, 1993) is for 1% yeast protein and 1% sugar, which is apparently unchanged from an original recommendation (for 3/4oz each of yeast and brown sugar in 1 gallon of water) from 1958 (Singh, 1990). Alternative ingredients include other yeasts, meat and fish extracts (fishmeal bait is used against the sorghum shoot fly in Gujarat, one of India's most vegetarian states) and various fermented preparations. A DFID project in Pakistan evaluated meat baits (Zia *et al.*, 2001; Stonehouse *et al.*, 2002a,b) but these are considered unacceptable for the large population of vegetarian farmers and consumers in India. In a review of largely unpublished sources from around the world Stoll (2000) lists in addition baits of (all in 1 litre of water):

- ½ cup of urine, 1.5 teaspoons of vanilla essence and 100g sugar
- peel or pulp of oranges or cucumber with 7.5ml of ammonia or urine
- 0.1 cups of honey, 0.1 teaspoons of vanilla essence and 0.1 cups of cucumber or fruit pulp
- 6ml of Marmite or Vegemite with 0.5g sodium sulphide (Na_2S)
- "juice mixed with sugar which will ferment"
- 0.5l of vinegar and 10 tablespoons of honey (Richardson, 2000)

In general, baits containing protein have been more effective than those containing sugar. Table 3 shows the outcome of a comparative study in India showing protein preferred to fruit and sugar preparations by both *Bactrocera dorsalis* and *B. zonata*.

Table 3. Average numbers of *Bactrocera* fruit flies caught per trap (N=3) by four traps with food baits between May and August 1997. *B. dorsalis* data from Kumar and Agarwal (1998); *B. zonata* data from Agarwal and Kumar (1999). There were significant differences between species caught (F=1851[1,16]*) and treatments (F=527[3,16]***) and for interactions between them (F=202[3,16]***).**

Clove oil (2ml) + Malathion 50EC (1ml) with:	*dorsalis*	*zonata*
- Protein hydrolysate (20g)	44	148
- Ripe mango pulp (20g)	28	132
- Fermented palm juice (20ml)	9	76
- Sugar (20g)	10	16

Much of the Indian literature concerns baits rich in sugar. Among these the richer, more complex and organic preparations seem preferable to more refined simpler sugars. Thus Sasidharan *et al.* (1991) found plantain fruit superior to jaggery, honey and molasses. Altogether, there is a suspicion that baits may follow the this order of descending effectiveness:-

1 - protein sources
2 - natural fruit products
3 - unrefined sugars such as jaggery or molasses
4 - refined sugar

Some evaluations and recommendations have been of bait applied as sprays (Gupta and Verma, 1982). Dale and Nair (1966) found application as coarse drops better than as fine. For tree fruit, Singh (1997) recommended application from 60 days before ripening of 20g of brewery waste suspended in 1l of water, hydrolysed by oven baking at 40 C for 48 hours, then mixed with 1ml of malathion, fenthion or chlorpyrifos, applied as squirts from 0.5l plastic bottles with a "delivery nozzle" to leaf undersurfaces or fences. In Kerala, Dale and Nair (1966) found application to leaf undersides gave best performance, and in Pakistan Zia *et al.* (2001) found brushes as good as sprayers, and foliage much superior to sawn timber, plastic sheet and cotton cloth. Others recommendations are as traps - dishes on bamboo poles (Nasir Uddin *et al.*, 2000c) or hung from the pandal (Sasidharan *et al.*, 1991). In Bangladesh, traps against melon fly are loaded with 100g of sweet gourd and 6 drops of dichlorphos, at 50-60 per hectare and changed every three to five days (Bangladesh Agricultural Research Institute, pers. comm.). The review by Stoll (2000) includes five trap types of broadly similar design, made of old plastic bottles or coconut shells. One (from Paraguay) specifies that entry holes of 0.5cm diameter permit the entry of flies but not of honeybees; although honeybees are not conventionally found in fruit fly traps, and traps are regularly checked for their presence, we know of at least one case, in Pakistan, where an unfounded rumour of bee casualties turned farmers against bait controls. It may be worthwhile thoroughly to compare the kill, duration and cost effectiveness of traps and spot sprays.

Lure

Methyl eugenol, the best-known parapheromone lure, is available and used over much of India. It is strongly attractive to males of *Bactrocera dorsalis*, *zonata* and *correcta*. Alternatives are available - holy basil or *tulsi* (*Ocimum sanctum*, a known methyl eugenol analogue) is used in Kerala (as 20g of crushed leaves with 0.5g each of citric acid and of carbofuran 3G in 100ml of water, at four traps/ha; Reghunath and Indira, 2000) and in Gujarat (where it is a sacred plant, and used in traps and also as live bushes sprayed with insecticide). The attraction to methyl eugenol of the melon fly, *Bactrocera cucurbitae*, is uncertain, and the generally-used melonfly lure, cue-lure, has recently become available in India commercially as soaked pads for melonfly control. A study by CIBC (1972) in Pakistan found catches of melon fly by cue-lure *versus* those by methyl eugenol were 120:19 in the hills, 168:47 in the foothills and 149:0 at Lahore, but 23:72 on the plains and 0:22 on the coast. In the Faisalabad area attack on bitter gourd, presumably by *B. cucurbitae*, was reduced from 66.33 to 21.33% by methyl eugenol traps at 8 per acre (Anon., 1988).

Benzyl acetate attracts *Bactrocera cucurbitae* and *dorsalis* (Kapoor, 1993). Adult *Dacus longistylus*, apparently largely males, are attracted to the plant *Calotropis gigantea* (GAU, pers.comm.). No lure is known against *Dacus ciliatus* (Patel and Patel, 1998b; Qureshi *et al.*, 1987, who found no response to seven known lures, three plant extracts, eight essential oils and two others), which also has shown only poor attraction to protein hydrolysate on St Helena (J Mumford, pers.comm.). There is concern at the occurrence in Pakistan of *Myiopardelis pardalina*, which appears indifferent to methyl eugenol, although it is found in traps containing cue-lure and gouminal. Some role in monitoring, if not control, may be played by coloured traps which mimic ripe fruit: Jalaluddin *et al*. (1998) found that *B. correcta* is more readily attracted to yellow and orange targets than to red, green, white, violet or blue.

MAT has been successfully used for Tephritid control in South Asia in mango (Moyhuddin and Mahmood 1993; Mahmood *et al*., 2000) and in guava (Qureshi *et al*., 1981; Marwat *et al*., 1992; Entomologist, 1997 - the latter showing a net increase in farmer income of 58% from MAT use, although no improvement was demonstrated in persimmon or cucurbit fields).

There is evidence of cue-lure serving for MAT control of *B. cucurbitae*. Table 4 shows the results of a trial in Bangladesh.

Table 4. Comparative effectiveness of BAT and MAT trapping against *B. cucurbitae* in cucumber in Bangladesh (Nasir Uddin *et al.*, 2000c). Data are means of three replicates.

Control	Nothing	Mashed pumpkin BAT	Cue-lure MAT
Percent infestation (%)	22	13	2
Yield (kg/plot of 4m^2	150	230	260

Apart from the nature of the attractant chemicals, the trap delivery system also affects the usefulness of lure-based killing points. Methyl eugenol or *tulsi* may be used in a variety of formulations such as plastic traps, with and without insecticide, and soaked-wood killer blocks; which of these are most cost-effective for farmers with different resource availabilities in terms of chemicals, traps and labour, would be a useful study. Indian researchers have developed effective research into, for example, “lobster-pot” methyl eugenol traps which trap and kill males without insecticide (Patel and Patel, 1995, 1996, 1998). There are also available commercially prepared blocks microformulated to release lure at a steady rate (Agrisense, pers.comm.) - these may use lure more cost-effectively than simpler preparations, but may be beyond the reach of all but the most sophisticated growers. To our knowledge, soaked-block trap MAT, which offers considerable advantages over all traps in terms of durability, efficiency and relative imperviousness to destruction by sunlight, wind, theft and mischief (Stonehouse, *et al.*, in prep. 20001 a&b) has not been successfully evaluated in India.

Mixtures

Bait/bait mixtures are widely recommended, as in the prevalence of mixtures of more than one ingredient in the list of different bait recommendations given above, though the specific comparison of different quantities of different ingredient have not much been systematically researched in India or anywhere. Lure/lure mixtures have recently been compared with melon fly in Bangladesh: Table 5 shows an interesting hint that for the attraction of melon fly a combination of cuelure and methyl eugenol may show a positive interaction and be greater than the sum of its parts.

Table 5. Inferred table (the "absent;absent" cell was in fact untried so its "0" value is assumed) of catch of *B. cucurbitae* by cuelure, methyl eugenol and both together (all with Naled) in Bangladesh (Nasir Uddin *et al.*, 2000a).

		Cue-lure	
		Absent	Present
Methyl eugenol	Absent	(0)	171.7
	Present	17.5	268.5

The record of lure/bait mixtures is patchy - in terms of the evolution of a pattern of responses to food and reproduction stimuli, there seems no *prima facie* reason why food and sex stimuli should benefit from each others' presence. Table 6 shows how methyl eugenol mixed with protein hydrolysate was less attractive than with mango pulp and sugar, to both species, but also that the two species significantly differed in their attractions.

Table 6. Average numbers of *Bactrocera* fruit flies caught per trap (N=3) by four traps with methyl eugenol between May and August 1997. *B. dorsalis* data from Kumar and Agarwal (1998); *B. zonata* data from Agarwal and Kumar (1999). There were significant differences between species caught (*F*=1426[1,16]*) and treatments (*F*=21[3,16]***) and for interactions between them (*F*=7[3,16]**).**

Methyl eugenol (2ml) + malathion 50EC (1ml) +:-	*dorsalis*	*zonata*
- Protein hydrolysate (20g)	821	2580
- Fermented palm juice (20ml)	1082	2394
- Sugar (20g)	970	2648
- Ripe mango pulp (20g)	1430	2797

Another study of a mixture of bait with lure, over the months of a year, found its average catch of male *B. zonata* to be higher than that of the two components separately; however this was largely because of the much higher catch in the single heaviest month - in all other months of the year, and when the monthly catches were converted to logarithms, the catch of the two combined was less than that of its components (Agarwal *et al.*, 1995). A study of attraction of *C. capitata* to trimedlure with and without protein found that the attraction of a mixture was less than that of lure alone for males, and less than that of bait alone for females, so that the total catch by the mixture was less than that by its two components separately (Stravens *et al.*, 2001).

Cultural Controls

Cultural controls most effectively used are the ploughing and/or harrowing of soil to destroy pupae and the collection and destruction of fallen fruit. In general, in other areas, the difficulty with fruit collection is its destruction - burial must be to at least 15cm to prevent adult emergence (Patel, 1994). Burial to shallower depths may actually increase survival: Makhmoor and Singh (1999) found survival of *Bactrocera cucurbitae* pupae was 87% at 10cm depth, but only 7% on the surface. Gathered fruit will not immediately burn and cannot be easily composted. The practice needs precise tailoring to farmer resources and views - in Réunion fruit is sun-baked in plastic bags, whereafter it will burn (Jeffrault, 2001). It may be fed to animals, probably the most beneficial use if it may be made practical to farmers. An additional area of study may be the extent to which larval and pupal and controls depend on scale-economies - whether the complete extermination of larvae and pupae over an area of, say, 1/4 acre will offer economic protection if the area is prone to reinvasion from neighbouring fields, and thus whether coordination between farms significantly enhances the usefulness of the method.

Other cultural controls may make small but useful differences. Host plant resistance is known for fruit flies, but is generally weak. Some resistance traits have been reported in jujube (Makhmoor and Singh, 1998; Sharma *et al*., 1998) and peach (Nijar *et al*., 1998) but overall strengths are only relative, and offer little real commercially resistance and are perhaps better termed “differential susceptibility” such as the different attack levels reported by several authors in bitter gourd (Tewatia and Dhankhar, 1996; Thakur *et al*., 1992, 1994a,b, 1996). Unfortunately, such resistance traits as are found tend (perhaps unsurprisingly) to be correlated negatively with traits making for attractive eating for humans, such as sugar content, pulp content, thin skin and other appetising characteristics (Arora *et al*., 1999; Kumar *et al*., 1994). Some authors have reported that sprays of giberellic acid and other physiologically active compounds enhance resistance in guava (Jalaluddin *et al*., 1998a,b) and mango (Kumar and Singh, 1993; Singh *et al*., 1995) but the use of these seems beyond the means of small farmers.

The way that cucurbit vines are trailed may affect attack (Joshi *et al*., 1995). Trap crops have been successfully developed for pests of Cruciferae (IIHR, undated a,b) but none are known for fruit flies. In Pakistan, Khan *et al.* (1992) found that cultural methods effectively controlled melon flies. In their trial of various techniques the best economic cost:benefit ratios were 1:9 for ash dusting, 1:7.9 for intercropped squashmelon as a trap crop and 1:2.7 for poisoned cut-melon baits. This is a curious result and not to our knowledge repeated.

Biological Control

Most studies have found only low levels of parasitoid attack on South Asian fruit flies. There are, however, exceptions: in Pakistan CIBC (1972) reported individual maximum attack levels of 44% (by *Trybibliographa daci*) and 10% and 37% (by *Opius longicaudatus*), although why this might have been is unclear.

Integrated Control

Most recommendations to farmers combine at least two control techniques as an integrated package. Examples in India include:
Karnataka (IIHR, pers.comm.)
- collection and destruction of fallen fruit
- raking/ploughing
- 1 or 2 cover sprays of carbaryl or decamethrin applied with reference to predictive model

Karnataka (Singh, 1997)
- fruit collection every 3 days and burial “deep”
- area-wide male annihilation, traps replenished every 10 days
- area-wide sterile male release
- bait sprays in “endemic areas”

Gujarat (GAU, pers.comm.)
- Jujube (*Carpomyia vesuviana*)
- 2 cover sprays of malathion/fenthion/neemark

- Mango, sapota (*Bactrocera* spp.)
    - sweet basil trap crop sprayed with insecticide
    - methyl eugenol traps, at one per 12 trees
    - cover sprays every 15 days, one in 12 trees also with methyl eugenol
- Cucurbits
    - methyl eugenol traps
    - bait sprays of jaggery and insecticide every 15 days
    - collection and destruction of fallen fruit
    - deep ploughing

Tamil Nadu (anon., udated)

- methyl eugenol traps at 12 per ha
- fallen fruit destruction
- raking and ploughing to disrupt pupae
- bait spray 1ml malathion 50EC/0.5ml fenthion 100EC with 10g crude sugar in 1l water
- giberellic acid spray to enhance resistance
- soil drench of azadirectin (neem) or neem seed extract

Uttar Pradesh (CISH, 1998) (mango)

- need-based bait sprays of protein OR molasses every 21 days
- methyl eugenol and malathion traps at 10 per ha
- fruit collection and disposal
- ploughing
- early harvest

A. Experimental Studies of On-Farm Management of Fruit Flies

1. The Nature and Assessment of Fruit Fly Infestation and Management

~03/12B[VST]: Bitter Gourd Fruit Losses to Fruit Flies by Infestation and Survivor Weight Loss in Eastern Uttar Pradesh

Stonehouse, JM, Swamy, S, Satpathy, S, Rai, S, Mumford, JD, Verghese, A

Abstract

In assessments of fruit fly infestation in a bitter gourd stand outside Varanasi, separate records of both the number and weight of both infested and uninfested fruit were taken on three occasions in eighteen differently-treated plots. It was found that, among “uninfested” fruit, the mass of each individual fruit declined significantly (P=0.0053) with increasing levels of overall infestation per plot. According to a regression model fitted to the data, at “50% infestation” the reduction in mass per uninfested fruit was 40%, and reached a theoretical maximum of 64% at maximum infestation. It was concluded that, under heavy levels of attack, the loss of mass of “uninfested” fruit leads loss estimates as “percentage infestation” to be underestimates.

Introduction, Materials and Methods

Fruit fly controls may be assessed by a variety of methods, including the percentages of fruit counted per unit area which are infested as opposed to uninfested. This experiment aimed to assess the accuracy of the “percentage infestation count” method, by an investigation of the relationship between the effects of fruit fly attack on the weight and number of fruit.

The experiment was laid out at IIVR, Varanasi, in 2003. A plot of bitter gourd 20x45m was divided into six plots of 20x7.5m (allowing for buffer areas) treated with different fruit fly protections. Samples were taken for the analysis of infestation from three separate sub-plots within each treated plot, and on three separate occasions (October 10, 20 and 30) so that each treated plot had nine records. Data were gathered within each area on each occasion as both the numbers and weights of both infested and uninfested fruit per unit area.

Results and Discussion

An analysis was made of the relationship between the percentage infestation of fruit and the mean weight of an individual uninfested fruit, in each of the cells evaluated (six “treatments” times three “replicates” times three assessments obtaining 54 cells altogether). A comparison was made, cell-by-cell, of the percentage infestation of fruit by number (#Inf/(#Inf+#Uninf)) and the mean mass of one uninfested fruit (MassUninf/#Uninf). This was on the supposition that in the process of fly attack some fruit, attacked relatively early on, are shed by the plant, and replacements developed instead, and that these replacements, as developing relatively late, are smaller and lighter than the originals they replaced would have been, and thus that under heavier infestation the mean mass of uninfested fruits may be lower than under lighter infestation, and therefore the estimate of losses by percentage infestation by numbers of fruits may be an underestimate of actual economic loss, as even the uninfested fruits amount to fewer KG per unit area. (It was noted these two variables are not independent, as both contain the same term in the number of uninfested fruit; this term appears in the same position, however - positive in the denominator - in both variables, and therefore if this lack of independence were to contribute to a false association this would be a positive association, whereas the test hypothesis was the presence of a negative association - that mean mass of uninfested fruit goes down as percentage infestation by number goes up - and so will not contribute to a false confirmation of the test hypothesis or Type I error).

In comparison of the regression relationships with the axes unlogged and logged, the closest fit, as the highest r^2 value (0.1402) was obtained with infestation unlogged and mass per fruit logged (for comparison, with both axes unlogged r^2=0.0712, with both axes logged r^2=0.1308, with infestation logged and mass per fruit unlogged r^2=0.0687). This association was highly significant (F=8.4812[1,52]*** {P=0.0053}) and obtained a regression equation of Mass/UninfestedFruit = EXP(-3.0124 -0.0103 %Infestation).

This led to the conclusion that percent loss by number, though useful for comparisons of treatments, is an underestimate of actual economic loss, which is most appropriately estimated as the loss of weight of uninfested fruit per unit area. In such cases, losses may be more effectively modelled by adjustment to include the loss of weight per uninfested fruit. This may be done by the multiplication of survival (i.e. 100-%inf) by the mass of each uninfested fruit as a percentage of that mass when infestation is zero (100%-%WeightLoss). Percentage weight loss for any infestation level is calculated as the mean weight per uninfested fruit when infestation is zero, minus the mean weight per uninfested fruit at that infestation level, subtracted from the mean weight per uninfested fruit at zero infestation to obtain the fractional loss of weight at that infestation level:

%WtLoss[x]=(FrtWt[0]-FrtWt[x])/FrtWt[0]

Percent loss is calculated as the percentage mass of fruit lost, as the percentage fruit uninfested (100=%Inf), multiplied by the weight per fruit at that infestation level as a fraction of individual fruit weight at zero infestation (100-%WtLoss), subtracted from 100:

%Loss[x]=100%-(100%-%Inf).(100%-%WtLoss)

In more formal mathematical notation, and replacing percentages with fractions:

I	Number of infested fruit
U	Number of uninfested fruit
F	Fraction of fruit infested = I/(U+I)
M	Mass of uninfested fruit
G	Mass of one individual uninfested fruit = M/U From regression: G = EXP(-3.0124-1.03F).
W	Fraction loss of mass / individual uninfested fruit at infestation F W[F] = (G[0]-G[F])/G[0]
L	Fraction loss of mass of uninfested fruit L[F] = 1-(1-F).(1-W[F])

Table 1. Model of the effects of the reduction of mass per uninfested fruit, in enhancing the influence of economic damage by fruit flies, at different levels of the percentage infestation of fruit by number. The mass of an individual fruit was regressed against percentage infestation; the loss of mass per individual fruit is estimated as the subtraction of the quantity in the regression equation from the mass of a fruit when infestation was zero; the loss of mass was obtained by the subtraction of the percentage surviving fruit by number of the losses in mass per individual fruit inferred.

Percentage infestation (F)	Mass of individual uninfested fruit (G[F])	Loss of mass per individual uninfested fruit (W[F])	Loss of mass of uninfested fruit (L[F])
0	0.049	0	0
10	0.044	10	19
20	0.040	19	35
30	0.036	27	49
40	0.033	34	60
50	0.029	40	70
60	0.027	46	78
70	0.024	51	85
80	0.022	56	91
90	0.019	60	96
100	0.018	64	100

Table 1 shows the effects of these calculations on bitter gourds in the case applicable, using percentages as more familiar than fractions. It may be seen that the inclusion of the fruit-mass-loss model considerably augments the loss estimates in comparison with those for percentage infestation alone. According to the regression relationship, when percentage infestation of harvested fruit is the only measure of infestation, this may be an underestimate by 40% at “50% infestation” up to a theoretical maximum of 64%.

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~04/10[IDT]: Modelling the Effects of Fruit Fly Attack on the Immature Stages of Cucurbit Fruit in Orissa and North Gujarat

Stonehouse, JM, Singh, Patel, Mumford, Verghese

Abstract

This study aimed to examine whether fruit fly losses may be measured by models more accurate and realistic than the use of percentage infestation only among fruit ready for harvest, as the latter may under-record losses of younger, smaller fruit which may be infested, lost from the plant before harvest, and incompletely replenished. This study assessed four different ways of modelling losses using infestation data from four successive cohorts from “forming” to “harvestable” fruit, as (1) the arithmetic mean of infestation in all four cohorts, (2) the infestation level in only the final (large, harvestable) cohort, (3) the infestation lost if no fruit are replaced, so that the overall survival is the product of the survival of each of the successive four cohorts, and (4) a successive loss of fruit in each cohort, as in model 3, but with the succession to the succeeding cohort some limited compensation and replenishment of losses - in this case replenishment levels set at a recovery of loss of 87.5% between “forming” and “small” fruit, 75% between “small” and “medium” and 50% between “medium” and “large”. Assessment was by taking a number of experimental cells from a variety of fruit fly control experiments - 23 in all from four separate experiments - where assessment in this way was replicated, and comparison of the coefficient of variation (CV, standard deviation divided by mean) among the identically-treated replicates within each cell to establish whether the various models obtained significantly different CV values. The “by cohort, compensated” model (mean CV=0.1816) obtained variability significantly less than the “large only” (mean 0.3363; P=0.0007) but not significantly less than the “arithmetic mean” (mean 0.2292; P=0.0744)

or the “by cohort, uncompensated” (mean 0.1966; P=0.5254). As the model with the lowest variation, the “compensated” model suggests itself as suitable for use until more data allow the models' usefulness to be more conclusively compared.

Introduction

It has been suspected that the recording of fruit fly damage as the percentage infestation of fruit when harvested may not fully capture losses if fruit attacked in earlier stages of development may be lost to the plant before maturity, and thus their loss go unrecorded. Flies attack immature fruit which do not survive to maturity to be infested at harvestable age, and which are therefore lost to the plant, and the replacement of these by other fruit, “brought forward from reserve” to fill the gaps, is not clearly able fully to replace these losses. A more accurate way to model losses may be by recording separately the percentage infestation in fruit of different maturity classes.

There are several alternative ways of addressing this calculation. Using the notation of “D1.. D4" for the fractional damage in, respectively, “very small/forming”, “small”, “medium-sized” and “large/harvestable” fruit, and also the fraction of losses which may be compensated by the plant so that these losses are themselves reduced in transition from one stage to the next, of “C1,2" for transition from “forming” to “small” fruit, “C2,3" for transition from “small” to “medium” and “C3,4" from “medium” to “large”, total loss may be estimated:

1. “Arithmetic mean,” as the arithmetic mean of the infestation levels at the four stages:-

    (D1+D2+D3+D4)/4

2. “Large fruit only,” as the infestation of large, harvestable fruit only - ignoring the levels in the previous three levels:-

    D4

3. “By cohort, uncompensated,” as the survival to each stage, from the stage preceding, only of that fraction of each cohort which is unattacked:-

    1-[(1-D4)*(1-D3)*(1-D2)*(1-D1)]

4. “By cohort, compensated,” as the survival to each stage, from the stage preceding, of that fraction of each cohort which is unattacked, modified by a level of compensation so that the losses of each cohort at each stage are reduced by a fraction:-

    1-[(1-D4)*(1-D3*{1-C3,4})*(1-D2*{1-C2,3})*(1-D1*{1-C1,2})]

It may be noted that both Models 2 and 3 are in fact variants of Model 4 - Model 2 is Model 4 with all compensation factors as 100%, so that only losses at the final stage have any effect; Model 3 is Model 4 with all compensation factors as zero, so that losses in all cohorts have equal, unmitigated effect. Discussion with farmers and fieldworkers led to the choice in this instance of:-

C1,2 = 0.875
C2,3 = 0.75
C3,4 = 0.5

Materials and Methods

Evaluation was on the argument that a more accurate and realistic model should have a role in “damping-out” random variation between cells of infestation assessment which were all treated the same way. Assessment was by taking a number of data sets of infestation assessments recording the percentage infestation of fruit in the four categories, each treated in the same way and containing at least two replications, and then comparing the coefficient of variation (CV, standard deviation divided by mean) among the identically-treated replicates within each cell to establish whether the various models obtained significantly different CV values and, in particular, whether the “compensated loss” model (number 4) obtained lower CV values than the others.

Cells for assessment, each containing two or more replicates and treated the same way, were taken from four experiments as follows:-

A - From Northern Gujarat, the four cells of the assessment of MAT and BAT alone and in combination in pumpkin (Experiment 02/01A[SBM]).

B - From Bhubaneswar the eight cells of the analysis of MAT and BAT controls in farmers fields of bitter gourd (Experiment 03/16[BBM]).
C - The Northern Gujarat village-level wide-area data set in pumpkin, in which only three cells were replicated (untreated cells in both years, and farm-only in Year 1), each replicated twice.
D - From Bhubaneswar the eight cells of the wide-area experiment in bitter gourd, each with two replicates.
The total number of experimental cells was 23 in all from the four separate experiments.

Results and Discussion

Table 1. Means and standard deviations (as <SD>; [N=23]) of the coefficients of variation (CV, as SD/mean) among the data from the various replications (N=2,4 or 5) in each experimental cell of four separate experiments, with "percentage infestation" calculated according to four different models as described in the text. Below are the outputs of planned, premeditated *t*-test comparisons [22] of the "by cohort, compensated" model with the other three.

Model	1	2	3	4
Variable	Arithmetic means	Large fruit only	By cohort, uncompensated	By cohort, compensated
Mean	0.2292	0.3363	0.1966	0.1816
<SD>	<0.1818>	<0.3383>	<0.1671>	<0.2077>
t(v.4)	1.8690+	3.8993***	0.6448ns	
{*P*}	{0.0744}	{0.0007}	{0.5254}	

The Coefficients of Variation obtained overall are summarised in Table 1, along with the outcome of planned *t*-test comparisons of the "by cohort, compensated" model (4) with each of the other three.

The use of infestation among only large fruit, ready for harvest, (Model 2) obtained significantly greater variation among replications of identically-treated cells than the compensated model. Among the other loss models coefficients of variation did not significantly differ although, as the model with the lowest variation, the "by cohort, compensated" model suggests itself as suitable for use until more data allow the models' usefulness to be more conclusively compared.

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~03/08[VSK]: Distribution of Dead Fruit Flies below Protein Bait Spots in Eastern Uttar Pradesh

Swamy, S, Satpathy, S, Rai, S, Stonehouse, JM, Verghese, A, Mumford, JD

Abstract

To assess how accurately the catch of flies in collectors hung underneath baitspots may reflect the total numbers of flies attracted and killed, a grid of catching receptacles was laid below a baitspot to allow the total kill of flies to be assessed by collecting corpses out to a distance of 0.7m. This allowed the estimation of the total number of flies killed, by least-squares-regression extrapolation of the pattern of fall, and the calculation of the percentage of this falling within circles of different radii. It was estimated that 75% of flies killed fell within 60cm and 85% within 70cm. The data showed a high level of variability, and it was not clear how reliably catches in collectors below baitspots may allow the estimation of total mortality caused by them.

Introduction

Fruit flies are commonly controlled by protein bait, mixed with insecticide, applied in spots or splashes to foliage - adult flies are attracted to these spots, feed and are killed. The experimental evaluation of different baits in the field is often as "single killing points" when a single spot is applied under realistic field conditions, and its effectiveness assessed by recording the numbers of adults attracted and killed by catching the dead flies in a receptacle hung below the spot. A difficulty with this approach is that not all flies killed by the spot may be recovered in the receptacle - dying flies which have received a lethal dose may fly or be blown beyond the receptacle rim. For the accurate assessment of mortality caused by spots, therefore, it is desirable to quantify the portions of the total kill at each point which may fall inside and outside the rim. This experiment aimed to create maps of the points below a killing spot where flies may fall.

Materials and Methods

The experiment was conducted at IIVR, Varanasi, Uttar Pradesh. Protein bait spots were applied to the undersides of leaves of brinjal plants in the manner of field controls, 40cm above the ground and 30cm in diameter. Below these plants were placed stiff plastic sheets indented to form a grid of pot-like cavities, available from horticultural and garden suppliers to provide sheets of pots for rearing seedlings. Each impressed pot on each sheet was 5cm in diameter and 6cm deep, arranged in a square pattern with 75 pots in five rows of fifteen on each sheet. Sheets of impressed pots were placed on the ground below each sprayed bait spot, and thus about 40cm below the level at which the bait was applied. As the flies fell into individual pots and remained there, inspection of the sheet, counting the flies in each pot, allowed a map to be drawn, within the limits of resolution dictated by the pot diameter, of where each fly fell.

Due to the limitations of space around the treated plants, which were in an actual stand of crop, sheets could not be laid neatly around each plant to provide continuous uninterrupted coverage of sheets radiating in all directions from the bait spot. Accordingly, catch location data were weighted to provide coverage estimates corrected for the extent of the sheet in each direction, in the following way. The pots embossed into each sheet were allocated into concentric circles each 5cm wide, and the number in each ring counted; the total numbers of catches in each ring of pots was then divided by the number of pots in that ring that were actually present, and multiplied by the number there would have been if the ring were unbroken all around 360 degrees.

Three plants were treated with bait spots, and the flies fallen into the pots mapped every day for five days. Data of numbers of flies were amalgamated into the four compass quadrants radiating away from each bait spot, and summed over the five days of observations.

Results and Discussion

Table 1. Catches of flies in concentric rings of 5cm thickness radiating away from bait spots, as means, standard deviations <SD> and Mean/SD ratio (for rings 1 to 9 N=3; outside ring 9 N=2). “% in” is the percentage of the estimated total kill (32 flies) catch found on all sheets to be found within the ring specified, given as means calculated directly, and upper and lower 95% confidence intervals calculated with data converted to arcsines.

Ring	Radius (cm)	Mean	<SD>	Mean /SD	% in		
					Upper	Mean	Lower
1	5	1	<1.1>	0.91	11	4	0
2	10	1.8	<1.3>	1.38	27	11	2
3	15	1.8	<1.6>	1.13	44	18	4
4	20	1.4	<0.4>	3.5	53	26	8
5	25	1	<0.8>	1.25	61	31	9
6	30	0.8	<0.7>	1.14	66	34	10
7	35	2.6	<1.8>	1.44	81	46	17
8	40	1.7	<1.0>	1.7	86	54	24
9	45	8	<8.2>	0.98	86	65	44
10	50	2.3	<1.1>	2.09	86	72	56
11	55	1.2	<1.7>	0.71	87	74	61
12	60	0.7	<0.9>	0.78	88	76	62
13	65	1.3	<1.9>	0.68	92	79	63
14	70	1.9	<2.7>	0.7	86	86	86

Table 1 shows the mean and standard deviation of numbers of flies in each ring radiating away from the bait spot, weighted as above to compensate for gaps in the surrounding sheets. The density of flies declined with an exponential decay, and was modelled by logarithmic regression across the fourteen bands (*r*2=0.6077; F=18.5908[1,12]** {*P*=0.0010}). Continuation of the modelled catch outwards to a radius of 2.5m (fifty 5cm bands) obtained a catch at this point of 31.3 flies, and the likely total kill was estimated as 32. The lower half of Table 1 shows the percentages of this figure found within bands of successively-increasing radius. An estimated 75% of the total kill was found within a 60cm radius.

The data showed a high level of variability, which increased steadily (as seen in the declining Mean/SD ratio) with distance from the centre. The confidence intervals for estimates of percentage fall inside areas may be considered too large for reliable calibration of such catch data into estimates of total kill.

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2. Varietal Resistance

~03/10[VVR]: Resistance and Susceptibility of Bitter Gourd Varieties to Melon Fruit Fly in Eastern Uttar Pradesh

Satpathy, S, Rai, S, Swamy, S, Stonehouse, JM, Mumford, JD, Verghese, A

Abstract

Ten different varieties of bitter gourd were assessed for differential infestation by melon flies in fields outside Varanasi. Levels of infestation varied between 21% and 29% and did not significantly differ (*P*=0.3214).

Introduction, Materials and Methods

Host cucurbit fruits are known to differ in their susceptibility to attack by the melon fly *Bactrocera cucurbitae*. This experiment assessed the differences in levels of attach suffered by ten varieties of bitter gourd, as listed in Table 1, planted in three complete randomised blocks in an area prone to melon fly attacks near Varanasi. At harvest, the numbers and weight of infested and uninfested fruit were recorded, to allow the calculation of the percentage infestation of fruit.

Results and Discussion

The infestation levels found are given in Table 1. Although differences between varieties were observed, these were not statistically significant. This finding corresponds with other which have found only limited levels of resistance to fruit flies among gourds.

Table 1. Means and standard deviations (<SD>; N=3) of percentage infestation (by number) of ten varieties of bitter gourd planted in the field near Varanasi. Means were not significantly different (*F*=1.2613[9.29]ns {*P*=0.3214}).

Baramasi	20.9	<5.9>
Jhalari	22.8	<2.3>
DVBTG-2	24	<3.9>
VRBT-85	24.2	<3.1>
IC-85645	25.2	<2.0>
Faizabadi	25.4	<3.4>
DVBTG-1	25.7	<1.9>
IC-85625	26.1	<1.1>
Priya F1	26.6	<4.8>
Jaunpuri	29.4	<2.5>

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3. Spatial Positioning of Point Controls

~03/25[MHT]: Heights of Flight Activity of Fruit Flies in a Cucurbit Crop in Southern Kerala

Jiji, T, Nair, B, Stonehouse, JM, Verghese, A, Mumford JD

Abstract

Observation indicates adult fruit flies have preferred heights of activity, and to identify these will assist the placing of controls at optimum heights, particularly when the crop is grown on pandals. This study trapped adult melonflies at different heights in a stand of bitter gourd outside Thiruvananthapuram. There was a pronounced peak in the height distribution at a level just below the pandal, indicating this as the optimum level for placing controls.

Introduction

Pest fruit flies (Diptera: Tephritidae) are often controlled by traps or bait-spots dispersed through the field. Observations have suggested that fruit flies in the field have heights within the crop canopy where are they are preferentially found. For optimal crop protection, therefore, traps or bait-spots should be positioned at the height within the crop where they have most effect. A study of orchard fruit flies among mango trees in Bangalore, India, found a preferred height of 0.9m, relatively low in the canopy (Madhura and Viraktamath, 2001). This experiment aimed to assess height distribution of the melonfly, *Bactrocera cucurbitae*, among gourds, an arable crop grown on wire pandals in Kerala.

Materials and Methods

The experiment was carried out at the Kerala Agricultural University campus outside Thiruvananthapuram, in a field of bitter gourd grown on pandals five feet (1.52m) high. Traps were installed at different heights within the canopy, in six complete randomised blocks. Traps were of a design used for melonfly control by local farmers: each was of a half-coconut shell, containing a piece of banana (of the local variety *Palayamkodam*, popular with farmers for this purpose) of approximately 20g and a pinch of carbofuran granules of approximately 0.1g. Baits were replenished weekly. Melonfly catches were counted between April 2004 and May 3, 2004.

Results and Discussion

Table 1 shows the total catches of flies at various heights. An initial analysis to assess differences among blocks found no significant differences between them (ANOVA F=1.1998[5,20]ns {P=0.3449}) and consequently block data were pooled for subsequent analysis to maximise degrees of freedom. Subsequently, catch data were modelled by fitting a linear equation and a series of stepwise polynomials (Zar, 1998) to the data with blocks pooled. The fit for the cubic form was superior, as can be seen by comparison of the model and data columns in Table 1 and was confirmed by statistical analysis (testing for the significance of additional slopes in the stepwise regression, for the linear model t=4.1055[28]*** {P=0.0003}; for the quadratic t=2.1000[27]* {P=0.0452}; for the cubic t=2.0855[26]* {P=0.0470}; for a possible quartic t=0.2036[25]ns {P=0.8403}).

Table 1. Total catches of melonflies in traps at five different heights over a 14-day period, as means and standard deviations (<SD>) of six traps at each height. Also given are the estimates obtained by regression models of the quadratic and cubic polynomial forms.

Height	Data (catch)		Polynomial model	
(M)	Mean	<SD>	Quadratic	Cubic
1.6	1.17	<1.47>	0.25	1.20
1.52	3.17	<0.98>	4.92	3.02
1.45	7.67	<4.03>	7.88	7.88
1.37	11.17	<5.98>	9.12	11.02
1.3	7.67	<3.08>	8.65	7.70

The significance of the association is remarkable, given the short vertical distance (30cm) between the traps, and this suggests that the choice of an optimum trap placement height may make a considerable difference to catches. The optimum height was at approximately 1.37m (in fact slightly below - the quadratic polynomial solved to a maximum catch at a height of 1.355m). This was just below the height of the pandal, and suggests that flies are most active in the area below the foliage where they are protected from wind and sunlight and where the fruits generally hang. Just below pandal level, where in fact traps are currently hung by farmers, therefore appears the optimum level.

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~04/17[AHC]: The Horizontal and Vertical Spatial Distribution of Melonflies in Gourd Fields in Central Gujarat

Sisodya, DB, Jhala, RC, Stonehouse, JM, Verghese, A, Mumford, JD

Study conducted as part of the IMFFI-associated project

Biology and Management of Bactrocera cucurbitae Infesting Bitter Gourd

Abstract

Cue-lure traps were placed in different parts of gourd fields near Anand (N=4) to assess the spatial distribution of *Bactrocera cucurbitae*. Significantly more flies were found at the field borders (a mean of 87 flies) than at the edge (17 flies; P=0.0015), and at the level just below the pandal (a mean of 112 flies) than just above it (35 flies) or at ground level (9 flies; P<0.0001). Just below the pandal at field borders was where flies were significantly more likely to be trapped.

Introduction, Materials and Methods

Melon fruit flies are known to be found most abundantly at certain heights in a canopy of host gourds when these are grown on a pandal, and also typically to roost in hedges and other taller vegetation around the perimeter of fields and thus to be more common in field edges than centres. This study evaluated the vertical and horizontal distribution of melonflies in a gourd field outside Anand by assessment of catches in traps placed at three different heights - ground level, 30.5cm above the pandal and 30.5cm below the pandal - and either in the centre or the border of the field. Traps were hung in these six locations in four complete randomized blocks, and catches counted weekly for twelve weeks from mid-September 2004.

Results and Discussion

Table 1 summarises the numbers of flies caught in traps in the six positions. Flies were very much more abundant at field edges than in the centre, and more abundant 30.5cm below the pandal than either above the pandal or at ground level. It may be concluded that the optimum location for the placement of traps or baitspots for melonfly control is (1) just below the pandal and (2) at the edges of the field.

Table 1. Means and standard deviations (as <SD>: N=4) of total catches of melonflies by cue-lure traps at three heights and in the centre or border of a bitter gourd field. There were highly significant differences due to trap height (*F*=60.7707[2,15]* {*P*<0.0001}), field position (*F*=15.0187[1,15]** {*P*=0.0015}) and interaction between them (*F*=28.4158[2,15]*** {*P*<0.0001}).**

Vertical location	Field centre	Field edge	Row means
30.5cm above pandal	13 <5>	58 <31>	35
30.5cm below pandal	33 <22>	192 <54>	112
Ground level	6 <2>	12 <6>	9
Column means	17	87	

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4. Attraction to Colours

~02/10B[ROV];02/11[ROM];03/30[MBL];03/14[BCL];03/44[ABL];03/50B[SBL]:
Attraction of Fruit Flies to Spheres of Different Colours in India

Thomas, J, Jiji, T, Singh, HS, Jhala, RC, Patel, RK, Vidya, CV, Napoleon, A, Mohantha, A, Sisodya, DB, Joshi, BK, Stonehouse, JM, Verghese, A, Mumford, JD

Abstract

Melonflies in bitter gourd near Thrissur in (N=3) were attracted to yellow (4), green (1) and red (1), but these differences were not significant (*P*=0.0772). A population inferred to be 60% melonflies and 40% orchard flies in melon near Thrissur (N=3) were attracted to yellow (0.3), orange (0.3) and red (0.3), but these differences were not significant (*P*=0.8587).
Flies inferred to be largely melonflies in bitter gourd near Thiruvananthapuram (N=7) were attracted to yellow (40.1), significantly {*P*=0.0003} more than green (28.7) and pink (27.6).
Flies near Bhubaneswar were attracted to green (1.75 flies), pink (1.75) but not to orange (0), but this difference was not significant (*P*=0.0870).
Flies, mostly *B cucurbitae*, near Anand (N=3) were attracted to pink (25), red (16) and green (13), but these differences were not significant (*P*=0.1256).
Bactrocera species near Palanpur (N=3) were attracted significantly more to balls of increasing redness along the scale yellow-orange-red, *B. zonata* from 2 to 6.3 flies (*P*=0.0370), *B. dorsalis* from 1.3 to 4.7 (*P*=0.0136) and *B. cucurbitae* from 0.7 to 2.7 (*P*=0.0557).

Introduction, Materials and Methods

Fruit flies often locate oviposition sites in fruit by sight, using shape and colour to orient themselves, and are known to be attracted to spheres of different colours, presumed to resemble fruits, as sites for either oviposition, feeding or courting mates. It is assumed that some colours are more attractive than others, presumed to resemble fruits at more attractive stages of development, and that this attraction may be exploited to create or augment points of attraction for control purposes. Whether some colours are preferred more strongly than others may give some indication of at which stage or stages host fruit are most vulnerable, and of whether colour and shape may be a useful component of controls based on attraction.

The attraction of flies to coloured spheres was assessed by hanging a variety of coloured plastic balls, coated in “stickum” trapping gum, in complete randomised blocks in fields at different locations in India, and counting flies attracted and trapped, with details as follows:
(1) In Thrissur, Kerala, 10cm balls in bitter gourd (N=3) for two weeks from May 14th, 2002.
(2) Also in Thrissur, 10cm balls in melons (N=3) for four weeks from December 15th, 2002.

(3) In Thiruvananthapuram, Kerala, 5cm balls in bitter gourds (N=7).
(4) In Bhubaneswar, Orissa, (N=4) for several weeks in 2003.
(5) In Anand, Gujarat, in bitter gourd (N=1) in 2002.
(6) Also in Anand, in little gourd (N=3) for two weeks in March, 2003.
(7) In Palanpur, 12cm balls (N=3) for four weeks in April and May, 2003.

Results and Discussion

Table 1 summarises the conditions and catches at each location, and the outcome in each case of a linear regression of catch totals against "redness" scored for each colour as indicated. There was indication of significantly larger catches with increased redness in Palanpur, but little overall.

Table1. Catches of fruit flies by sticky balls of different colours in different environments. Given at each site are the predominant host, predominant *Bactrocera* species, number of replicates ([N]), mean and standard deviation (<SD>) of catches, and the outcome of linear regressions of catches against colour scored on a scale of increasing "redness" as green-yellow-pink-orange-red, given as regression *F* with [degrees of freedom], the sign of the slope of association (as "+" for greater catch with increasing "redness" and vice-versa), and significance levels {*P*}. Regressions were for complete randomised blocks if the between-block variation in the initial ANOVA was significant at 0.1 or less; otherwise with blocks pooled.

Site/Host	Species	N	Green	Yellow	Pink	Orange	Red	F[d.f.]	(±)/{P}
Thrissur	*cucurbitae*	3	1.3	4.3			1	2.6000	(-)
Bitter gourd	(100%)1		<1.5>	<3.1>			<1.7>	[1,4]ns	0.1822
Thrissur	*cucurbitae*	3		0.3		0.3	0.3	0.0000	(NA)
Melon	(60%)2			<0.6>		<0.6>	<0.6>	-	1.0000
Thiruvananthapuram	*cucurbitae*	7	28.7	40.1	27.6			0.0876	(-)
Bitter gourd	(90%)3		<2.7>	<4.9>	<4.6>			[1,19]ns	0.7705
Bhubaneswar		4	1.75		1.75	0		3.9410	(-)
All			<1.71>		<1.26>	<0.00>		[1,10]+	0.0617
Anand		1	0	0		0	1	0.6000	(+)
Bitter gourd			-	-		-	-	[1,2]ns	0.2254
Anand		3	13		25		16	0.7807	(+)
Little gourd			<4>		<14>		<6>	[1,4]ns	0.4268
	zonata	3		2		4.7	6.3	10.0806	(+)
				<1.0>		<2.1>	<3.1>	[1,4]*	0.0337
Palanpur	*dorsalis*	3		1.3		3.7	4.7	35.1955	(+)
All				<1.2>		<1.5>	<1.2>	[1,4]**	0.0040
	cucurbitae	3		0.7		1.7	2.7	5.2500	(+)
				<1.2>		<1.2>	<1.2>	[1,7]+	0.0557

1. Associated catch 151 by cue-lure, 0 by methyl-eugenol
2. Associated catch 59 by cue-lure, 38 by methyl-eugenol (also 0.7 by protein hydrolysate)
3. Estimate

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~03/42[ACL]: The Effects of Colour on the Attraction of Fruit Flies to Lures in Central Gujarat

Jhala, RC, Sisodya, DB, Verghese, A, Mumford, JD, Stonehouse, JM

Abstract

Traps of eight colours and one unpainted clear trap, containing cue-lure and methyl-eugenol attractants were hung out in little gourd fields near Anand (N=3), and data recorded as total catches and as half-lives of their persistence. Among total catches the ordering for *B. dorsalis* was significantly different (*P*=0.0019), with the largest catch by yellow (6), then white (5), green (4), grey (2) and with least (all 1) red, black, blue and orange, and no catch by the clear trap; that for *B. cucurbitae* was not significant

(*P*=0.1186) by the clear trap (118), green (116), yellow (115), white (108), blue (93), orange (92), red (79), black (68) and grey (67). Differences for *B. zonata* and *B. correcta* were not significant (*P*>0.25). Among half lives there were no differences. Overall, no significant differences could reliably be attributed to different colours.

Introduction, Materials and Methods

This experiment assessed the effects of different colours on fruit fly traps containing parapheromone lures. Treatments were transparent traps each with a strawboard block dripped with five drops of cue-lure, five drops of methyl-eugenol and five drops of DDVP. The transparent plastic traps were painted with nine different colours - Red, White, Yellow, Black, Green, Blue, Orange, Grey (ash) and Clear (unpainted). They were installed in three complete randomised blocks in a field of little gourd outside Anand, Gujarat in February-March, 2003, and the numbers of fruit flies caught per trap recorded daily for 30 days.

Results and Discussion

The catches of different fly species by traps of different colours are summarised in Table 1, as total catches, for individual species, and as half-lives of persistence separately for *B. cucurbitae* and pooled for other flies (due to the small number of catches). No significant differences could reliably be attributed to different colours.

Table 1. Means and standard deviations (as <SD>) of total numbers and persistence of catches of fruit flies of different species by parapheromone lure traps of different colours in Central Gujarat. Total catches are over a period of 30 days, half-lives given in days (calculated by exponential regression of catches against days for each trap, until the daily catch had remained at zero for two successive days). Data for orchard flies were inadequate for calculation of half-lives by species so these were pooled as "others". N was in all cases 3, except for the cells in *italics* where it was two (for ANOVA, each of these three cells was filled with the mean of its row and column, and for each such substitution one was deducted from the residual degrees of freedom). Given are ANOVA *F* values for treatments with *P* in each case (in all cases df=[8,16] except in the final column where [8,13]).

	Catch				1/2-life	
Bactrocera	*cucurbitae*	*dorsalis*	*zonata*	*correcta*	*cucurbitae*	Others
Red	79	1	0	0	-262	*251*
	<13>	<1>	<1>	<0>	<513>	*<30>*
White	108	5	1	0	39	127
	<16>	<2>	<1>	<1>	<27>	<53>
Yellow	115	6	1	1	214	-65
	<29>	<3>	<2>	<1>	<393>	<245>
Black	68	1	0	0	185	*291*
	<27>	<2>	<0>	<0>	<182>	*<294>*
Green	116	4	0	0	266	-128
	<25>	<3>	<1>	<0>	<435>	<412>
Blue	93	1	1	0	60	203
	<28>	<1>	<1>	<1>	<38>	<113>
Orange	92	1	1	0	93	<-1020
	<31>	<0>	<1>	<0>	<69>	<1020>
Grey	67	2	2	1	4	109
	<17>	<1>	<1>	<1>	<78>	<32>
Clear	118	0	1	0	26	*224*
	<24>	<0>	<1>	<0>	<12>	*<154>*
F	1.9675	5.4754	1.3636	1.2647	0.9607	0.8125
	ns	**	ns	ns	ns	ns
{*P*}	0.1186	0.0019	0.2836	0.3269	0.4980	0.6045

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~04/07[MCL]: Attraction of Fruit Flies to Colours under Different Conditions in Southern Kerala

Jiji, T, Nair, B, Verghese, A, Mumford, JD, Stonehouse, JM

Abstract

Flies were attracted to sticky balls of six different colours, two sizes and two heights in the canopy, hung in bitter gourd fields near Thiruvananthapuram. There were highly significant differences due to colours (*P*<0.0001), with most flies attracted to orange (mean 155.5), then yellow (140.5), violet (41.0), green (27.5), red (24.5) and blue (22.5). Significantly more flies were attracted to balls of 8cm diameter (254.5) than of 6cm (157.0) (*P*<0.0001), but numbers attracted to balls at 1.35m height (203.5) did not significantly differ from those at 1.2m (208.0) (*P*=0.7108).

Introduction, Materials and Methods

Flies were caught on coloured balls, coated with sticking gum, installed in two complete randomised blocks in fields of bitter gourd near Thiruvananthapuram. Balls were of six colours - yellow, green, blue, red, violet and orange - two sizes - six and eight centimetres in diameter - and installed at two different heights - 1.2m and 1.35m above the ground.

Table 1. Means and standard deviations (<SD>) of catches of fruit flies by balls of six colours and two sizes at two different heights above ground, and overall sums for each colour, size and height.

Colour	Size (cm)	Height (m)	Mean	<SD>	Sums		
					Colour	Size	Height
Orange	8	1.35	45	<2.8>	155.5	254.5	203.5
		1.2	49.5	<2.1>			208
	6	1.35	26.5	<3.5>		157	
		1.2	34.5	<2.1>			
Yellow	8	1.35	51.5	<13.4>	140.5		
		1.2	41.0	<7.1>			
	6	1.35	27.5	<3.5>			
		1.2	20.5	<2.1>			
Violet	8	1.35	10.0	<2.8>	41		
		1.2	14	<2.8>			
	6	1.35	7.5	<0.7>			
		1.2	9.5	<0.7>			
Green	8	1.35	11	<7.1>	27.5		
		1.2	8.5	<3.5>			
	6	1.35	4	<1.4>			
		1.2	4	<1.4>			
Red	8	1.35	6.0	<5.7>	24.5		
		1.2	5.5	<0.7>			
	6	1.35	6.0	<1.4>			
		1.2	7.0	<2.8>			
Blue	8	1.35	5.5	<0.7>	22.5		
		1.2	7.0	<0.0>			
	6	1.35	3	<0.0>			
		1.2	7.0	<1.4>			

Table 2. ANOVA output from analysis of the data summarised in Table 1, as *F*, degrees of freedom ([df]), and significance (*P*) by main effects and interactions.

Source	*F*	[df]	{*P*}
Colour	160.6549	[5,23]	{<0.0001}
Size	66.1404	[1,23]	{<0.0001}
Height	0.1409	[1,23]	{0.7108}
Interactions			
Colour/Size	14.2592	[5,23]	{<0.0001}
Colour/Height	4.4407	[5,23]	{0.0056}
Size/Height	0.9201	[1,23]	{0.3474}
All three	0.1771	[5,23]	{0.9685}

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5. Food Baits

~LAB[SLB;ALB;MLB;BLB;VLB]:
The Attraction of Baits to Tephritid Fruit Flies in the Laboratory in India

Stonehouse, JM, Verghese, A, Mumford, JD, Singh, HS, Jiji, T, Jhala, RC, Patel, RK, Mohantha, A, Nair, B, Sisodya, D, Joshi, B

Abstract

A systematic programme of comparisons of fruit fly baits was conducted at four locations in India using local populations of *Bactrocera cucurbitae*. Banana and jaggery performed as well as protein hydrolysate. Baits generally performed better as sprays than in traps in Gujarat and Orissa, though not in Kerala. Baits did not proportionally increase their attraction with increases in dose, a doubling in dose producing increased attraction less then doubled. Mixtures of banana and jaggery did not enhance performance over either bait used alone. The addition of tinned tuna fish obtained mixed results. There were clear indications that the responses of local flies to various baits differed among localities.

Introduction, Materials and Methods

This experiment used laboratory comparative studies to assess the relative attraction and lethality to fruit flies of food baits, in a controlled, replicable environment allowing data from different areas of India to be compared. The principle and methodology were as described by Stonehouse et al (1998). Assessments were carried out in long, thin cages, 2mx0.5mx0.5m, in which two candidate controls of bait-and-insecticide were placed, one at each end, so that adult fruit flies, released from a container in the centre of the cage, could be attracted to, and killed by, either one of the two. The relative attraction-and-killing power of each control could therefore be assessed by the relative numbers of dead flies falling within range of each. In each cage for each comparison twenty flies were released and when all were dead (typically 24 hours later) a count was made of the numbers on either side of the centre line. Cages were built, at each research location, in banks of six to allow replication of each comparison as it was carried out, with the treatments applied to the bank in a latin square design to balance out any bias to one end or the other. All assessments started with two comparisons to check the neutrality of the cages: the first used identical preparations, of protein hydrolysate and insecticide, at each end, which was expected to obtain equal numbers of casualties at each end if the cage was balanced; the second used protein hydrolysate with insecticide at one end, and insecticide by itself at the other, which was expected to obtain the great majority of casualties at the end with the protein if the cage allowed flies to detect and seek out food baits. Cages were built to an identical standardised design in eight research Centres; these differed somewhat in details of construction and appearance and a photographic record of their structures is given in Appendix 2 [File: iy5ffr2].

All treatments contained the same insecticide, malathion, at the same dose under all situations. When baits were experimentally tested as liquid “spray” bait formulations malathion was mixed in at the local recommended label rate of dilution for spray use. When baits were tested as solid “trap” formulations the total quantity of malathion on each preparation was the same as when in a liquid “spray”. With liquid preparations applied “as spray” this quantity was mixed into the liquid; with preparations applied as solids, “in traps”, the quantity was applied to the surface of the food bait.

Standard dose “as spray” was 0.5ml, applied to the underside of a leaf as a liquid in a number of droplets with a measuring pipette or a graduated syringe (without needle), although for viscous slurries of bait (such as suspensions of fruit pulp) it was sometimes only possible to apply directly with a spatula. Standard dose “in trap” was dry or wet material in receptacles. Doses were as followed:-
“Standard PH as spray”: 0.5ml of 3% protein hydrolysate in water.
“Standard banana in trap”: a cube of banana 5x5x5mm (0.125ml).
“Standard banana as spray”: 0.125ml macerated in 0.375ml of water, to obtain a slurry of 0.5ml, applied to the underside of leaves of the target plant.
“Standard jaggery as spray”: 0.5ml of solution as 100g of jaggery in 900ml of water, to obtain a 10% (weight:volume) solution.
“Standard jaggery in trap”: the same volume of jaggery as in the standard spray dose, dry in the bottom of a trap, thus 0.5x0.1=0.05g.
“Standard tuna as spray”: (as for banana) - a block of tinned tuna fish 5x5x5mm macerated in 0.5ml of water (from the same batch and so directly compatible).

Fourteen comparisons were carried out as follows:-

1: A: Standard PH as spray — B: Standard PH as spray
2: A: Standard PH as spray — B: Insecticide in water
3: A: Standard PH as spray — B: Standard banana as spray
4: A: Standard PH as spray — B: Standard jaggery as spray
5: A: Standard PH as spray — B: Standard banana as spray at double dose
6: A: Standard PH as spray — B: Standard jaggery as spray at double dose
7: A: Standard PH as spray — B: Standard jaggery spray with standard banana spray
8: A: Standard PH as spray
B: Standard jaggery spray, with standard banana spray and standard tuna spray
9: A: Standard jaggery as spray — B: Standard jaggery in trap
10: A: Standard banana as spray — B: Standard banana in trap
11: A: Standard PH as spray — B: Standard PH in trap
12: A: Standard PH in trap — B: Standard banana in trap
13: A: Standard PH in trap — B: Standard jaggery in trap
14: A: Standard jaggery as spray mixed with standard banana as spray
B: Standard jaggery spray, standard banana spray and standard tuna spray

The data from the two ends of each cage were given compressed into one number, to allow comparison between locations, by expressing the outcome as the mean percentage of catch by Treatment A divided by the mean of catch by Treatments A and B together. So if A had 20 flies and B had 10 flies, number would be 133, if A had 10 flies and B had 20 flies, number would be 67, if both were equal number would be 100.

Results

Table 1 shows the outcomes of each of the individual fourteen comparisons

Table 1. Outcomes of fourteen pairwise comparisons of baits ("A" and "B") in cages, as in all cases the catch by "A" as a percentage of the mean of "A" and "B"). Given are means, standard deviations (as <SD>; all N=6), and the outcome of related *t*-tests as *t* (all d.f.=[5]) and *P*.

	Bait A	PH	No-Bait	Banana	Jaggery	2 X Banana	2 X Jaggery	Banana + Jaggery	Banana + Jaggery + Fish	Jaggery	Banana	PH	Banana	Jaggery	Banana + Jaggery + Fish
	Bait B	PH	PH	PH	PH	PH	PH	PH	PH	Jaggery	Banana	PH	PH	PH	Banana + Jaggery
	Carrier A	Spray	Spray	Spray	Spray	Spray	Spray	Spray	Spray	Spray	Spray	Spray	Trap	Trap	Spray
	Carrier B	Spray	Spray	Spray	Spray	Spray	Spray	Spray	Spray	Trap	Trap	Trap	Trap	Trap	Spray
Palanpur	**Mean**	**98**	**85**	**102**	**115**	**100**	**133**	**122**	**121**	**112**	**102**	**122**	**77**	**105**	**92**
	<SD>	<4>	<14>	<8>	<8>	<14>	<12>	<12>	<18>	<12>	<8>	<12>	<5>	<10>	<10>
	t	1.0000	2.6656	0.5423	4.3916	0.0000	6.7420	4.5398	2.3355	2.4445	0.5423	4.5398	11.0680	1.1677	2.0761
	P	0.3632	0.0446	0.6109	0.0071	1.0000	0.0011	0.0062	0.0668	0.0583	0.6109	0.0062	0.0001	0.2956	0.0925
Bhubaneswar	**Mean**	**106**	**28**	**164**	**131**	**157**	**172**	**92**	**164**	**45**	**116**	**144**	**159**	**176**	**151**
	SD	<7>	<5>	<6>	<76>	<6>	<13>	<19>	<3>	<10>	<12>	<14>	<19>	<3>	<6>
	t	1.9385	22.6274	18.8712	0.7629	6.6742	16.1139	1.3369	20.4906	7.1139	3.1863	6.7000	7.1674	25.1577	5.5365
	P	0.1103	0.0000	0.0000	0.4799	0.0011	0.0000	0.2388	0.0000	0.0009	0.0244	0.0011	0.0008	0.0000	0.0026
Thiruvananthapuram	**Mean**	**89**	**22**	**143**	**128**	**133**	**133**	**140**	**125**	**68**	**77**	**72**	**148**	**137**	**77**
	SD	<16>	<8>	<6>	<16>	<16>	<12>	<15>	<9>	<18>	<11>	<19>	<8>	<8>	<8>
	t	1.6982	25.4893	17.0000	4.3710	4.9610	6.0828	6.7612	7.3193	4.2274	5.0844	3.5760	15.7275	11.0000	7.0000
	P	0.1502	0.0000	0.0000	0.0072	0.0042	0.0017	0.0011	0.0007	0.0083	0.0038	0.0159	0.0000	0.0001	0.0009
Anand	**Mean**	**98**	**53**	**73**	**109**	**140**	**160**	**150**	**147**	**127**	**183**	**122**	**67**	**100**	**140**
	SD	<16>	<16>	<21>	<16>	<25>	<22>	<21>	<16>	<16>	<18>	<32>	<30>	<30>	<18>
	t	0.2548	7.0000	3.1623	1.3969	3.8730	6.7082	5.8387	7.0000	4.0000	11.1803	1.6327	2.7386	0.0000	5.4772
	P	0.8090	0.0009	0.0250	0.2213	0.0117	0.0011	0.0021	0.0009	0.0103	0.0001	0.1635	0.0409	1.0000	0.0028

The two method checks in the first two comparisons appeared to indicate reliability of the outcomes. It appeared the comparison which was "meant" to be balanced was indeed balance (smallest *P* value over 0.1) and that "meant" to be asymmetrical was so also (largest *P* less than 0.05). The two home-made baits, banana and jaggery, overall obtained results comparable to or better than the protein hydrolysate.

Subsequent analyses took the form of specific sets of comparisons. These are tabulated below. In all tables, to allow the cross-comparison of values from different locations, the significance of means is encoded as indicated in Table 2.

Table 2. System for encoding significance of means in subsequent tables, as derived from values in Table 1.

0.1>*P*>0.05	0.05>*P*>0.01	0.01>*P*>0.001	*P*<0.001
0.1234	*0.1234*	***0.1234***	***0.1234***

1. Home-made and Imported Bait

Table 3 summarises the attraction-and-killing power, all relative to protein hydrolysate as a reference bait, of banana and jaggery in traps and as sprays.

Table 3. Catches by banana and jaggery baits, as percentages of the mean in a comparison with a reference bait of protein hydrolysate, in four locations in India.

	Palanpur			Bhubaneswar			Thiruvananthapuram			Anand		
	Banana	Jaggery	Mean	Banana	Jaggery	Mean	Banana	Jaggery	Mean	Banana	Jaggery	Mean
Spray	102	***115***	108	***164***	131	148	***143***	***128***	135	73	109	91
Trap	***77***	105	91	***159***	***176***	168	***148***	***137***	143	*67*	100	83
Mean	89	110		161	154		146	132		70	104	

2. Baits in Traps and as Sprays

Table 4 summarizes relative performance of three baits in traps and as sprays. The comparison of baits, of identical composition when applied in traps and as sprays indicated that all baits performed better as sprays than in traps though the Thiruvananthapuram finding contradicts this. The results of these direct comparisons were comparable to those of the indirect comparisons summarised in Table 3.

Table 4. Catches by application as "spray" as a percentage of the mean of those of "spray" and "trap".

	Palanpur	Bhubaneswar	Thiruvananthapuram	Anand
Protein Hydrolysate	***122***	***144***	*72*	122
Banana	102	*116*	***77***	***183***
Jagggery	*112*	***45***	***68***	*127*

3. Dose Augmentation

The effects of increasing dose was assessed by comparing the power of a double dose (in comparison with a reference bait of protein hydrolysate) with double the power of a single dose. This ratio of double-dose to twice-single-dose is shown in Table 5. Double-dose was in all cases much less than double the value for single-dose.

Table 5. Ratio of double-dose to twice-single-dose.

	Palanpur	Bhubaneswar	Thiruvananthapuram	Anand
Banana	49	48	46	*95*
Jagggery	*58*	65	52	***74***

4. Banana and Jaggery in Isolation and Combination

Mixtures of banana and jaggery were not as good as either used alone. The addition of the two principal candidate baits - banana and jaggery - to each other in search of interaction effects was assessed in two ways. The first was in comparison of standard-dose-of-X-plus-standard-dose-of-Y with double-standard-dose of each of X and Y, to compare the augmentation of a standard dose of each bait with either a standard dose of the other or a further standard dose of itself. The results are summarized in Table 6, which compares the addition to each bait of the other with a doubling of itself. doubling the dose of one was not very different from adding the other instead.

Table 6. Percentage obtained by addition to a dose of each bait (banana, jaggery) of a dose of the other as opposed to an additional dose of itself.

	Palanpur	Bhubaneswar	Thiruvananthapuram	Anand
Banana	*122*	***59***	106	107
Jaggery	*91*	***54***	105	94

The second assessment was to compare the increase in attraction-and-killing power obtained by a mixture, as a fraction of that to be expected from a multiplication of the power of each ingredient individually. This was calculated as the product of the power (relative to no-bait) of banana alone jaggery alone (so that, for example, if banana had an attraction of twice that of no-bait, and jaggery one of three times that of no-bait, the expected power of a combination of the two would be six). The actual power of mixtures, as a fraction of this expected, notional mixture power, are given in Table 7.

Table 7. Attraction-and-killing power of a mixture of banana and jaggery, as a fraction of that expected without interaction, calculated as the product of the power of each individually.

Palanpur	Bhubaneswar	Thiruvananthapuram	Anand
88	*12*	***17***	100

5. Addition of Fish Protein

This was assessed in two ways, directly as the comparison of banana-and-jaggery bait with and without fish added, and indirectly as the comparison of the same bait, with and without fish, with a reference bait of protein hydrolysate. The comparisons are summarized in Table 8. The evidence for the addition of fish as protein was ambivalent - it seemed to produce a major improvement in Bhubaneswar, elsewhere less so. Overall, there was evidence for an improvement from the addition of fish to the jaggery-and-banana baits. Between centres the two ways of deriving the relationship obtained similar results.

Table 8. The performance of baits with the addition of tinned tuna fish, added to a mixture of banana and jaggery, calculated directly by a comparison of the mixed bait with and without the fish, and indirectly as the relative performance of each to a reference bait of protein hydrolysate.

	Palanpur	Bhubaneswar	Thiruvananthapuram	Anand
Direct	*92*	***151***	***77***	***140***
Indirect	100	***178***	*89*	98

Conclusions

It appears that differences in food preferences among the same species in different locations reflected real differences, and not merely aberrations in the data, which will have major importance for the development of recommendations.

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~03/54[MLB]: Laboratory Responses of Melon Fruit Flies to Baits in Southern Kerala

Jiji, T, Nair, B, Napoleon, A, Senthilkumar, Verghese, A, Stonehouse, JM, Mumford, JD

Abstract

A variety of different local bananas and baits of jaggery, starch, honey and protein hydrolysate were assessed in pairwise comparisons (N=6) in laboratory cages using melonflies from a stock collected in Thiruvananthapuram. A weaker jaggery solution (20%) was superior by 77% to a stronger (80%) {P=0.0100} implying that "stronger is not always better" in bait applications. There was no significant difference (P=0.7412) between black and white jaggeries. Among bananas, *Rasakadali* and *Robusta* varieties were found to be superior to *Palayamkodam* (by respectively 70% {P=0.0007} and 44% {P=0.0235}). Bananas were significantly superior to all other baits and combinations tried: of snake

gourd, jaggery, starch, yeast and honey in various combinations, the best performer was snakegourd and jaggery, with a power of 55% {*P*=0.0009}) of *Palayamkodam*. The addition of jaggery significantly (*P*=0.0127) enhanced the attraction of *Robusta* by 63%.

Introduction, Materials and Methods

In Southern Kerala many different banana varieties are used for the bait attraction of fruit flies, and some are considered by farmers to have more attractive properties than others. This study used the standard IMFFI two-way choice chamber methodology with *Bactrocera cucurbitae* to assess the attractions of different bananas and other baits, alone and in combination, in Southern Kerala.

Results and Discussion

Table 1. Pairwise comparisons of different food baits in the attraction-and-killing of melon fruit flies in Southern Kerala. Each row represents a choice experiment; "A as %" is the mean percentage (in all cases N=6) of all flies found around Choice A (i.e. if A as % is greater than 50, A was inferred more attractive than B); "<SD(%A)>" is the standard deviation of that mean; *t*[5] and *P* are the outcome of a paired *t*-test comparison of the two. Comparisons are grouped in classes of (1) jaggery solution strengths, (2) different jaggeries, (3) different bananas, (4) bananas and other, non-banana baits and (5) the addition of jaggery to bananas. The last comparison, of *rasakadali*-with-jaggery to *palayamkodam*, did not allow direct evaluation of the addition of jaggery to *rasakadali*, though this was possible indirectly by comparison of the ratio of *rasakadali*-with-jaggery over *palayamkodam* (66%) with that of *rasakadali*-alone over *palayamkodam* (63%) - the differences between the two ratios were not significant (unrelated *t*=1.2888[10]ns {*P*=0.2265}).

Choice A	Choice B	A as %	<SD(%A)>	*t*	{*P*}
Strength					
Jaggery 20% solution	Jaggery 80% solution	64	<9>	3.7051	{0.0100}
Jaggeries					
Black jaggery	White jaggery	52	<12>	0.3460	{0.7412}
Bananas v. bananas					
Rasakadali	Palayamkodam	63	<4>	6.3521	{0.0010}
Robusta	Palayamkodam	59	<7>	3.0155	{0.0235}
Bananas v. non-bananas					
Rasakadali	Jaggery	73	<8>	6.0583	{0.0010}
Palayamkodam	Jaggery	73	<8>	6.0583	{0.0009}
Palayamkodam	PH	71	<18>	2.7616	{0.0328}
Palayamkodam	Starch & yeast	71	<6>	7.3420	{0.0003}
Palayamkodam	Snakegourd & jaggery	69	<7>	6.1070	{0.0010}
Palayamkodam	Honey	72	<8>	6.0963	{0.0010}
Palayamkodam	Snakegourd & jaggery	76	<6>	8.8366	{<0.0001}
Robusta	Starch	76	<6>	8.8366	{<0.0001}
Rasakadali	Starch	76	<6>	8.8366	{<0.0001}
Addition of jaggery to banana					
Robusta & jaggery	Robusta alone	62	<8>	3.5097	{0.0127}
Rasakadali & jaggery	Palayamkodam	66	<5>	7.3707	{<0.0001}

The first experiment indicated that a weaker jaggery solution (20%) was superior by (64-36)/36=77% to a stronger (80%) {*P*=0.0100} implying that "stronger is not always better" in bait applications. The second found no significant difference (<9% {*P*=0.7412}) between black and white jaggeries. The third comparison set found both *Rasakadali* and *Robusta* varieties to be superior to *Palayamkodam* (by respectively (63-37)/37=70% {*P*=0.0007} and (59-41)/41=44% {*P*=0.0235}), though the latter is generally favoured by farmers). The fourth comparison set found bananas significantly superior to all other baits and combinations tried - of snake gourd, jaggery, starch, yeast and honey in various combinations - the best performer was snakegourd and jaggery, with a power of (69-31)/69=55% {*P*=0.0009}) of palayamkodam. The fifth comparison set found the addition of jaggery significantly enhanced the attraction of *Robusta* by (62-38)/38=63%, {*P*=0.0127}; an indirect assessment of the addition of jaggery to *Rasakadali* was inconclusive. Overall, bananas were superior to most other baits in isolation, but the inclusion of additive attractants may further enhance their effectiveness.

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~02/13[MDL];02/14[MTP];03/23B[MSK];03/27[MJB];04/04[MBG];03/28[MJP];03/29[MBA];04/05[MCO];03/11[VBN];02/12[MYL];03/26[MOC]: Field Assessment of Fruit Fly Baits and Lures in Southern Kerala

Jiji, T, Napoleon, A, Nair, B, Senthilkumar, Satpathy, S, Rai, S, Swamy, S, Verghese, A, Stonehouse, JM, Mumford, JD

Abstract

Field “Single-Killing-Point” (SKP) studies were conducted to assess the capacity of different baits and lures to attract and kill fruit flies in Southern Kerala. A suite of eight different studies assessed the following:-

(1) Protein hydrolysate at three different concentrations (5, 7.5 and 10%), and banana. Banana caught the largest number of flies (an average total 13.3 as opposed to 12.0 for the strongest protein concentration) but this was not significant (*P*=0.0980). There was a significant positive association of catch and protein hydrolysate concentration (*P*=0.0482) with, within this data range, no evidence of a peak in catch at a specific concentration.

(2) Traps containing a mixture of starch and jaggery (N=3) caught significantly more flies (93) than banana traps (74) and those with protein hydrolysate and autolysate (home-made from brewer’s yeast with papain) significantly fewer (no flies at all for either).

(3) Although parapheromone and tulsi traps alongside caught some flies, catches by bait and colour traps (orange, yellow, green) were very low (N=3), with banana and colour-ball traps catching no flies at all, and starch-jaggery traps a mean of 0.3, which was not significantly superior (*P*=0.4444).

(4) The largest mean catch numbers (N=4) were by banana-with-boiled-jaggery (8.00), banana (4.75) and banana-with-jaggery (4.25), followed by jaggery (3.50), protein hydrolysate (2.50) and no-attractant (0.0). The largest percentage of females in the catch was obtained by protein hydrolysate (100), followed by banana (42) with no significant differences among the others (15 to 33).

(5) Catch by the traps with containing sliced banana with boiled jaggery was significantly superior to with unboiled by 2.3:1 or 128% (*P*<0.0001; N=8).

(6) Ocimum, jaggery, protein hydrolysate and dry fish caught very few flies (all with a mean catch of <1; N=3), and starch with yeast rather more (mean of 5). All banana treatments (with jaggery added) caught significantly more - in rank order from the best *Rasakadali* (mean of 45.3), *Palayamkodam* (20.0), *Robusta* (12.0), *Red* (11.3) and *Poovan* (10.7). The addition of jaggery to protein hydrolysate did not enhance its catch (*P*=1). The addition of citric acid as a preservative had no detectable effect, but boiling of jaggery did approximately double the effectiveness of *Palayamkodam* (*P*<0.05).

(7) Among fifteen combination treatments (N=6) there were no significant differences attributable to three jaggery treatments (mean catches were 4.5 for no-jaggery, 4.7 for unboiled and 4.8 for boiled {*P*=0.7832}) nor for their interaction with the other baits (*P*=0.7259). Among the other five treatments, *red* and *robusta* bananas, both with mean catches of 6.8, were significantly superior to starch, with 1.8, with the other bananas - *palayamkodam* with 4.7 and *rasakadali* with 3.5 - significantly different from no other treatment. In a two-way assessment, jaggery alone obtained a significant catch, of 4.8 (*P*=0.0134), and the five other food baits a mean of 4.7 (*P*<0.0001); the combinations obtained a mean catch of 4.9, with a significant interaction term (*P*=0.223), indicating the mixture of jaggery and others was “less than the sum of its parts”. Black jaggery caught more flies (mean 5.5) than white(4.8) but this difference was not significant (*P*=0.1747).

(8) By counts of fly catches (N=8) *rasakadali* was significantly superior to *palayamkodam*, by 1.7:1 or 70%, and plastic 1L table-water bottles superior to half-coconut-shells, by 2.1:1 or 111% (both *P*<0.0001). .

(9) Three banana varieties from Southern Kerala, with reputations of differing levels of attraction to native melonflies, were assessed in traps outside Varanasi. *Rasakadali* caught more flies than *Palayamkodam* which caught more than *Robusta*, but these differences were not significant (P=0.4181).
(10) The protection of bitter gourd from fruit flies was assessed by eight treatments - no-control, cover sprays, banana traps and protein hydrolysate BAT as a mixture of trap and spray-spot application, all both with and without additional ocimum/jaggery traps- in six complete randomised blocks over two years. Overall, significant increases in yield (P=0.0013) attributable to controls were 16% for cover sprays, 61% for protein baits and 62% for banana traps, and an increase of 12% attributable to ocimum-jaggery (though this was not significant {P=0.1345}), but no interaction between them (P=0.7578). Trap catches to assess the attraction and killing of flies confirmed the significant superiority (P=0.0011) of banana, with mean weekly catches of 10.5, to protein traps with mean weekly catches of 6.6 - although banana traps contained a significantly lower (P=0.0021) percentage of females (53) than the protein traps (69).

Introduction

In South India, banana slices are used to bait traps for fruit flies. Farmers in Kerala report that some varieties of banana are superior to others for this purpose. In particular, two local varieties - *Palayamkodam* and *Rasakadali* - are considered superior to the conventional *Robusta* variety found elsewhere in India.

Materials and Methods

All experiments were conducted with traps containing insecticide, baits and lures in complete randomised blocks in research station and farm fields of cucurbit gourds outside Thiruvananthapuram. Single-killing-point studies cannot compare the control efficacies of MAT lures (working by the control of males alone) and baits (working largely by the control of females but also males), so the assessment of control efficacy focussed on the catches of both sexes by bait controls.

(1) Dilution experiment
Baits assessed were protein hydrolysate at three different dilution strengths(5, 7.5 and 10%), banana and ocimum (N=4).

(2) Four-treatment experiment
The lures methyl-eugenol, cue-lure and ocimum, and the baits protein hydrolysate (3%), home-made protein autolysate (made from brewer's yeast autolysed with papain), banana and starch-jaggery (starch solution mixed with 2g yeast + 10g jaggery), were deployed from April to July inclusive (the entire growing season), 2002.

(3) Eight-treatment experiment
Traps were three different coloured balls (orange, yellow, green) 2.5cm in diameter, the parapheromones methyl-eugenol and cue-lure, banana slices, ocimum-jaggery mixture and starch-jaggery mixture, assessed monthly over the fruiting season between April and July 2003.

(4) Six-treatment experiment
Six treatments were deployed as listed in Table jb1 (N=4). Baits were 20g of banana and/or 10g of jaggery in all cases. After seven days catches were counted and sexed.

(5) Jaggery boiling experiment
Traps contained palayamkodam banana mixed with jaggery which was either boiled or unboiled (N=8), over the growing season of 2004.

(6) Fifteen-treatment experiment

Fifteen treatments, as given in Table jp1, were assigned as follows: the five bananas (*Palayamkodam*, *Robusta*, *Red*, *Rasakadali* and *Poovan*) as 20g; jaggery (boiled and unboiled) as 10g, starch as 100ml with added 2 granules of yeast, ocimum leaves as 20g; carbofuran and malathion as 0.5g; dried fish as 10g, citric acid as 0.5ml, protein hydrolysate as 100ml of 6.5% solution, water as 100ml. All banana treatments but one were macerated and mixed in with water; *Palayamkodam* was also applied dry as a single block, as this is how it is widely used by local farmers. Two adjustments of baits - boiling and the addition of citric acid - were assessed as preservatives to see if they would extend the life, and therefore catch, of the baits.

(7) Twenty-treatment experiment

Twenty treatments were assessed, in the 2003 field season, comprising six main attractants:

1 to 4. 20g of banana pulp of 4 varieties (*Red*, *Robusta*, *Palayamkodam*, *Rasakadali*)

5. 100ml of starch solution

6. 30g of tulsi (ocimum) leaves in 50ml of water

Each of the above six was combined in the following ways:

A. Alone

B. With 10g unboiled white jaggery

C. With 10g boiled white jaggery

Additionally, there were two independent jaggery treatments, of “speciality jaggeries” from central Gujarat:

X. 20g of white jaggery in 50ml water

Y. 20g of black jaggery in 50ml water

(8) Trap vessel experiment

This study compared two banana varieties - palayamkodam and rasakadali - deployed in two trap vessels - half-coconut-shells and plastic 1L table-water bottles (N=8) in 2004.

(9) Kerala bananas in Uttar Pradesh

This experiment assessed the relative attraction of three Kerala varieties to flies in the North Indian state of Uttar Pradesh. Examples of three bananas from a market in Thiruvananthapuram, Kerala - *Robusta*, *Palayamkodam* and *Rasakadali* - were flown to Varanasi, Uttar Pradesh for an assay of their attraction to local fruit flies. The trial was conducted in the field station of the Indian Institute of Vegetable Research (IIVR) Varanasi and due to the prevalence of arable vegetables the flies accessible in the trial were all the melonfly *Bactrocera cucurbitae*.

(10) Yield outcome experiment

This experiment aimed to compare the effectiveness of various baits, in comparison with cover sprays, for the actual protection of crops and increase in yield, as a confirmation of the indirect inferences available from the SKP experiments. Eight treatments were compared, in traps made of 1L mineral water bottles (protein hydrolysate treatment) or half coconut shells (all others) and replenished weekly:-

1. Banana trap containing 20g of banana and 0.5g furadan, at two traps per plot (625/Ha)
2. Cover spray of malathion 0.2% at a volume rate of 1.6L per plot (500/Ha)
3. Protein hydrolysate bait applied as traps containing 100ml of 10%PH and as 40ml spots of 10%PH and 0.2% malathion, at two traps and two spots per plot (each 625/Ha)
4. Untreated control

Each treatment was implemented both with and without a further treatment of ocimum/jaggery traps each containing 20g crushed ocimum leaves and 10g jaggery, mixed with 0.2% malathion, at two traps per plot (625/Ha). Each treatment was replicated in both 2002 and 2003 in three complete randomised blocks, in 32sqm plots in fields of bitter gourd planted at 2x2m spacing. Assessment was both as single killing points to compare their ability to attract and kill flies, and as plot yield.

Results

(1) Dilution experiment

The catch data are summarised in Table 1, and were found not to differ significantly between treatments. The presence of flies in the ocimum trap, whose attractant ingredient, methyl-eugenol, is taken to attract only “orchard flies” indicated some catches of orchard flies as well as those attacking cucurbits. The total fly catch by protein hydrolysate was regressed against its concentration as a percentage; this found a significant, positive association (catch=0.4833+0.7(concentration); r2=0.366; *F*=5.0602[1,10]* {*P*=0.0482}). Quadratic regression found no evidence for a peak catch at a particular concentration - the quadratic model had a trough below the data range, rather than a peak above it, and the additional goodness of fit from the quadratic slope was not significant (*t*=0.3545[1]ns {*P*=0.3784}).

Table 1. Catches of fruit flies by different protein hydrolysate (PH) concentrations, and other baits, given as means and standard deviations (<SD>; N=4) of total weekly catches and sex ratios (as percentages of females among totals). ANOVA comparisons found no significant differences either among total catches (*F*=2.5021[4,12]ns {*P*=0.0980; MSD=5.4890}) or sex ratios (*F*=0.01032[4,12]ns {*P*=0.1032; MSD=0.4057}).

	PH@5%	PH@7.5%	PH@10%	Banana	Ocimum
Totals	8.5	9.8	12	13.3	9.8
	<2.1>	<2.6>	<2.2>	<2.2>	<3.0>
Sex ratio	59	63	66	62	61
	<10>	<13>	<23>	<12>	<20>

(2) Four-treatment experiment

Not all flies caught were identified as to species, but the great majority were melonflies (unsurprisingly in the gourd field environment) and it was apparent that methyl-eugenol was effective for trapping *Bactrocera dorsalis*, and cue-lure effective for trapping *Bactrocera cucurbitae* (*Bactrocera caudata* was also trapped). Table 2 gives the means and standard deviations of catches. Starch/jaggery was significantly superior to banana, which was significantly to the two protein preparations.

Table 2. Means and standard deviations (<SD>; N=3) of catches of fruit flies (in most part *B. cucurbitae*) in various traps, from April to July inclusive, 2002, in gourd fields outside Thiruvananthapuram, as average monthly totals and sex ratios as percentages of females among totals. Values followed by different letters differed at *P*<0.05 (Tukey’s HSD: for statistical analysis, percentages were transformed to arcsines).

	ME	CL	Ocimum	Starch-jaggery	Banana	Protein hydrolysate	Protein autolysate
Totals	26	588	49	93a	74b	0c	0c
	<2>	<78>	<1>	<4>	<5>	<0>	<0>
Sex ratio	11a	4b	33c	36c	37c	-	-
	<2>	<1>	<2>	<4>	<2>	-	-

(3) Eight-treatment experiment

The great majority of catches were of *B. dorsalis*. Catch numbers by each trap are summarised in Table 3. Food baits caught very few flies.

Table 3. Means and standard deviations (<SD>; N=3) of catches by eight different fruit fly traps in Southern Kerala in 2003. The catches for coloured balls of three different colours have been pooled, as all caught nothing. Mean catches obtained were compared by ANOVA: the difference between all six treatments is not given as self-evident; for the four non-commercial, home-made treatments (excluding ME and CL) *F*=87.3843[3,6]* {*P*<0.0001}); for the food-only, non-lure baits (banana, starch-jaggery and colour) *F*=1.0000[2,4]ns {*P*=0.4444}**.

Methyl-eugenol	Cue-lure	Banana	Ocimum-jaggery	Starch-jaggery	Coloured balls
605.3	5.0	0.0	27.3	0.3	0.0
<136.1>	<2.6>	<0.0>	<4.9>	<0.6>	<0.0>

(4) Six-treatment experiment

Table 4 gives the mean catches and sex ratios for all six treatments, and Table 5 the catches by banana and jaggery, mixed and in isolation, re-cast as a two-way analysis. These results indicated that natural baits were more effective in isolation than in mixtures: the two baits of banana and jaggery significantly diminished each others' performance. Boiling jaggery significantly enhanced its performance, however, and boiled jaggery, mixed with banana, significantly performed better than almost all other treatments.

Table 4. Means and standard deviations (<SD>; N=4) of total catches after seven days in traps containing a standard dose of insecticide and baits as indicated. Means in the same row not followed by the same letter were significantly different (*P*<0.05; for totals Tukey's HSD=3.484, for sex ratio HSD=24.6).

	Banana + boiled jaggery	Banana	Banana + jaggery	Jaggery	Protein Hydrolysate	Nothing
Total catch	8.00a	4.75ab	4.25b	3.50b	2.50bc	0.00c
	<1.63>	<1.71>	<2.63>	<0.58>	<0.58>	<0.00>
% Females	26bc	42b	33bc	15c	100a	-
	<6>	<7>	<12>	<17>	<0>	-

Table 5. The pertinent columns of Table 4 recast to indicate the role and interaction of banana and jaggery baits in isolation and combination. Assessed by a two-way interactive ANOVA for complete randomised blocks, there was no significant effect attributable to jaggery (*F*=2.9189[1,9]ns {*P*=0.1217}) but significant effects were attributed to banana (*F*=9.8108[1,9]* {*P*=0.0121}) and to interaction between them (*F*=5.1892[1,9]* {*P*=0.0487}).

		Banana		Row
		no	yes	means
Jaggery	no	0.00	3.50	1.75
	yes	4.75	4.25	4.5
Column means		2.38	3.88	

(5) Jaggery boiling experiment

Table 6 summarises catches by boiled and unboiled jaggery. It was concluded that the boiling of jaggery significantly enhanced its catching power when mixed with banana.

Table 6. Means and standard deviations (<SD>, N=8). Means were highly significantly different by 42.8/18.8=2.3:1; or (42.8-18.8)/18.8=128% (*t*=13.7747[7]* {*P*<0.0001}).**

Unboiled jaggery	Boiled Jaggery
18.8	42.8
<2.0>	<3.6>

(6) Fifteen-treatment experiment

Not all flies were identified as to species, but the great majority were melonflies. Catches are summarised in Table 7. Table 8 shows the outcome of a further factorial analysis of the effects of the mixing of jaggery and protein hydrolysate. Ocimum, jaggery, protein hydrolysate and dry fish caught very few flies; all banana treatments caught significantly more flies, and starch with yeast was intermediate. The banana *Rasakadali* caught more flies than any other treatment. The addition of jaggery to protein hydrolysate did not enhance its catch. The addition of citric acid as a preservative had no detectable effect, but boiling of jaggery did apparently significantly enhance the effectiveness of *Palayamkodam*.

Table 7. Means and standard deviations (<SD>; N=3) of catches by traps with different baits. Means not followed by the same letter were significantly different (*P*<0.05; Tukey's HSD=7.585).

Ocimum, carbofuran, water	0.0a	<0.0>
Ocimum, citric acid, carbofuran, water	0.0a	<0.0>
Ocimum, jaggery, carbofuran, water	0.0a	<0.0>
Protein hydrolysate, malathion	0.7a	<1.2>
Fish (dry, no water), carbofuran	0.7a	<1.2>
Protein hydrolysate, jaggery, malathion	0.7a	<1.2>
Starch, jaggery, yeast, carbofuran, water	5.0ab	<2.6>
Poovan, jaggery, carbofuran, water	10.7bc	<1.2>
Red, jaggery, carbofuran, water	11.3bc	<2.5>
Robusta, jaggery, carbofuran, water	12.0bc	<2.6>
Palayamkodam (dry, no water), carbofuran	14.3cd	<4.2>
Palayamkodam, citric acid, carbofuran, water	15.0cd	<2.6>
Palayamkodam, jaggery, carbofuran, water	20.0d	<1.0>
Palayamkodam, boiled jaggery, carbofuran, water	41.7e	<2.5>
Rasakadali, jaggery, carbofuran, water	45.3e	<5.8>

Table 8. The relevant data from Table 7 recast as a 2x2 factorial of jaggery, protein hydrolysate and interaction between them. Two-way factorial ANOVA (all d.f. [2,52]) found significant effects attributable to protein hydrolysate (*F*=26.0000ns {*P*<0.0001}), but not to jaggery nor interaction between them (for both *F*=0ns {*P*=1}).

		Protein hydrolysate		Row
		no	yes	means
Jaggery	no	0.00	0.70	0.35
	yes	0.00	0.70	0.35
Column means		0.00	0.70	

(7) Twenty-treatment experiment

Catches were of *Bactrocera cucurbitae*, except in ocimum traps, where the catch was *B. dorsalis*. Table 9 shows the catches by baits in isolation, and Table 10 those by combinations of banana and other baits. The analyses found banana baits significant but no effects due to jaggery. Overall, fresh banana baits performed better than the "preserved" baits. Table 11 shows the sex-ratios obtained in the eighteen main treatments. Table 12 shows the data from Tables 9 and 10 recast as a two-way assessment with a suppositional "0" catch in a hypothetical trap with no bait, to analyse interactions between banana and (white) jaggery baits. Jaggery alone obtained a significant catch of 4.8, the five other food baits a mean of 4.7, but the combinations a mean of 4.9, with a significant interaction term, indicating the mixture of jaggery and others was "less than the sum of its parts". Boiling of jaggery had little effect on its performance. Table 13 shows the comparison of white and black jaggery: black jaggery was not significantly superior to white.

Table 9. Means and standard deviations (<SD>; N=6) of total catches by banana and jaggery baits in isolation. Means not followed by the same letter differed significantly (*P*<0.05; Tukey's HSD=0.82).

Bananas				Jaggery		Others	
Red	*Robusta*	*Palayamkodam*	*Rasakadali*	Black	White	Tulsi	Starch
6.8a	6.8a	4.7ab	3.5ab	5.5ab	4.8ab	3.2ab	1.8b
<1.9>	<1.5>	<2.4>	<1.6>	<0.8>	<0.8>	<3.4>	<1.5>

Table 10. Means and standard deviations (<SD>; N=6) of total catches of banana and starch baits with and without added jaggery. Analysis by two-way ANOVA found significant differences due to non-jaggery baits (*F*=10.9580[5,85]* {*P*<0.0001}) but none to jaggery baits (*F*=0.2451[2,85]ns {*P*=0.7832}) nor to interaction between them (*F*=0.6957[10,85]ns {*P*=0.7259}).**

Combination	*Palayamkodam*	*Robusta*	*Rasakadali*	*Red*	Starch	Tulsi	Row means
Nothing	4.7 <2.4>	6.8 <1.5>	3.5 <1.6>	6.8 <1.9>	1.8 <1.5>	3.2 <3.4>	4.5
Jaggery	4.3 <2.3>	7.0 <1.9>	4.2 <0.8>	6.7 <2.1>	2.5 <1.2>	3.3 <2.7>	4.7
Boiled jaggery	4 <1.7>	5.8 <2.3>	4.8 <1.8>	6.0 <1.3>	3.3 <2.3>	4.8 <2.7>	4.8
Column means	4.3	6.6	4.2	6.5	2.6	3.8	

Table 11. Means and standard deviations (<SD>; N=6) of sex-ratios, as percentages of females, of total catches of banana and starch baits with and without added jaggery. (In three traps - one of starch and two of tulsi with jaggery - there were no flies so the ratio could not be calculated, so for these two N was concomitantly reduced). Analysis by two-way ANOVA found significant differences due to non-jaggery baits (*F*=5.2979[5,83]* {*P*=0.0003}) but none due to jaggery baits (*F*=2.0717[2,83]ns {*P*=0.1325}) nor interaction between them (*F*=1.7207[10,83]ns {*P*=0.0897}). (Missing values in ANOVA were replaced by cell means, and Error DF concomitantly reduced).**

Combination	*Palayamkodam*	*Robusta*	*Rasakadali*	*Red*	Starch	Tulsi	Row means
Nothing	36 <20>	36 <6>	28 <17>	44 <8>	0 <0>	0 <0>	24
Jaggery	42 <9>	29 <20>	46 <22>	49 <20>	6 <14>	31 <14>	34
Boiled jaggery	33 <27>	33 <18>	30 <21>	48 <7>	20 <23>	16 <14>	30
Column means	37	33	35	47	8	16	

Table 12. Data from Tables 9 and 10 recast, and with the addition of an assumed catch of zero in traps containing no attractant, to show interaction between jaggery and other food baits. There were significant differences attributable to jaggery (*F*=6.5569[1,52]* {*P*=0.0134}), other foods (*F*=19.5186[5,52]* {*P*<0.0001}) and interaction between them (*F*=4.3345[5,52]** {*P*=0.0023}).**

	Nothing	*Palayamkodam*	*Robusta*	*Rasakadali*	*Red*	Starch	Row means
Nothing	0.0	4.7	6.8	3.5	6.8	1.8	3.9
Jaggery	4.8	4.3	7.0	4.2	6.7	2.5	4.9
Column means	2.4	4.5	6.9	3.8	6.8	2.2	

Table 13. Means and standard deviations (<SD>; N=6) of total catches and sex-ratios (as percentages females among the total) in traps of white and black jaggery. Differences were not significant (for totals *t*=1.5811[5]ns {*P*=0.1747}; for sex ratios *t*=0.1385[5]ns {*P*=0.8953}).

Jaggery	Black	White
Total	5.5 <0.8>	4.8 <0.8>
Sex ratio	35 <12>	34 <14>

(8) Trap vessel experiment

Table 14 summarises the catches of flies by traps of the four types. *Rasakadali* was superior to *Palayamkodam* by 51/30=1.7:1, or (51-30)/30=70%; bottles were superior to coconuts by 55/26=2.1:1, or (55-26)/26=111%. There was significant though unexplained interaction in that the advantages of bottles over coconuts were relatively greater for *Palayamkodam* than for *Rasakadali*.

Table 14. Means and standard deviations (as <SD>; N=8) of catches of fruit flies, inferred to be mostly melonflies, in traps of two vessel types - coconut shells and plastic water bottles - and containing two banana varieties. There were highly significant differences due to bananas (*F*=85.4418[1,9]* {*P*<0.0001}), vessels *F*=130.8398[1,9]*** {*P*<0.0001}), and interaction between them *F*=32.8191[1,9]*** {*P*=0.0003}).**

	Coconut	Bottle	Row means
Palayamkodam	13 <2>	47 <4>	30
Rasakadali	40 <6>	63 <12>	51
Column means	26	55	

(9) Kerala bananas in Uttar Pradesh

Results are given in Table 15. There were no detectable differences between varieties.

Table 15. Catches of traps as total adult insects and half-lives of the decline in catches in days, as means and standard deviations (<SD>) of traps. For total catches N=6, for half lives (because in two replicates all catches but one were zero) N=4. Banana varieties differed in neither total catch (*F*=0.9526[2,10]ns {*P*=0.4181}) nor in half-life (*F*=0.2376[2,6]ns {*P*=0.7956}).

	Robusta	*Rasakadali*	*Palayamkodam*
Catch (adults)	4.2 <3.3>	8.5 <12.0>	6.3 <5.9>
Half-life (days)	11.3 <6.0>	9 <6.4>	10 <14.9>

(10) Yield outcome experiment

Data were as yield for all eight treatments and, for those four which were trap treatments, total catches and sex ratios. Initially all were analysed for differences between the two years, but none of these were significant (for yield *F*=1.3024[1,32]ns {*P*=0.2623}; for total trap catches *F*=0.0016[1,16]ns {*P*=0.9688}; for trap catch sex-ratios *F*=0.3868[1,16]ns {*P*=0.5428}) so subsequent analysis was by two-way ANOVA of different treatments, with years treated as additional blocks (and thus in all cases N=6). Table 16 shows the results in harvested yield of gourd, Table 17 those in total trap catches, and Table 18 those in the sex-ratio of catches. Ocimum/jaggery traps had little effect. The lack of response of the sex-ratio to ocimum indicates both the predominance of melonflies over orchard flies in the area, and the lack of attraction of ocimum to melonfly males (male *B. cucurbitae*, unlike the orchard fruit flies *zonata* and *dorsalis*, are not attracted by methyl-eugenol, which is the principal attractant in ocimum). There was evidence that banana traps obtained superior control to protein traps and cover sprays, but this was only weakly confirmed by statistical analysis.

Table 16. Means and standard deviations (as <SD>; N=6) of harvested yield in KG/Ha, with percentages increases these represent over the untreated No-Control plot (%). Two-way ANOVA found significant effects due to baits (*F*=6.4908[3,35] {*P*=0.0013}) but not due to ocimum/jaggery (*F*=2.3473[1,35]ns {*P*=0.1345}) or interaction (*F*=0.3944[3,35]ns {*P*=0.7578}).**

Ocimum /jaggery	No control	Cover spray	Protein BAT	Banana traps	Row means
Without	4330 <783> (0%)	4856 <932> (12%)	5691 <1483> (31%)	7014 <1667> (62%)	5473 (0%)
With	4806 <1011> (11%)	5698 <1791> (32%)	6978 <1945> (61%)	7034 <1625> (62%)	6129 (12%)
Column means	4568 (0%)	5277 (16%)	6335 (39%)	7024 (54%)	

Table 17. Means and standard deviations (as <SD>; N=6) of average weekly catches by traps. Two-way ANOVA (all d.f.=[1,15]) found significant effects due to baits (*F*=16.1827 {*P*=0.0011}) and ocimum/jaggery traps (*F*=6.4186* {*P*=0.0229}) but not to interaction between them (*F*=0.8231ns {*P*=0.3786}).**

Ocimum /jaggery	PH	Banana	Row means
Without	5.8 <2.6>	8.9 <3.0>	7.3
With	7.4 <2.2>	12.2 <1.7>	9.8
Column means	6.6	10.5	

Table 18. Means and standard deviations (as <SD>; N=6) of trap catch sex ratios as females as % of total. Two-way ANOVA (all d.f.=[1,15]) found significant effects due to baits (*F*=13.7347 {*P*=0.0021}) but not to ocimum/jaggery (*F*=1.4611ns {*P*=0.2455}) or interaction (*F*=0.5771ns {*P*=0.4592}).**

Ocimum /jaggery	PH	Banana	Row means
Without	73 <13>	54 <7>	64
With	65 <14>	52 <9>	59
Column means	69	53	

Discussion

There was little evidence for the superiority of any banana varieties to any others. The combination of baits together in mixtures did not appear to enhance their attraction over and above baits used alone.

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~03/33[MBJ]: Attraction to Fruit Flies of Banana and Jaggery in Isolation and Combination in Southern Kerala

Stonehouse, JM, Jiji, T, Sentilkumar, Verghese, A, Mumford, JD

Abstract

This experiment used catches of flies in baited traps to find (1) the concentration of banana and jaggery bait in traps which obtained the maximum catch of fruit flies and then, using these optimum concentrations, (2) the mixture ratio of the two baits which optimised their performance as a mixture. The initial assessment (1) of baits at five strengths between 0 and 40% (N=3) found the maximum catch by jaggery at 10% and that by banana at 20%. Using suspensions of the two baits at these strengths, the subsequent assessment (2) indicated a "hump" in catches, although not statistically confirmed, at approximately 75% jaggery and 25% banana.

Introduction, Materials and Methods

In order to optimise the effectiveness of food-baited traps for melon fruit flies for both research and control, it is desirable to establish the optimum concentration of bait in traps. This experiment aimed to assess these optima for two home-made baits in isolation and combination in the field in Southern Kerala. Two fruit fly bait ingredients - jaggery and banana - were assessed in the field in traps, as liquid solutions/suspensions of the solid food bait macerated in water, in isolation and combination. The study comprised two experiments.

Experiment 1: Baits in Isolation

Traps contained the two candidate baits in five different concentrations in water, as percentages (weight:volume) of 0, 5, 10, 20 and 40. Traps containing these suspensions were hung in three complete randomised blocks in fields of gourds outside Thiruvananthapuram, and emptied and recharged three times in the first three weeks of July 2004. Records were taken on each occasion of melon fly catches in all traps. From this were derived equivalent strengths of the two, to allow a rough estimate of which quantity of jaggery would be equivalent to which quantity of banana.

Experiment 2: Baits in Combination

Jaggery and banana solution/suspensions were prepared at the strengths found by Experiment 1 to obtain rough parity of catches for the two baits. These two preparations were mixed together in traps on a scale of different percentages of 100, 75, 50, 25 and 0% of each (and conversely of the other). These five treatments were hung in the field at spacing of at least 2m in three complete randomised blocks and inspected weekly at the ends of the third and fourth weeks of July and first week of August.

Results and Discussion

Experiment 1: Baits in Isolation

The means and standard deviations of melonfly catches by the two baits at different concentrations are presented in Table 1. Initial ANOVA comparisons established that there were no significant differences between replicate blocks (for jaggery F=0.1985[2,8]ns {P=0.8239}; for banana F=1.0000[2,8]ns {P=0.4096}), and consequently block data were pooled to maximise degrees of freedom for regression analysis. This modelled catch data responses to concentration by fitting linear equations and a series of stepwise polynomials. For banana, the quadratic nature of the curve was significant (for addition of the quadratic term to a linear model t=5.9093[12]*** {P<0.0001}); the further addition of a cubic did not improve the fit (t=0.3488[11]ns {P=0.7338}); a quartic obtained a close fit (t=8.8776[10]*** {P<0.0001}). For jaggery, the significance of the addition of the quadratic to the linear term (t=4.6930[12]*** {P=0.0005}) was enhanced by the addition of a cubic term (t=5.98708*** {P<0.0001}) but not a quartic (t=0.3025ns {P=0.7685}). In both cases, therefore, the "peak" in response, with lesser responses at both weaker and stronger concentrations, was pronounced and significant. Accordingly, concentrations were selected, in order to optimise trap performance, of 10% in the case of jaggery and 20% in the case of banana.

Table 1. Means and standard deviation (<SD>; N=3) of catches of melon flies by different strengths (wt:vol) of banana and jaggery in traps in gourd fields in Southern Kerala. Each datum was the sum of findings on separate visits on July 7, 14 and 21, 2004.

%	0	5	10	20	40
Jaggery	0.0 <0.0>	10.3 <3.2>	15.0 <2.6>	11.0 <1.0>	5.0 <0.0>
Banana	0.0 <0.0>	0.0 <0.0>	13 <1.7>	14.0 <1.0>	6.0 <1.7>

Experiment 2: Baits in Combination

Traps contained 50ml of liquid comprising mixed ratios of 10% jaggery and 20% banana suspensions. Table 2 shows the mean number of melonflies caught per trap over three weeks. There were significant differences due to treatments (F=8.6261[4,8]** {P=0.0053} but not between replicate blocks (F=0.7752[2,8]ns {P=0.4924}) and accordingly blocks were pooled to save degrees of freedom in the subsequent regression analysis. This found a significant linear association (t=2.4144[13]* {P=0.0312} but there was less clarity in those at quadratic (t=1.8872[12]ns {P=0.0836}), cubic (t=1.9873[11]ns {P=0.0724} and quartic (t=2.8409[10]ns {P=0.0175}) levels. Table 3 shows the mean sex ratio of catches, as percentages of females in the total; differences between treatments were not significant (ANOVA F=0.3813[4,14]ns {P=0.8163}).

Table 2. Means and standard deviations (<SD>; N=3) of catches of melonflies per trap over three weeks, by baited traps with jaggery and banana mixed in different proportions in July and August 2004 in Southern Kerala.

% Jaggery	100	75	50	25	0
% Banana	0	25	50	75	100
Mean	41	66	39	38	25
<SD>	<14>	<9>	<4>	<7>	<8>

Table 3. Means and standard deviations (<SD>; N=3) of sex ratios as percentages of females among the total melonfly catches by baited traps with jaggery and banana mixed in different proportions.

% Jaggery	100	75	50	25	0
% Banana	0	25	50	75	100
Mean	32	41	32	36	30
<SD>	<11>	<6>	<11>	<10>	<15>

Although not statistically confirmed, the indication was of a “hump” in the response at approximately 75% jaggery and 25% (and, less clearly, of a maximum percentage of females among the catch at this same point).

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~02/10A[ROV];02/09[RBC];03/20[RJB]:
Melon Fruit Fly Attraction and Control by Baits in Central Kerala

Thomas, J, Vidya, CV, Stonehouse, JM, Verghese, A, Mumford, JD

Abstract

(1) Melonflies were caught in a series of traps in bitter gourd near Thrissur in May 2002 (N=3). Among food baits, protein hydrolysate caught 30 flies, brewers’ yeast protein autolysate 27 and sliced banana 26, but these differences were not significant (P=0.5985). Catches by coloured balls were substantially smaller (all less than five).

(2) Bitter gourd plots near Thrissur were protected from fruit flies by protein bait sprays, protein bait traps and banana traps (N=2), and the ensuing infestation assessed by the mean percentage infestation over the season and the totals and sex-ratios of catches in the two trap treatments. Infestation protected by bait traps was 8.1%, by protein sprays 7.6 and by banana traps 8.0; these were not significantly different (*P*=0.9811). Total catches in protein traps were 61 flies and in banana traps 103 flies; these were not significantly different (*P*=0.2317).
(3) A variety of home-made and imported baits and lures were assessed in fields of bitter gourd outside Thrissur, deployed as 10g or 10ml doses in traps. Assessed by means of both (a) numbers of insects caught and (b) percentage decrease in levels of fly infestation relative to an untreated control, the best performer was a 50:50 mix of banana and jaggery (80 flies caught; 69% reduction in infestation) followed by banana alone (respectively 54, 44), jaggery alone (39,25) and traps containing *Ocimum* and protein hydrolysate (both less than 16 and 0, respectively). Treatments differed significantly among trap catches (*P*<0.0001) though protection levels not did not (*P*=0.1708). There was a presumption of a positive interaction in the mixing of banana with jaggery as bait.

Introduction, Materials and Methods

Melonflies infesting melons, cucurbits and similar fruit in India may be controlled by the application of food baits with insecticide in the bait application technique. This experiment aimed to assess the control effectiveness of home-made and imported baits for this purpose in bitter gourd protection in Central Kerala. All experiments were conducted laid out in complete randomised blocks in research and farm fields of bitter gourd outside Thrissur, Kerala. Traps were all of the same design, of half a coconut shell, and all had the same dose (approximately 1g) of carbofuran insecticide.

(1) Trap attraction comparison
Flies were caught in traps containing two parapheromone lures - methyl-eugenol and cue-lure - three food baits - banana slices, protein hydrolysate, and protein autolysate made from brewers' yeast lysed with papain - and three coloured 10cm plastic balls - checked weekly for two weeks from May 14th, 2002 (N=3).

(2) Trap and spray comparison
The attraction of flies to baits may be influenced by both the bait itself and the means of its delivery. In this experiment protein hydrolysate sprays, protein hydrolysate traps and banana fruit traps were compared for fruit fly control (N=2), beginning in the first week of July 2002, and evaluated by fly numbers caught in traps and by percentage fruit fly infestation.

(3) Jaggery and banana comparison
Five food bait controls were assessed in traps (N=4), spaced so that each was in the centre of an area of 0.02Ha, and infested fruit were assessed over this area. The five were:

- Untreated	- no trap installed
- Banana	- 10g of solid banana
- Jaggery	- 10g jaggery macerated in approximately 10ml of water
- J&B	- 5g of banana and 5g of jaggery macerated in 10ml of water
- PH	- 10ml of 100% protein hydrolysate liquid
- Ocimum	- approximately 40g of leaves of *Ocimum sanctum*

Results

(1) Trap attraction comparison
Fly catches are summarised in Table 1. Only *Bactrocera cucurbitae* were counted; most attractive to these was cue-lure; methyl-eugenol caught no melonflies at all, but between approximately 50 and 60 *B. dorsalis* per day. One or two *B. dorsalis* weekly were found in cue-lure traps. There were no significant differences among the baits.

Table 1. Means and standard deviations (<SD>; N=3) of catches by various traps in Central Kerala bitter gourd fields over two weeks. There were no significant differences among the three baits (2-way ANOVA *F*=0.5853[2,4]ns {*P*=0.5985}).

Cue-lure	Methyl eugenol	Protein hydrolysate	Protein autolysate	Banana fruit
151	0	30	27	26
<14>	<0>	<4>	<5>	<6>

(2) Trap and spray comparison

Yield data from the protected plots are given in Table 2. Catch data from the traps in the two treatments which used them are given in Table 3. No differences were significant.

Table 2. Mean weekly losses to fruit flies in experimental plots, starting July 7th, 2002 (N=2), as the volume of fruit collected and the percentage infestation under each protection regime. Mean loss overall was the mean percentage loss over all weeks, weighted for the volume of production in each week, given as means and standard deviations (<SD>). There were no significant differences among treatments(*F*=0.0192[2,2]ns {*P*=0.9811}).

		Infestation with protection		
Week	Volume collected	Protein trap	Protein spray	Banana trap
1	30	0	0	0
2	30	0	0	0
3	65	1	0	1
4	78	0	1	0
5	80	2	3	2
6	80	1	2	1
7	80	3	4	3
8	80	2	0	1
9	80	2	3	4
10	80	9	7	6
11	65	19	18	22
12	70	20	17	22
13	67	30	26	26
14	48	26	28	27
Loss	Mean	8.02	7.55	7.97
	<SD>	<2.79>	<1.90>	<1.53>

Table 3. Means and standard deviations (<SD>; N=2) of catches of flies in traps in experimental plots, as total numbers and the sex ratio as females as a percent of the total. There were no significant differences between treatments in either totals (*t*=2.6250[1]ns {*P*=0.2317}) or sex ratios (*t*=4.2782[1]ns {*P*=0.1365}).

Trap	Protein		Banana	
Totals	61	<4>	103	<27>
Sex ratio	92	<2>	56	<10>

(3) Jaggery and banana comparison

Table 4 summarises the percentage infestation of gourds under the various protection regimes. Table 5 summarises the catches by the traps in the various plots and indicates their correspondence with protection levels. Planned comparisons of the performance of banana with that of jaggery were not statistically significant (for catch *t*=1.4482[3]ns {*P*=0.2434}; for infestation *t*=0.8783[3]ns {*P*=0.4444}); planned comparisons of the performance of the mixture of jaggery and banana with the means of those of the two as individuals were significant for trap catches (*t*=4.8823[3]* {*P*=0.0164}) though not for protection (*t*=2.0913[3]ns {*P*=0.1276}). The data appeared to confirm a positive interaction effect when banana and jaggery were combined.

Table 4. Percentage infestation of bitter gourds in plots protected by different traps as mean as standard deviation (<SD>; N=4). There were no significant differences between treatments (*F*=1.8125[5,15]ns {*P*=0.1708}).

Untreated	PH	Ocimum	Jaggery	Banana	J&B
20	23.75	20.00	15.00	11.25	6.25
<12.25>	<9.46>	<12.25>	<8.16>	<2.50>	<4.79>

Table 5. Catches of fruit flies by different traps in a bitter gourd field as mean as standard deviation (<SD>; N=4). There were highly significant differences between treatments (*F*=36.8622[4,12]* {*P*<0.0001}). The bottom row in bold gives for each treatment the mean percentage reduction in infestation inferred to be obtained, calculated from the percent infestation under each protection (%P) and unprotected (%U) from Table 4 ({percent reduction}=(%U-%P)/%U.100). The rank-order of trap catch and protection level was the same.**

PH	Ocimum	Jaggery	Banana	J&B
10	15.50	39.25	54.00	80.25
<5.89>	<1.91>	<11.32>	<12.25>	<11.03>
-18.75	0.00	25.00	43.75	68.75

Discussion

Overall, banana appeared superior to jaggery, and a mixture of both superior to either. Protein hydrolysate did not, at these concentrations, provide better control than locally-sourced baits.

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~03/07[V5T];03/04[V8T];03/09[VPC];04/06[VTT]: Attraction and Control of Melon Fruit Flies by Food Baits in Eastern Uttar Pradesh

Satpathy, S, Rai, S, Swamy, S, Verghese, A, Stonehouse, JM, Mumford, JD

Abstract

(1) The attraction of food baits to melonflies was assessed in laboratory cages outside Varanasi (N=3). 100g of banana (catching a mean of 20.0 flies) was significantly superior (*P*<0.0001) to a mixture of 50g banana with 50g jaggery (a mean of 4.3 flies), 100ml of protein hydrolysate (4.0) and 100g of jaggery (1.7).

(2/3) Eight food baits and mixtures to attract and kill melonflies were assessed in two unreplicated experiments in the laboratory outside Varanasi. Banana was significantly superior to pumpkin (mean catches 84 and 42 respectively, *P*=0.0261) though not to molasses (mean catches 34.5 and 30.5 respectively, *P*=0.4097).

(4) Traps containing protein hydrolysate in fields (N=1) caught 30 flies at 100% concentration and 19 at 30%. The lower value of the ratio between catches (1.58) than that between concentrations (3.33) suggested a diminishing return to increases in concentration.

(5) Three bait treatments - protein hydrolysate, banana and jaggery - were compared in the protection of bitter gourd from fruit flies in plots near Varanasi (N=3). By three measures the baits performed in similar manners, with jaggery significantly superior to the other two, which were broadly equivalent - jaggery caught 622 flies in traps, protein 313 and banana 227 (*P*<0.0001), jaggery obtained reductions in infestation of 43%, banana 33% and protein 31% (*P*=0.0001), and jaggery obtained increases in yield of 56%, protein 49% and banana 48% (*P*=0.1616). As the assessment value proceeded from the assessment of insect abundance to the assessment of economic returns, the *P*-values were observed to decline.

Introduction, Materials and Methods

Food baits for fruit fly control may be assessed in the laboratory by comparison of their power to attract and kill adult flies under cage conditions, and these compared with results obtained in the field.

Three laboratory experiments aimed to compare the capacity of different food baits to attract melon fruit flies under laboratory conditions in Eastern Uttar Pradesh. They assessed the attraction of laboratory-reared melon fruit flies to different food baits, mixed with insecticide, in laboratory choice chambers at IIVR, Varanasi. Flies, both dead and alive, were counted and sexed around each bait attractant point. A fourth experiment continued the assessment to field conditions.

(1) Five baits, as specified in Table 1, were compared in the laboratory, with three replications.
(2) Three baits - banana, molasses and protein hydrolysates (PH), each of 100g with 5g of furadan insecticide - were compared in an aspirated three-way choice chamber (N=1).
(3) Four baits - banana, molasses, PH and pumpkin - in four combinations as listed in Table 2, each of 100g with 5g of furadan, were compared in the laboratory (N=1).
(4) In an assessment of the catch response to bait strength, bottle traps containing protein hydrolysate at 30% and 100% concentration were deployed in fields outside Varanasi in the second and third weeks of December 2003 (N=1).
(5) Three baits (molasses, banana, protein hydrolysate) were assessed in the field by each of four measures - the numbers and sexes of adults trapped by the baits, the percentage infestation of the harvestable fruits and the total yield per unit area. The experiment was set up in a field of bitter gourd at Varanasi, with the three treatments, together with an untreated control, in three complete randomised blocks. Trap catches were recorded below the baitspots in the three treated plots, and recorded as totals by each sex. Infestation was recorded in each plot on nine occasions weekly over nine successive weeks. Harvested yield per plot was recorded at the end of the season.

Results and Discussion

(1) Five-treatment laboratory experiment

Table 1 gives the catches by the five treatments. It can be seen that, compared by total fly catch, the five differed significantly, but that the four excepting 100g of banana, by far the most effective killer, did not. The superiority of banana to other baits is in agreement with other experimental results, as is the poor performance of the banana mixtures in comparison with unadulterated banana.

Table 1. Means and standard deviations (<SD>) of total numbers and sex-ratios (as percentage of females among the total) of melon fruit flies attracted and killed by five different baits in laboratory cages (N=3 for all totals and all sex ratios except molasses where N=2 and banana with molasses where N=1). (Each cage also contained, in addition to the food materials listed, 1ml of cue-lure parapheromone and 1g of sevin insecticide). By total catch, all five treatments differed significantly (2-way ANOVA F=29.4717[4,8]* {P<0.0001}) but the four treatments without 100g banana did not (F=2.4299[3,6]ns {P=0.1634}). By sex-ratio, all five treatments differed significantly (1-way ANOVA F=3.5404[4,10]* {P=0.0477}) but the four treatments without 100ml PH did not (F=1.2615[3,8]ns {P=0.3509}).**

	Banana 100g	Banana 50g + Molasses 50g	Molasses 100g	Banana 50g + PH 50ml	PH 100ml
Total	20 <4.6>	4.3 <0.6>	1.7 <1.5>	1.3 <2.3>	4.0 <2.0>
Sex-ratio	49 <5>	32 <16>	42 <12>	50 <->	78 <25>

(2) Three-treatment laboratory experiment

Not all released flies dead by the time the experiment ended, and data are given as total counts, and sex ratios as percentages of females among the totals, of flies both dead and alive around each bait source. Those attracted to the three baits are summarised in Table 2.

Table 2. Flies attracted by three baits in an unreplicated run in a three-way aspirated choice-chamber, as totals and sex ratios (as percentage of females among the total).

	Banana	Molasses	PH
Totals	44	43	16
Sex ratio	39	35	25

(3) Eight-treatment laboratory experiment

Not all released flies dead by the time the experiment ended, and data are given as total counts, and sex ratios as percentages of females among the totals, of flies both dead and alive around each bait source. Those attracted to the eight baits are summarised in Table 3, and the total values re-cast as a two-way table in Table 4. Both experiments (2) and (3) seemed to indicate a superiority of banana and molasses to protein hydrolysate, but this was not confirmed when their data for the three were combined as two replicates (for totals attracted ANOVA F=2.9813[2,2]ns {P=0.2512}; for sex-ratios F=2.7975[2,2]ns {P=0.2633}). The second experiment indicated that the fresh fruit baits of pumpkin and banana, with their moist flesh, were more attractive than the dry, preserved baits of molasses and protein hydrolysate, but this was not confirmed. In planned comparisons of fresh baits banana was significantly superior to pumpkin (data from Table 4 related t=6.0622[2]* {P=0.0261}) though not to molasses (data from Tables 2 and 3, banana mean catch = (44+25)/2=34.5; molasses mean catch = (43+18)/2=30.5; related t=1.3333[1]ns {P=0.4097}). The influence of interactions among different baits when mixed could not be quantified.

Table 3. Totals and sex-ratios of flies attracted by eight bait treatments.

	Banana	PH	Pumpkin	Molasses	Banana + PH	Banana + molasses	Pumpkin + PH	Pumpkin + molasses
Total	25	14	15	18	34	25	16	11
Sex ratio	52	43	47	39	47	36	31	36

Table 4. The total catch data from Table 3 re-cast as a two-way table to show baits individually and in mixtures (with the additional of a suppositional "zero" value for a trap with no bait). There were no significant differences among rows ("preserved" baits - ANOVA *F*=1.2938[2,4]ns {*P*=0.3687}) or columns ("fresh" baits - *F*=6.7774[2,4]ns {*P*=0.0519}).

	Nothing	Banana	Pumpkin	Row totals
Nothing	0	25	15	40
PH	14	34	16	64
Molasses	18	25	11	54
Column totals	32	84	42	

(4) Bait dilution experiment

In the field trap comparison of bait strengths, the protein hydrolysate at 100% caught 30 flies in two weeks and the 30% 19. The lower value of the ratio between catches (30/19=1.58) than the ratio between concentrations (100/30=3.33) suggested a diminishing return to increases in concentration.

(5) Field experiment

Table 5 shows the yield and infestation of fruit (the latter as the mean of 9 weekly assessments) of all four treatments, and Table 6 the numbers and sex-ratios of flies caught in the traps deployed in the three treatments with BAT baits. Table 7 recasts the data to show by four different criteria the relative performance of the three BAT treatments. In the case of sex-ratio of catches there were no meaningful differences between treatments; in all others the baits performed in similar manners, with jaggery significantly superior to the other two, which were broadly equivalent. As the assessment value proceeded from the assessment of insect abundance to the assessment of economic returns (in the sequence trap-catch to percentage-infestation to yield), the P-values were observed to decline.

Table 5. Means and standard deviations (<SD>; N=3) of the yield in KG/plot (above) and percentage infestation (below) of bitter gourds under four treatment regimes. Differences were not significant among the three control treatments in terms of yield,(F=2.9748[2,8]ns {P=0.1616}) but were highly significant in terms of infestation (F=215.7171[2,8]* {P=0.0001}).**

	PH	Molasses	Banana	Untreated
Yield	49	56	48	30
	<1>	<7>	<3>	<2>
Infestation	43	36	42	63
	<0>	<1>	<1>	<1>

Table 6. Trap catches as totals (above) and sex-ratios (below). There were significant differences among total catches (F=298.6117[2,8]* {P<0.0001}) but not among sex-ratios (F=0.0696[2,8]ns {P=0.9339}).**

	PH	Molasses	Banana
Totals	313	622	227
	<29>	<12>	<23>
Sex-ratios	53	54	53
	<6>	<2>	<9>

Table 7. Mean values from Tables 5 and 6 recast to show the rank-order of the control treatments by various measures. Catches and sex-ratios are as in Table 6; infestation and yield data are percentage improvements relative to the untreated control, taken from Table 5 and given as in all cases the differences between each treated plot value and untreated plot value, divided by the untreated plot value. In order to indicate the rank-order of each treatment by each measure, in each row the highest-scoring treatment is in bold and the second-highest in italics.

Altogether	PH	Molasses	Banana
Total trap catches	*313*	**622**	227
Trap catch sex-ratios	*53*	**54**	53
Infestation	31	**43**	*33*
Yield	*49*	**56**	48

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~03/15[BBT]: Attraction to Fruit Flies of Food Baits in Bitter Gourd in Orissa

Singh, HS, Mohantha, A, Stonehouse, JM, Verghese, A, Mumford, JD

Abstract

The attraction to fruit flies of different food baits was assessed in traps, containing 50g or 50ml of each, in a field of bitter gourd outside Bhubaneswar. Numbers of flies attracted were highest to banana (mean catch of 5.0 flies), then jaggery (4.6), mashed bitter gourd (2.5) and protein hydrolysate, water and a mixture of sugar and yeast (all <1.0). The relative attraction of 100% protein hydrolysate was five times greater than that of a solution 33 times weaker, implying diminishing returns to stronger doses of protein traps.

Introduction, Materials and Methods

Fruit flies may be attracted by a variety of synthetic and natural food baits. This experiment assessed the relative attraction of some of these in single killing points in bottle traps outside Bhubaneswar. Natural bait traps also contained borax as a preservative. The banana used was the local Orissa variety *Champa*. All traps contained 5 drops of malathion in addition to the baits and preservatives.

- 50ml protein hydrolysate at 100%
- 50ml protein hydrolysate at 3%
- 50g mashed bitter gourd + 5g borax

- 50g banana + 5g borax
- 50g jaggery + 5g borax
- 25g yeast + 25g sugar + 5g borax
- 50ml water

Baits were evaluated for their ability to attract fruit flies in bottle traps in a farm field of bitter gourd outside Bhubaneswar in March 2003. Treatments were deployed in five complete randomised blocks. Baits were replaced at 10 day intervals. Fruit flies in each trap were counted over a period of 20 days.

Results and Discussion

Table 1. Means and standard deviations (<SD>; N=5) of catches of fruit flies by different food bait attractants deployed in traps in bitter gourd fields in Orissa. Means not followed by the same letter differed significantly (P<0.05; Tukey's HSD=3.383; overall ANOVA for treatments *F*=8.2326[6,24]*).**

Banana	Jaggery	Bitter gourd	Yeast-sugar	PH (100%)	PH (3%)	Water
5.00a	4.64a	2.52ab	0.52b	0.60b	0.12b	0.12b
<3.61>	<2.68>	<0.54>	<0.30>	<0.37>	<0.11>	<0.27>

Table 1 shows the results from the comparison of the trap catches. It may be seen that the protein hydrolysate and yeast-sugar mixtures did not obtain catches significantly superior to the water which was used as a "no-treatment control" but that the banana and jaggery were both significantly superior to these three. Bitter gourd baits occupied an intermediate position. This provides an encouraging scenario for Indian agriculture, as implying that locally home-made materials may be as good as, if not better than, imported and specialised ones. The superiority of attraction of protein hydrolysate at 100% was 60/12=5 times more than at 3% - less than the concentration ratio of 100/3=33 - and not statistically significant - implying diminishing returns to stronger doses of protein traps.

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~03/13[BDU];04/08[MDU]: The Control of Fruit Flies by Baits in Sprays and Traps in Orissa and Southern Kerala

Stonehouse, JM, Singh, HS, Jiji, T, Mohantha, A, Sentilkumar, Verghese, A, Mumford, JD

Abstract

The infestation of fruit flies in bitter gourd was assessed by two two-way factorial comparisons of protection by three different baits applied in two different ways but at the same dose per unit area, conducted outside Bhubaneswar and Thiruvananthapuram (N=3 in each). In Orissa, among baits, the mean percentage protection obtained was by banana 41%, by jaggery 38% and by protein hydrolysate 33%, but these differences were not significant (*P*=0.1290); among application methods, that by sprays was significantly superior to that by traps (respectively 51 and 19%; *P*<0.0001; for interaction between the two factors *P*=0.2570). In Kerala, among baits, the mean percentage protection obtained was by banana 64%, by jaggery 56% and by protein hydrolysate 62%, but these differences were not significant (*P*=0.6726); among application methods, that by traps was significantly superior to that by sprays (respectively 72 and 50%; *P*=0.0378; for interaction between the two factors *P*=0.0003). These results were sharply contradictory between the two research sites, as while banana emerged as (narrowly) the most effective material, in Orissa it was significantly more effective as a spray, but in Kerala in a trap.

Introduction, Materials and Methods

Food baits for the control of fruit flies may be applied on the one hand as sprays or splashes, squirted or daubed onto surfaces as liquids, or on the other as liquids or solids in receptacles as traps. Their relative efficiency in these two delivery modes is of clear importance, and this experiment set out to evaluate the crop protection abilities of three bait materials in each mode.

The experiment took place in fields of bitter gourd in 2004, in three fields near Bhubaneswar, Orissa, in March and three near Thiruvananthapuram, Kerala, in August 2004. Baits evaluated were the commercially available (though imported) protein hydrolysate, and two home-made baits in widespread use in India - sliced banana and jaggery. Doses were in all cases adjusted so that the volume of bait and insecticide per unit area were always the same whether the baits were deployed as splashes or in traps.

Results and Discussion

Table 1 shows the percentage infestation of gourds with the six different treatment regimes and (in Orissa) an untreated control, as means and standard deviations of three complete blocks.

Table 1. Percentage infestation of gourds in plots with different types of protection in Orissa and Southern Kerala in 2004, as means and standard deviation (<SD>; in each location N=3) of consecutive weekly visit, each a week after a bait application. In Orissa were four visits, beginning on March 1; in Kerala, were three visits, beginning on August 6. In Kerala a no-control plot was foregone to spare pressure on the farmers' fields.

Application	Spray			Trap			No control
Bait	Banana	Jaggery	Protein	Banana	Jaggery	Protein	
Orissa	1.7 <0.1>	2 <0.2>	1.9 <0.3>	3.1 <0.2>	3.0 <0.3>	3.5 <0.2>	4 <0.3>
Kerala	16 <2>	19 <5>	3 <3>	2 <2>	3 <0>	16 <5>	- -

Table 2 shows the means from Table 1 recast to show differences between baits and application methods. Data from each of the protected plots was converted to a percentage for reduction in infestation relative to the relevant unprotected plot, and these are arranged to show the relationships of different baits and application methods. In Orissa, while the baits did not differ in their effectiveness, all were much more effective when applied as splashes to leaves than when applied in traps; in Kerala, while the baits did not differ in their effectiveness, they differed, and in different ways, in their response to the different application methods - banana and jaggery were more effective in traps, and protein in sprays.

Table 2. The means from Table 1 recast to show differences between application methods and bait materials. Percentage infestation data from each protected plot (%Pr) were converted to percentage reductions in infestation from the percentage infestation level in the appropriate unprotected plot (%Unpr) as (%Unpr-%Pr)/%Unpr*100 (so that, for example, a reduction from 10% infestation to 3% infestation by a protection treatment would be (10-3)/10*100=70% reduction in infestation) and the table realigned to show values for different application methods as rows and for bait materials as columns. (In Kerala, where there were no uprotected plots, a notional "unprotected plot" damage of 25% was used). Data were analysed by two-way factorial ANOVA for complete randomised blocks, with data converted to logarithms. In Orissa there were highly significant differences between application methods (*F*=123.7309[1,1]* {*P*<0.0001}) but not between bait materials (*F*=2.5306[2,10]ns {*P*=0.1290}) nor for interaction between them (*F*=1.5611[2,10]ns {*P*=0.2570}); in Kerala there were significant differences between application methods (*F*=5.7259[1,10]* {*P*=0.0378}), none between bait materials (*F*=0.6726[2,10]ns {*P*=0.5321}) and highly significant interaction between them (*F*=20.7770[2,10]*** {*P*=0.0003}).**

Orissa				
Application	Bait			Row means
	Banana	Jaggery	Protein	
Spray	59	51	52	51
Trap	23	25	14	19
Column means	41	38	33	

Kerala				
Application	Bait			Row means
	Banana	Jaggery	Protein	
Spray	38	24	87	50
Trap	91	87	38	72
Column means	64	56	62	

These results were sharply contradictory between the two research sites, as while banana emerged as (narrowly) the most effective material, in Orissa it was significantly more effective as a spray, but in Kerala in a trap.

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~03/53[ALB]: Laboratory Responses of Melonflies to Baits in Central Gujarat

Jhala, RC, Sisodya, D, Stonehouse, JM, Mumford, JD, Verghese, A

Abstract

Black and white jaggeries, and the effects of fermentation on baits of white jaggery and local banana, were assessed in pairwise comparisons (N=6) in laboratory cages using melonflies from a stock collected in Anand. Fermentation significantly enhanced the attractiveness of white jaggery (by 170% (*P*=0.0023}) but that of banana only insignificantly (by 13% {*P*=0.6606}). Black jaggery was significantly superior to white (by 50% {*P*=0.0409}).

Introduction, Materials and Methods

Many fruit fly baits have been found to have their attractiveness increased by fermentation, to produce a richer cocktail of appetising chemicals. This study used the standard IMFFI two-way choice chamber methodology with *Bactrocera cucurbitae* to assess the fermentation of banana and jaggery bait, and the attraction of two different sorts of jaggery available in Central Gujarat.

Results and Discussion

Table 1. Pairwise comparisons of the effects of fermentation on food baits and of different jaggeries in the attraction-and-killing of melon flies in Central Gujarat. Each row represents a choice experiment; “A as %” is the mean percentage (all N=6) of all flies found around Choice A (i.e. if A as % is greater than 50, A was inferred more attractive than B); “<SD(%A)>” is the standard deviation of that mean; *t*[5] and *P* are the outcome of a paired *t*-test comparison of the two.

Choice A	Choice B	A as %	<SD(%A)>	*t*[5]	{*P*}
Fermented banana & yeast	Fresh banana	53	<18>	0.4616	{0.6606}
Fermented white jaggery	Fresh white jaggery	73	<10>	5.0623	{0.0023}
Black jaggery	White jaggery	60	<9>	2.5964	{0.0409}

Numbers of flies attracted to either choice are summarised in Table 1. The fermentation significantly enhanced the attractiveness of white jaggery (by (73-27)/27=170% (*P*=0.0023}) but that of banana only insignificantly (by (53-47)/47=13% {*P*=0.6606}). Black jaggery was significantly superior to white (by (60-40)/40=50% {*P*=0.0409}).

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~04/18[AFB]: The Attraction of Fifteen Food Baits to Melonflies in the Field in Central Gujarat

Jhala, RC, Sisodya, D, Stonehouse, JM, Mumford, JD, Verghese, A

Abstract

The relative attraction of food baits to melonflies was assessed by placing some of each with insecticide in traps in gourd fields near Anand (N=8) and counting and sexing weekly catches. Mean catches of flies differed significantly (*P*<0.001) and were highest by papaya (3.75 flies), followed by jaggery (3.625), protein hydrolysate (2.25), banana (2.0), guava (1.5), tuna (1.5), meat (1.375), sapota (1.25), pumpkin (1.25), bitter gourd (1.0), small gourd (0.75), cucumber (0.5), ridge gourd (0.25), bottle gourd (0.25) and smooth gourd (0.0). The most promising catch sex-ratios, as percentages of females in the total catch and omitting those gourd catches too small for reliable assessment, were by meat (71%), papaya (65%), guava (61%) and sapota (58%) with all others between 42 and 55%, but these differences were not significant (*P*=0.1093). Overall, sugar sources such as papaya, jaggery, banana and guava performed well, meat and fish intermediately, and cucurbit oviposition hosts least well.

Introduction, Materials and Methods

The relative attraction of different candidate food baits to *Bactrocera cucurbitae* adults was assessed by placing some of each with insecticide in traps in complete randomised blocks in gourd fields near Anand for a week, and counting male and female flies caught. Each bait was assessed in two locations, and assessments repeated on four occasions, to obtain eight replicates.

Results and Discussion

Table 1 summarises the numbers of flies caught by each bait, and Table 2 the sex-ratios of these.

Table 1. Means and standard deviations (<SD>; N=8) of weekly catches by traps containing fifteen different food baits. There were significant differences between treatments (*F*=6.1338[14,98]* {*P*<0.0001}); treatments not followed by the same letter differed at the 0.05 significance level (Tukey's HSD=2.242).**

Bait	Mean	<SD>
Papaya	3.75a	<3.24>
Jaggery	3.63ab	<2.39>
Protein hydrolysate	2.25abc	<1.04>
Banana	2.00abcd	<1.31>
Guava	1.50bcd	<1.41>
Tuna	1.50bcd	<1.31>
Meat	1.38cd	<0.74>
Sapota	1.25cd	<0.89>
Pumpkin	1.25cd	<1.39>
Bitter gourd	1.00cd	<1.31>
Small gourd	0.75cd	<1.39>
Cucumber	0.50cd	<0.76>
Ridge gourd	0.25cd	<0.46>
Bottle gourd	0.25cd	<0.71>
Smooth gourd	0.00d	<0.00>

Table 2. Means and standard deviations (<SD>) of sex ratios of catches, as percentages of females among the total, for those baits where replication was greater than three. There were no significant differences among treatments (*F*=1.6837[9,70]ns {*P*=0.1093}).

Bait	Mean	<SD>	[N]
Meat	71	<39>	[7]
Papaya	65	<31>	[8]
Guava	61	<38>	[6]
Sapota	58	<38>	[6]
Protein hydrolysate	55	<13>	[7]
Jaggery	54	<13>	[7]
Pumpkin	54	<32>	[4]
Banana	50	<30>	[7]
Tuna	42	<38>	[6]
Bitter gourd	25	<32>	[4]

Overall, sugar sources such as papaya, jaggery, banana and guava performed well, muscle protein sources such as meat and fish intermediately, and oviposition hosts such as gourds and cucumbers least well. The results suggest a role for fruit pulp in melonfly baits.

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~03/37[GSK]: Comparison of Banana and Protein Hydrolysate in Traps in Southern Gujarat

Patel, ZP, Jagadale, ZP, Stonehouse, JM, Verghese, A, Mumford, JD

Abstract

Local *robusta* banana slices and protein hydrolysate (3%) were compared in traps outside Gandevi. Bananas caught more flies (mean 15.7) than protein (8.7), but this was not significant (*P*=0.0728); half-lives in days did not differ significantly (for banana 2.4 days, for protein 3.3 days; *P*=0.3954).

Introduction, Materials and Methods

Banana is widely used in traps in Southern India for fruit fly control. This experiment compared its effectiveness with that of imported protein hydrolysate in traps. Protein hydrolysate and local *robusta* banana were deployed in traps in three complete randomised blocks in orchards outside Gandevi, southern Gujarat in 2003. Flies caught in each trap were counted daily between 30 July and 5 August, when all daily catches settled at zero.

Results and Discussion

Table 1 gives the results as total catches and half-lives of catching efficiency in days. It cannot be conclusively confirmed that the banana bait caught more flies than the protein bait, although the matter deserves further investigation.

Table 1. Means and standard deviations (<SD>; N=3) of catches of fruit flies in traps baited with banana and protein hydrolysate (3% in a traps) as total catches over seven days and as half-lives of catch decay in days. In neither was there a statistically significant difference between baits (for total catch related *t*=3.5000[2]ns {*P*=0.0728}; for half-life related *t*=1.0733[2]ns {*P*=0.3954}).

	Banana	Protein
Totals	15.7	8.7
	<4.0>	<1.5>
Half-lives	2.4	3.3
	<0.2>	<1.3>

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~05/01[MSP]: The Effects of Bait Trap Potency on the Protection of Gourds from Fruit Flies in Southern Kerala

Jiji, T, Stonehouse, JM, Mumford, JD, Verghese, A

Abstract

Areas of snake gourd outside Thiruvananthapuram were protected from fruit flies by banana/jaggery traps at four different trap densitie, between 2.0 and 3.5M (N=3). The mean level of percentage infestation increase with increasing trap density, from 17.4% at 2M spacing, to 18.6 at 2.5M, 21.8 at 3M and 20.8 at 3.5M - a significant linear association (*P*=0.0286): quadratic regression gave a slight indication, without statistical significance, of a “flattening off” of infestation levels at and above 3M spacing.

Introduction, Materials and Methods

In order to test the relationship between the density of BAT killing points and the protection of crops from fruit flies, plots were laid out in fields of snake gourd near Thiruvananthapuram, protected by BAT traps containing banana (*Palayamkodan*), jaggery and water, spaced at between-trap distances of 2, 2.5, 3 and 3.5M, in five complete randomised blocks, and the percentage infestation by fruit flies assessed at each of the four densities. All traps were the same strength, so with increasing spacing there was decreasing dose per unit area.

Results and Discussion

Table 1. Mean and standard deviation (as <SD>; N=5) of percentage infestation of snake gourds when protected by banana/jaggery BAT traps at five different spacings, from 2x2M to 3.5x3.5M as indicated.

2.0x2.0m	2.5x2.5m	3.0x3.0m	3.5x3.5m
17.4	18.6	21.8	20.8
<2.9>	<3.0>	<2.6>	<2.2>

Table 1 shows the mean percentage infestation by flies in plots of gourd protected by traps at each of the four densities. It was found that differences between replicate blocks were not significant (AOV *F*=0.2463[4,19]ns {*P*=0.9064}), so blocks were pooled to save degrees of freedom. Subsequently the percentage infestation in plots was regressed against the area requiring protection by each trap in each plot (i.e. the square of the spacing between traps). A linear regression was significant (slope=0.4696 <SD=0.1982>; *t*=2.3694[19]* {*P*=0.0286}), but the quadratic terms in a quadratic regression was not significant (quadratic slope=−0.1000 <0.0804>; *t*=1.2450ns[18]ns {*P*=0.2291}). In other words, as the spacing of traps increased, the percentage infestation also increased; there some, but poor and non-significant, indication that this effect flattened off as spacing increased above 3M.

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6A. Parapheromone Lures: Attractants, Insecticides and Traps

~03/38[GTL];04/10[AOC]: *Ocimum* and Methyl-Eugenol in Fruit Fly Traps in Southern and Central Gujarat

Patel, ZP, Jhala, RC, Jagadale, V, Sisodya, D, Stonehouse, J, Verghese, A, Mumford, JD

Abstract

In Southern Gujarat in 2003, the attraction of methyl-eugenol to fruit flies as in soaked-plywood blocks (containing approximately 5ml of methyl-eugenol each) and as 100g of crushed *Ocimum sanctum* were compared in traps in orchards outside Gandevi (N=3). At day 17, when catches by the first tulsi trap had dropped to zero, blocks had caught 10.6 times more flies than tulsi (a superiority of 960%); at day 87, when catches by the first block trap had dropped to zero, this was 18.5 times more (a superiority of 1745%). It was estimated the power of 1ml of methyl-eugenol would be obtained by 370g of tulsi. Half-lives were estimated as 5.9 days for blocks and 2.2 days for tulsi. In Central Gujarat in 2004, traps containing aqueous extracts of three strains of *Ocimum* (tulsi) were compared with a methyl-eugenol trap in a guava orchard outside Anand for three weeks in August 2004, in an unreplicated assessment of their ability to attract fruit flies. Of the flies attracted, 75% were *Bactrocera dorsalis*, 17% *B. zonata* and 9% *B. correcta*. *Ocimum basilicum* (var. "Damaro") caught no flies at all; the others caught numbers which, relative to the doses, implied that the equivalent strength of 1ml of methyl-eugenol would be obtained by the aqueous extract of 46g of "Black" tulsi (*Ocimum sanctum* var. "Krishna") and 417g of "Green" tulsi (*O. sanctum* var. "Rama").

Introduction

Tulsi or Holy Basil (*Ocimum sanctum*) is known to contain methyl-eugenol, and is periodically recommended for home-made trap control of methy-eugenol-attracted fruit flies. Tulsi in Navsari, Gujarat has been found to contain approximately 20.4% of its essential oils as methyl-eugenol (Shah and Patel, 1976). These experiments aimed to compare the size and duration of catching efficiency of conventional soaked-wood methyl-eugenol blocks with home-made tulsi traps.

Materials and Methods

In orchards outside Gandevi, soaked-plywood-block traps, each containing approximately 5ml of methyl-eugenol, and traps containing 100ml of solution of 100g of crushed Black Tulsi (*Ocimum sanctum*) were compared in three complete randomised blocks in 2003. Traps were emptied daily for the first three weeks, and weekly thereafter. Flies caught in each trap on each date were counted.

In orchards outside Anand, the attraction to *Bactrocera* fruit flies of various species of *Ocimum* were assessed in comparison with liquid, synthetic methyl-eugenol from a commercial preparation. Methyl-eugenol and three *Ocimum* preparations were deployed in traps, after preparation as follows. Tulsi preparations were all as 5ml of aqueous leaf extract, 25%W/V (i.e. 1g of crushed leaf in 4ml of water), with 5 drops of DDVP, deposited on a 5x5cm square of sponge. These comprised (1) "Green tulsi"

(*Ocimum sanctum* Var. Green “Rama”, (2) “Black tulsi” (*Ocimum sanctum* Var. Black “Krishna” and (3) “Damaro” (*Ocimum basilicum* “Basil tulsi”). These were compared with an identical 5x5cm sponge carrying 5 drops of methyl-eugenol and 5 drops of DDVP. Traps were installed equidistantly in a guava orchard outside Anand. Counts of catches of fruit flies (*B. dorsalis*, *B. zonata* and *B. correcta*) were made daily for 15 days in August 2004. The experiment was unreplicated.

Results and Discussion

In Gandevi, catches in tulsi traps decayed to zero after 21 days. Of the three methyl-eugenol traps, two caught flies after 81 days, and one after 87 days when the trial was dismantled. Table 1 gives the catches for the different traps at Day 17, when the first tulsi trap catch dropped to zero, and Day 87, when the trial was ended, and the half-lives of catch decays in days, calculated to Day 7 (as ME trap catches tended to fluctuate with the local fly population, and increased over the second and third weeks of deployment). Methyl-eugenol traps caught significantly more flies, and lasted significantly longer, than tulsi traps. At day 17, when catches by the first tulsi trap had dropped to zero, blocks had caught an average of 1843 flies and tulsi 174 (a superiority of 1843/174=10.6:1 or (1843-174)/174=960%); at day 87, when catches by the first block trap had dropped to zero, this was 3248 to 176 (a superiority of 3248/176=18.5:1 or (3248-176)/176=1745%). This does not mean, however, that they are in all cases to be preferred - it the shortcomings of tulsi traps may be made good by increasing doses (to compensate for low catches) and trap replacement (to compensate for short duration) they may offer a cost-effective control in cases where methyl-eugenol is unobtainable or expensive. As methyl-eugenol traps contained approximately 5ml, and tulsi traps approximately 100g, it is estimated the equivalent strength of 1ml of methyl-eugenol would be obtained by 18.5/5*100=370g of fresh tulsi leaves.

Table 1. The performance of tulsi and methyl-eugenol traps as total catches after 17 and 87 days, and the half-life of catch decay calculated over seven days. Given are means and standard deviations (<SD>; N=3), and the output of statistical comparisons by related *t*-tests as *t* (all degrees of freedom [2]) and {*P*}.

Value	Tulsi	ME	*t*[2], {*P*}
Catch at	174	1843	7.6430*
Day 17	<64>	<375>	{0.0167}
Catch at	176	3248	4.5622*
Day 87	<66>	<1136>	{0.0448}
Half-life at	2.2	5.9	8.6625*
Day 7	<1.0>	<1.5>	{0.0131}

In Anand, the catches of each of the three species in each of the four traps after three weeks were as summarised in Table 2. Assuming no interaction between methyl-eugenol source and fly species, the attraction of Basil was estimated as non-existent, and those of Green and Black tulsi as respectively 2% and 9%. If 25% W/V of 5ml is taken as 1.25g, and if one “drop” is taken as 0.06ml, then 1.25g of Black Basil had 9% of the power of 0.3ml of methyl-eugenol, so the equivalent strength of 1ml of methyl-eugenol would be obtained by the aqueous extract of 1.25x100/9x1/0.3=46g of Black and 1.25x100/1x1/0.3=417g of Green tulsi.

Table 2. Catches after three weeks of fruit flies of three different species in traps containing methyl-eugenol and aqueous extracts of three different strains of tulsi (*Ocimum*). The experiment was unreplicated.

	Ocimum species			Methyl
Bactrocera	Green	Black	Basil	eugenol
dorsalis	2	7	0	75
zonata	0	2	0	17
correcta	0	0	0	9
Totals	2	9	0	101

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~03/35[GTP];04/20[ASP;ASQ]: Commercial Dispensers, Traps and Blocks for MAT in Southern and Central Gujarat

Patel, ZP, Jhala, RC, Jagadale, VS, Sisodya, D, Stonehouse, JM, Mumford, JD, Verghese, A

Abstract

In Southern Gujarat, a number of home-made and commercial cue-lure traps were assessed for fruit fly attraction in the field (N=1). A soaked-wooden-block trap caught most flies, 33, followed by the "Rakshak Protector", with 29. The block half-life was estimated as 36 days. In Central Gujarat, commercial traps containing both methy-eugenol and cue-lure were hung in, respectively, fruit orchards and gourd fields near Anand for comparison of their catches with soaked-plywood blocks containing approximately 5ml of lure. Commercial methyl-eugenol traps obtained between 11 and 57% of the catch of soaked blocks, and with similar persistence rates (between 14 and 17 days of half-life, in comparison with 20 days for soaked blocks); commercial cue-lure traps obtained only 1% of that of soaked blocks (and decayed completely within eight weeks, in comparison with soaked-block half-lives of 33 days). The implication from Anand was that due to its much greater costs, commercial preparations of cue-lure, to remain within the budget of farmers, contain less lure than commercial preparations of methyl-eugenol, but this was contradicted by the good performance of the commercial "Rak-Shak" cue-lure in Gandevi. Methyl-eugenol traps caught 815 *B. dorsalis* and 11 *B. zonata*.

Introduction, Materials and Methods

Various different traps, both commercial and home-made, are available for fruit fly management in India. These experiments aimed to compare some of them.

Near Gandevi five traps, as listed in Table 1, were loaded with cue-lure, placed in fields of bitter gourd, and emptied weekly between November 14, 2003, and January 29, 2004 (N=1). Results were derived as total catches and as the half-life of catch duration, from the exponential regression of catch numbers against time elapsed.

Near Anand, a number of commercial preparations were compared with home-made soaked plywood blocks, hung in traps in fields in the growing seasons of 2004. Four methyl eugenol dispensers, as listed in Table 2, were hung unreplicated in fruit orchards for 20 weeks from mid-July, and three cue-lure dispensers, as listed in Table 3, were hung in two complete randomised blocks for 26 weeks from the beginning of April. Fly catches were counted weekly.

Results and Discussion

Table 1 gives the totals and half-lives of catches of *Bactrocera cucurbitae* near Gandevi, and Tables 2 and 3 the catches of flies from Anand.

Table 1. Catches by five commercially-available and home-made traps for fruit flies in Southern Gujarat, as total catches and half-lives of persistence as calculated by exponential regression against days elapsed.

	Conventional	McPhail	Rakshak "Protector"	Block	"Patel"
Catch (number)	5	16	29	33	6
Half-life (days)	63	29	26	36	47

Table 2. Summary of catches by an unreplicated comparison of four methyl-eugenol dispensers over 20 weeksnear Anand. Species were identified separately for the first 4 weeks, then this was discontinued as perceived to have no interaction with trap performance (numbers caught up to that point were 815 *Bactrocera dorsalis* and 11 *B. zonata*).

Trap	Brooklands	Chem Tica International	Pest Control India	Plywood block
Total catch	220	327	61	573
Catch as % block	38%	57%	11%	100%
Half-life (days)	17	17	14	20

Table 3. Means and standard deviations (as <SD>; N=2) of catches by three cue-lure dispensers near Anand. Catches by commercial lures all fell to zero after eight weeks, but were too small to allow decay to be quantified. The half-life of the plywood blocks was calculated as 33 days <SD=0.1>.

Pest Control India	Agrisense	Plywood block
8	4	687
<2>	<0>	<155>
1%	1%	100%

The implication from Anand was that due to its much greater costs, commercial preparations of cue-lure, to remain within the budget of farmers, contain less lure than commercial preparations of methyl-eugenol, but this was contradicted by the good performance of the commercial “Rak-Shak” cue-lure in Gandevi.

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~03/45[AJR]: Fruit Fly Catches by Lure Traps with Two and Four Plume-Dispersal Holes in Central Gujarat

Jhala, RC, Sisodya, D, Stonehouse, JM, Verghese, A, Mumford, JD

Abstract

Traps containing blocks soaked in parapheromone lures were hung in gourd fields near Anand. Lures were cue-lure, to attract melonflies, and methyl-eugenol to attract the orchard fly guild; traps were made of 1L bottles or jars, and contained two or four plume-dispersal holes. The experiment was unreplicated. Flies caught were counted weekly for 25 weeks in the field season of 2004, and summarised as total catch and the half-life in days of its decline. A model of exponential decay in catches over time was a significantly superior fit (P=0.0017) to the data than one of linear decay. There were no significant differences between bottle traps (a mean total catch of 356 flies with a half-life of 31 days) and jar traps (a catch of 278 flies with a half-life of 29 days) (for total P=0.5470; for half-life P=0.3912), and none between traps with four (catch 391, half-life 29 days) and two (catch 243, half-life 31 days) plume-dispersal holes (for total P=0.3497; for half-life P=0.3832). There were no significant interactions (all P>0.15) between vessels, hole number and fly guild.

Introduction

Fruit fly populations are commonly monitored by traps comprising a lure and insecticide in a trap which is a vessel, of about 1L capacity, with holed cut in its sides and hanging in a tree. Insects are attracted by the lure plume which permeates out through the holes, fly in through the holes, are overcome by the insecticide and then collected from the bottom of the vessel. It may be that traps with a larger number of holes thus attract and kill more flies. It may also be that, if the amount of lure which is permeate out into the environment over the entire life of the trap is the same, a trap with smaller or fewer holes may emit its lure vapour more slowly, and thus collect fewer flies initially but persist for longer. This experiment aimed to test this.

Materials and Methods

The assessment was of traps containing 5x5cm square strawboard MAT blocks with applied to each five drops each of cue-lure, methyl-eugenol and DDVP insecticide. All holes in trap sides were round, 2.5cm in diameter. Traps were:-
A - 1L Mineral water bottle in a vertical position with four equidistantly-placed holes around the circumference of the upper portion of its side
B - 1L Mineral water bottle in a horizontal position with two holes, one at each end.
C - 1L Plastic jar in a vertical position with four equidistantly-placed holes around the circumference of the upper portion of its side.
D - 1L Plastic jar in a horizontal position with two holes, one at each end.
The four traps were placed 20m apart in a little gourd field from July to December, 2003. The experiment was unreplicated. Fruit flies were collected weekly, and identified as *B. cucurbitae* or "Others" - mostly "orchard flies" attracted to methyl-eugenol.

Results and Discussion

Traps were assessed as total catches over 25 weeks, and as half-lives, calculated in days by exponential regression of catches against days until catches settled to zero for two successive days. The exponential regression of catches against time obtained a significantly superior fit to a linear regression - over the eight species-and-trap combinations, the mean regression r^2, <± standard deviation> was for unlogged data 0.8267 <±0.0828> and for logged data 0.9570 <±0.0184> and this difference was statistically significant (related t=4.9103[7]** {P=0.0017}). The catches by each trap are summarised in Table 1 and their half-lives in Table 2. ANOVA analysis results are summarised in Table 3.

Table 1. Total catches of flies over 25 weeks, by three-way disposition of eight cells. Data are given for melon flies (*B. cucurbitae*) and other flies, mostly orchard flies attracted to methyl-eugenol, for bottle and jar traps, in a vertical position with four holes and a horizontal position with two holes. The experiment was unreplicated. Within the ink box are the values obtained in each cell (N=1), on the margins the marginal means and standard deviations (<SD>) for fly species, vessel type and vessel orientation.

		Fly		Hole number		Vessel	
Vessel	Hole number	Melon	Orchard	Mean	<SD>	Mean	<SD>
Bottle	4	841	133	391	<345>	356	<343>
	2	354	97	243	<159>		
Jar	4	483	108			278	<194>
	2	404	117				
Fly	Mean	521	114				
	<SD>	220	15				

Table 2. Half-lives (in days) as half-lives in days derived from exponential regression of catches against day elapsed until catches remained at zero for two days, by three-way disposition of eight cells (N=1) given as in Table 1.

		Fly		Hole number		Vessel	
Vessel	Hole number	Melon	Orchard	Mean	<SD>	Mean	<SD
Bottle	4	39	26	29	<7>	31	<8>
	2	36	22	31	<8>		
Jar	4	30	22			29	<8>
	2	40	25				
Fly	Mean	36	24				
	<SD>	<5>	<2>				

Table 3. Output tables of the three-way unreplicated ANOVA analysis of the data in Tables 1 and 2 (all d.f.=[1,1]).

	Totals		Half-lives	
Variation source	*F*	{*P*}	*F*	{*P*}
Fly	20.0892	{0.1397}	95.1808	{0.0650}
Hole number	2.6687	{0.3497}	2.1194	{0.3832}
Vessel	0.7435	{0.5470}	2.0080	{0.3912}
Vessel/Hole number	1.5573	{0.4301}	15.2091	{0.1598}
Fly/vessel	0.6967	{0.5572}	1.0223	{0.4965}
Fly/Hole number	2.2048	{0.3773}	1.9612	{0.3948}

No differences among traps were statistically significant, but this may be attributed to the low replication level. The four-holed vertically-positioned vessels caught more flies than the two-holed horizontally-positioned ones in three out of four cases, and had less-insignificant effects than the vessels used. In only two of the four cases did the two-holed trap indicate a longer half-life of effect than the four-holed trap.

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~02/05[ATR];02/04[SMC]: Potentiation and Interference among Methyl-Eugenol and Cue-Lure in Central and Northern Gujarat

Jhala, RC, Patel, RK, Sisodya, D, Joshi, B, Stonehouse, JM, Verghese, A, Mumford, JS

Abstract

Outside Anand, traps containing strawboard blocks treated with lure and insecticide were hung in a field of small gourd for eight weeks (N=5). Cue-lure by itself caught a mean of 54 melonflies, and 57 with added methyl-eugenol, a difference which was not significant (*P*=0.5228). Methyl-eugenol by itself caught a mean of 58 “orchard flies” (and six melonflies), and 24 with added cue-lure, a difference which was significant (*P*=0.0058). Mixes of lures appeared to offer no advantages over those used individually. Outside Palanpur, traps containing strawboard blocks treated with lure and insecticide were hung in a mango orchard for eight weeks (N=5). Mean numbers of fruit flies caught were fifteen by those containing methyl-eugenol, three by cue-lure and sixty-five by a mixture of both, indicating a statistically significant potentiation by the two used in a mixture (*P*=0.0377).

Introduction, Materials and Methods

This experiment aimed to assess whether when used together methyl-eugenol and cue-lure attracted flies independently or interacted with each other. “Straw Board” blocks of 5x5cm were soaked in 3 drops of DDVP insecticide and either five drops of methyl-eugenol, five drops of cue-lure, five drops each of both, or nothing, hung in 1l plastic bottle traps, separated by at least 10m, in five complete randomised blocks, and the catches counted at regular intervals. Outside Anand traps were hung in farm fields of small gourd (*Coccinia indica*) on May 15, 2002, and observations taken after 1, 8, 18, 27, 35 and 49 days; outside Palanpur three observations were taken at 15-day intervals. In Anand, Tephritid catches were sorted into melonflies (*Bactrocera cucurbitae*) and others - mostly the orchard flies *B. zonata* and *B. dorsalis*.

Results and Discussion

Table 1. Means and standard deviations (<SD>; N=5) of catches by traps containing cue-lure (CL) and methyl-eugenol (ME) individually and as mixtures; only in Anand were catches sorted as to species.

Site	Lure	CL	ME	Both	Neither
Anand	Melonfly	54 <35>	0 <0>	57 <38>	0 <0>
Anand	Orchard flies	6 <4>	58 <37>	24 <28>	0 <0>
Palanpur	All flies	3 <2>	15 <15>	65 <41>	0 <0>

Fly catches are summarised in Table 1. In Anand, catching melonflies, cue-lure performed as intended, methyl-eugenol caught none, and the addition of methyl-eugenol to cue-lure did not significantly affect its performance either way (related *t*=0.6994[4]ns {*P*=0.5228}); by contrast, catching tree fruit flies, although methyl-eugenol catches were large as expected, some were also caught by cue-lure; conversely, the addition of cue-lure to methyl-eugenol apparently interfered with its capacity, as catches of the mixture were significantly inferior to those of methyl-eugenol alone (related *t*=5.3606[4]** {*P*=0.0058}). In Palanpur, flies were all male but were not distinguished as to species: there was significant potentiation in catches when the two were used together, obtaining catching power "greater than the sum of its parts" (two-way factorial ANOVA for complete randomised blocks, all with d.f. [1,9], ME *F*=16.0482** {*P*=0.0031}, CL *F*=7.7029* {*P*=0.0216}, interaction *F*=5.9294* {*P*=0.0377}). Graphic inspection gave no indication of differences in persistence among treatments in either location.

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~03/39[GME]: The Role of Lure and Insecticide in MAT in Southern Gujarat

Patel, ZP, Stonehouse, JM, Verghese, A, Mumford, JD

Abstract

This experiment conducted two assessments simultaneously, using soaked-wood methyl-eugenol blocks in traps (N=5) in orchards outside Gandevi. The first compared blocks soaked in UK-sourced lure with a concentration of 70% with those with an India-sourced lure of 98%, and found that the total catch by the UK lure was 64.4% that of the Indian - close to the ratio in concentrations; catch half-lives were calculated as 9.5 days for the UK, 8.7 for the Indian, but this difference was not significant (*P*=0.0630). The second comparison was of insecticides in the soaking mixture, to assess whether the high-volatility DDVP would obtain higher kills but lower persistence than the lower-volatility malathion. To evaluate the risk of the decay of insecticide but not lure in the block's load, straightforwardly-soaked blocks were compared with others in which the insecticide was replenished, to allow insecticide decay to be detected as a difference in persistence in the differentially-replenished blocks. The catches by DDVP blocks were significantly larger than those by malathion by 1.35:1, an increase of 35% (*P*=0.0013), and not significantly enhanced by the replenishment of insecticide (for both insecticides replenishment {*P*=0.7281}; for insecticide/replenishment interaction *P*=0.4571). In terms of half-lives of duration, means were 8.7 days for DDVP and 9.3 days for malathion (malathion longer than DDVP by 1.07:1, or 7%), and no differences were significant (*P*=0.7368).

Introduction

MAT (Male Annihilation Technique) is being assessed for farm- and village-level control of orchard fruit flies in Gujarat. MAT liquid for soaking blocks is a mixture of methyl-eugenol (ME) lure, insecticide and solvent, and this experiment aimed to assess two ME lures and two insecticides for their relative effectiveness.

Materials and Methods

The two lures compared were sourced from India (Sisco Research Laboratories (PVT) Ltd, Mumbai 400-093) and the UK (International Pheromone Systems Ltd, Ellesmere Port, South Wirral L65 4TY). The Indian lure is a laboratory-grade product of c.98% purity, the UK lure an agricultural-grade product of c.70% purity. In spite of its UK origin, the UK lure is considerably less expensive than the Indian(about one quarter the price), reflecting the diminishing returns to cost in the process of purifying methyl-eugenol after its initial synthesis.

The two insecticides compared were malathion and DDVP. DDVP is known to have a low vapour pressure and consequently some fumigant action; as a result it was suspected that it may have some advantage in kill effect over malathion but also that, being more prone to evaporation, it may decline more quickly in effectiveness.

Lure and insecticide combinations were all mixed into soakate liquids as 6:4:1 by volume ethanol:lure:insecticide and soaked into local plywood blocks of 5x5x1cm for seven days. Five treatments were used, in five complete randomised blocks, of individual blocks hung inside traps made of 1L plastic water bottles to allow insect kills to be counted. Traps were insta1, 2003, in orchards at Gandevi, Gujarat, and emptied weekly until August 7, three weeks after catches in all traps had declined to zero.

Blocks were assessed in two ways. First was as the total catch over the period of deployment. Second was to check for differences in the durability or decay of effectiveness over time.

Decay rates were assessed in two ways. First was by the calculation for all blocks of the half-life of their effectiveness as it decayed, for direct comparison. Half-lives were calculated in the following way. (1) The individual catch totals for each trap in each week were adjusted for the fluctuations in the local background population by dividing them by the comparable population estimates obtained by hand-smoothing the data from the ME traps in the nearby Gandevi component of the IMFFI nationwide trap grid, of three ME traps replenished in a regular, staggered three-month rotation. (2) Each adjusted datum was converted to its natural logarithm after the addition of 1.0 to forestall the calculation of log(0). (3) The log-data were regressed against days elapsed between trap installation and the week each catch finally stabilised at zero. (4) The half-life of each was calculated as the natural logarithm of 0.5 divided by the slope of this regression.

The second assessment of the decay of effectiveness was, for the insecticides, by the mounting additional to each straightforward soaked block a similar one in which the insecticide dose was the same and unchanged but the insecticide component constantly replenished by the weekly application of a few drops of insecticide with a dropper to the wood. This allowed a check to be made of the danger that the insecticide may decay in effectiveness faster than the lure, creating the unappealing prospect of an old block continuing to attract flies into its area, but then leaving them unharmed. The comparison of catches between the blocks with replenished and unreplenished insecticides allowed this to be detected as a difference in catches.

Accordingly, the five treatments compared were as follows:-

1. UK methyl-eugenol; DDVP, unreplenished
2. India methyl-eugenol; DDVP, unreplenished
3. India methyl-eugenol; DDVP, replenished
4. India methyl-eugenol; malathion, unreplenished
5. India methyl-eugenol; malathion, replenished

The data were analysed as two experiments sharing one treatment (number 2). Indian and UK lures were compared by (a) total kill and (b) half-life of treatments 1 and 2 by related *t*-tests. DDVP and malathion were compared by (a) total kill and (b) half-life of treatments 2,3,4 and 5 by 2x2 factorial analyses of variance.

Results

1. Comparison of Indian and UK ME

1a. Total Catch. Total numbers of insects caught over the duration of the experiment, as means and standard deviations (<±SD>) were for Indian ME 576.6 <±103.4> and for UK 371.2 <±92.9>. The difference was not statistically significant (related *t*=2.6900[4]ns {*P*=0.0547}). The catch of the UK represented 64.4% of that of the Indian - close to the 70% represented of its ME concentration.

1b. Half-Life. Half-lives of the decaying numbers of catches were for Indian ME 8.7 <±0.8> days and for UK 9.5 <±0.9> days. The difference was not statistically significant (related *t*=2.5550[4]ns {*P*=0.0630}).

2. Comparison of DDVP and Malathion

2a. Total Catch. Table 1 summarises the catch data and their analysis. The catches by DDVP blocks were significantly larger than those by malathion by 577/426=1.35:1, an increase of (577-426)/426=35%, and not significantly enhanced by the replenishment of insecticide.

Table 1. Means and standard deviations (<SD>; N=5) of total catches by blocks of ME and either DDVP or malathion, the insecticides either unreplenished or replenished every week. Differences were significant between insecticides (*F*=17.4521[1,12] {*P*=0.0013}) but not between replenishment conditions (*F*=0.1266[1,12]ns {*P*=0.7281}) or interactions between them (*F*=0.5905[1,12]ns {*P*=0.4571}).**

Insecticide	DDVP		Malathion	
Replenishment	no	yes	no	yes
Mean	577	595	426	377
<SD>	<103>	<84>	<112>	<84>

2b. Half-Life. Table 2 summarises the half-life data and their analysis. Mean half-lives were 8.7 days for DDVP and 9.3 days for malathion (malathion longer than DDVP by 9.3/8.7=1.07:1, or (9.3-8.7)/8.7=7%), and no differences were significant.

Table 2. Means and standard deviations (<SD>; N=5) of half-lives in days of the decay of catches by blocks of ME and either DDVP or malathion, the insecticides either unreplenished or replenished every week. Differences between treatments were not significant (*F*=0.4276[3,12]ns {*P*=0.7368}).

Insecticide	DDVP		Malathion	
Replenishment	no	yes	no	yes
Mean	8.7	9.1	9.3	8.8
<SD>	<0.8>	<1.0>	<1.3>	<0.6>

Discussion

The total catch of the UK ME, as a percentage of the Indian, apparently reflected the ratio of their different concentrations of ME active ingredient. It should be noted that, as catches were apparently associated with ME content, the agricultural-grade UK product appears to represent the much more cost-effective option, as to obtain an increase of 50% by increasing the dose would entail the use of 50% more product, and thus a cost increase of 50%, but to obtain the same increase by the use of the Indian product instead would entail a four-fold, or 300% cost increase.

DDVP caught significantly more flies than malathion, but there was no indication that it decayed at a faster rate. Neither DDVP nor malathion indicated a tendency to decay in effectiveness at a faster rate than the lure they were mixed with.

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~03/51[BWT]: Performance, Persistence and Rain-Fastness of Insecticides in MAT Blocks in Orissa

Stonehouse, JM, Singh, HS, Mohantha, A, Verghese, A, Mumford, JD

Abstract

The performance of different insecticides as the killing component in soaked MAT blocks was assessed by the use of malathion and DDVP with methyl-eugenol in blocks in traps near Bhubaneswar (N=5) under three simulated rainfall regimes - dry, “light” and “heavy” (respectively 0, 25 and 125mm of simulated rain per week). In total catch while dry the two insecticides did not differ (DDVP killed 25 flies, malathion 30, for the difference between them P=0.3313). In persistence (half-lives in days) overall the duration was cut short by rain (from dry 17 days to lightly-wetted 13 days to heavily-wetted 11 days: P=0.0440); insecticides did not significantly differ (malathion 13 days, DDVP 15 days: P=0.2519) though they did significantly interact with wetting regimes (interaction P=0.0211). The implication was that the decline with increasing wetting heaviness in half-lives was steeper for DDVP (23..12..11) than for malathion (12..14.12). An analysis of the persistence of wetted blocks as a fraction of dry blocks confirmed that the persistence under wetting of malathion was significantly greater than that of DDVP (mean half life as a fraction of dry for wet malathion blocks 26 days, for wet DDVP blocks 11 days, a significant difference {P=0.0350} with no interaction between insecticides and wetting intensity levels {P=0.2938}). While dry, the persistence of DDVP was not significantly inferior to malathion, but it was under rain-imitation conditions.

Introduction

Fruit flies may be managed by male annihilation technique (MAT) by wooden blocks soaked in parapheromone lures and insecticide. Selection of a suitable insecticide component is important in that its potency must be adequate to kill all flies that come into contact with it and its persistence must be as durable as that of the lure to avoid the disagreeable prospect of flies being attracted but not killed. As an insecticide with a low vapour pressure and slight fumigant action, DDVP is reputed to be potent in killing insects around blocks, but to decay faster than the malathion traditionally used. This experiment compared malathion and DDVP for catch, durability and fastness to rain.

Material and Methods

Blocks were prepared as 5x5x1.2cm cuboids of plywood soaked in a mixture of 6:4:1 by volume of ethanol, methyl-eugenol and insecticide as a commercially available emulsifiable concentrate (EC) formulation - either malathion or DDVP (“Nuvan”). Some of each were subjected to regimes of simulated rainfall, as either “light” (25mm of rain per week) or “heavy” (125mm per week). Rain was simulated as fresh water dripped with a dropper onto the block held flat horizontally; the surface area exposed was 5x5=25sqcm, so the volume of water to obtain 25mm of rain = 2.5x25=62.5ml, and that to obtain 125mm of rain = 12.5x25=312.5ml. Traps with each of two insecticides treated as either dry, under light rain or under heavy rain obtained six experimental treatments in all.

Blocks were hung in traps to allow their kill and catch of flies to be counted and to protect them from the (real) rain. Traps were hung in the field outside Bhubaneswar in five complete randomised blocks for eleven weeks from mid-July 2004. Each block of traps was visited weekly and the caught flies counted and simulated rain applied to the wet blocks.

Results

The performance by the two insecticide blocks under the three simulated rain regimes is summarised in Table 1 as total fly catches, and in Table 2 as the persistence of these catches as half-lives in days, derived from the slope a regression fit of catches (converted to logarithms for a geometric decline) against days passed. In neither case was there a significant difference between the dry blocks. The implication was that the decline with increasing wetting heaviness in half-lives was steeper for DDVP (23..12..11) than for malathion (12..14.12).

Table 1. Means and standard deviations (<SD>; N=5) of total catches by six blocks. The difference between the two dry blocks was not significant (planned related *t*=1.1047[4]ns {*P*=0.3313}).

	Dry	Light rain	Heavy rain	Row means
Malathion	30 <6>	19 <10>	17 <9>	22
DDVP	25 <7>	27 <15>	24 <6>	26
Column means	28	23	21	

Table 2. Means and standard deviations (<SD>; N=5) of half-lives of catch persistence in days by six blocks. There was a significant reduction in persistence of all blocks by rain (*F*=3.6662[2,11]* {*P*=0.0440}), no significant effects due to insecticides overall (*F*=1.3919[1,11]ns {*P*=0.2519}), but significant interaction between them (*F*=4.7059[1,11]* {*P*=0.0211}). The difference between the two dry blocks was not significant (planned related *t*=2.6024[4]ns {*P*=0.0599}).

	Dry	Light rain	Heavy rain	Row means
Malathion	12 <1>	14 <7>	12 <2>	13
DDVP	23 <10>	12 <4>	11 <1>	15
Column means	17	13	11	

Table 3. Half-lives in days of fractional catches by wetted blocks as fractions of those by corresponding dry ones. There was a significant difference due to insecticide (*F*=5.6492[1,12]* {*P*=0.0350}) but none due to rain intensity (*F*=1.1477[1,12]ns {*P*=0.3051}) or to interaction between them (*F*=1.2052[1,12]ns {*P*=0.2938}).

	Light	Heavy	Row means
Malathion	36	15	26
DDVP	11	11	11
Column means	24	13	

Table 3 summarises the response to rain-wetting of the two insecticide blocks, as half-lives in days of the catch of each wet block as a fraction of its corresponding dry one (for example, it was estimated to take 36 days for the catch by a lightly-wetted malathion block to fall to half of the catch of a corresponding dry malathion block). Assessment by two-way ANOVA found that the persistence of wetted malathion blocks, as a fraction of dry ones, was significantly greater than that of wetted DDVP blocks. There were no significant effects due to the intensity of wetting.

Discussion

There were no perceptible differences between insecticides in dry blocks in terms of catch; contrary to expectation there was a suggestion that the persistence of dry DDVP blocks may be greater than that of those containing malathion. Under simulated rain-wetting regimes, the persistence of both blocks was reduced; the reduction of the effectiveness of the malathion block, as a fraction of a corresponding dry block, was significantly slower than that of a DDVP block.

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6B. Parapheromone Lures: Soaking Substrates

~03/02[LTP]: Methyl-Eugenol in Wood Blocks and Water Traps in Mango Orchards in Central Uttar Pradesh

Shukla, RP, Manzar, A, Stonehouse, JM, Verghese, A, Mumford, JD

Abstract

In two experiments, methyl-eugenol catches of flies by unreplenished soaked wooden blocks, containing approximately 2ml of lure, and weekly-replenished water traps containing 0.1ml of lure, were compared in mango orchards near Lucknow, to assess their catching power per unit volume of lure used, which would require the block to maintain higher catches than the water trap for twenty weeks for the two traps to perform equivalently. Results were sharply contrasting: in one comparison a best-fit unlogged model predicted a break-even catch between the two traps after fifty weeks; in the other a best-fit logged model predicted a break-even catch after six weeks. Traps hung alongside containing insecticide with 100ml of water, 100ml of protein hydrolysate, and 50% mango pulp or 40% jaggery in 100ml water all caught no flies at all.

Introduction, Materials and Methods

These experiments compared the effectiveness of a bottle trap and a killing block of methyl-eugenol with insecticide soaked into plywood. Two separate comparisons were carried out in mango orchards outside Lucknow, of the conventional “water trap” containing 100ml of water with 0.1% ME and 0.1% malathion (as recommended in "Integrated management schedule for fruit fly" advice in Uttar Pradesh) with the soaked-block trap (a 5x5x1.2cm plywood block soaked in methyl-eugenol, ethanol and insecticide at 4:6:1 V:V:V, absorbing approximately 2ml of methyl-eugenol). Catches were recorded, and water-jar traps replenished, every week. The first comparison was on two farms between April 3 and October 16, 2003, the second in three replicates in a fully-randomised (unblocked) design between April 13 and May 19, 2004.

Results and Discussion

Traps hung alongside the first comparison containing insecticide with 100ml of water, 100ml of protein hydrolysate, and 50% mango pulp or 40% jaggery in 100ml water all caught no flies at all.

In the first comparison, the mean total number of flies caught was, for the two water traps 1190 <SD=230.5> and for the two block traps 17786 <SD=144.2>; in the second, for the three water traps 114 <SD=23> and the three block traps 223 <SD=22>. The catch by the block trap was significantly larger (in the first comparison related t=272.0656[1]** {P=0.0023}; in the second unrelated t=5.9181[4]** {P=0.0041}).

Meaningful comparison of the difference in performance, however, requires adjustment of data for the approximately twenty-fold larger absorption of lure by the soaked-block trap than the water-jar trap, and the more frequent replacement cycle of the latter. For the soaked-block trap to be superior to the water-jar trap overall, it would need to continue to catch more flies, on a week-by-week basis, for at least twenty weeks, or 140 days; this comparison was modelled by least-squares regression of the decline, over time elapsed, of the weekly soaked-block catch as a fraction of the water-jar catch. This ratio was regressed against days elapsed, and the results, separately for the ratio between the two catches and the ratio between their logarithms, are given for the two comparisons in Table 1.

Table 1. Summaries of regressions against weeks elapsed of two indicators of the ratio between the catches by the soaked-block and water-jar traps, either their ratio or that between their logarithms (in the 2003 comparison N=2; in 2004 N=3). Given for each regression is the intercept, slope, correlation coefficient r^2 and the *F*-value and significance level of the regression. In the 2003 comparison (unlogged model) the ratio would fall to unity after 353 days; in the 2004 comparison (logged model) after 42 days.

Comparison	2003		2004	
Numerator Denominator	Block catch Jar catch	LN(Block catch) LN(Jar catch)	Block catch Jar catch	LN(Block catch) LN(Jar catch)
Intercept	15.7643	1.4935	1.7287	1.6693
Slope	-0.0418	0.0008	0.0217	-0.0158
r^2	0.0841	0.0154	0.0704	0.1114
F	5.1417[1,56]*	0.8730[1,56]ns	1.2117[1,16]ns	2.0061[1,6]ns
P	{0.0272}	{0.3541}	{0.2873}	{0.1758}

In the first comparison the unlogged data produced the most meaningful fit, as both the larger correlation coefficient and the negative slope which the situation would seem to demand, and was statistically significant: under the unlogged model, the catch ratio declined to unity in 353 days, longer than the 140 postulated as necessary for the soaked block to outperform the water jar. In the second comparison, in complete contrast, the log:log data produced both the larger correlation coefficient and a negative slope, although neither regression was statistically significant: under the log:log model, the catch ratio declined to unity in 42 days - less than the 140 postulated. It cannot be concluded that the soaked block may catch more flies than the water jar, when its larger load of lure was taken into account.

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~03/52[BTP]: Methyl-Eugenol in Wicks and Blocks in Fruit Fly Traps in Orissa

Singh, HS, Mohantha, A, Stonehouse, JM, Mumford, JD, Verghese, A

Abstract

A study was conducted to assess the cost-effectiveness of catches of fruit flies by methyl-eugenol in blocks, wicks and water in traps over eleven weeks among orchards outside Bhubaneswar (N=4). Traps contained lure and insecticide soaked into plywood blocks, costing IRs27.2 each and not replenished, or cotton-wool wicks or water, replenished every week, with “low” or “high” doses - 0.1 or 1.0ml/block - costing, respectively as fixed-costs+(weekly-costs) for low-dose wicks IRs3.5+(IRs1.5), for high-dose wicks 7.7+(5.7), for low-dose water 3.6+(1.6), and for high-dose water 7.8+5.8). The relations of fixed to recurring costs dictated that the cumulative field cost of each “high-dose” replenished trap would rise to reach that of the unreplenished wooden block after five weeks, and that of each “low-dose” replenished trap an equivalent level after seventeen weeks, and after these periods of time the cumulative catches by blocks were compared with those by replenished traps: against high-dose traps after five weeks, the block, with 150 flies, was inferior to the water trap with 417 {*P*=0.0327} and to the wick trap with 266 {*P*=0.0461}; against low-dose traps after seventeen weeks, the block, with 468 flies, was inferior to the water trap with 619 {*P*=0.1015} but superior to the wick trap with 231 {*P*=0.0204}. Formal modelling of the interception points of lines representing cumulative costs and catches, however, was prevented by the fact that over the course of the experiment block catches, counter to expectation, declined more slowly than those of the replenished traps. Among replenished traps, the catches by larger doses were 130% larger than those by smaller doses (*P*<0.0001), but this was less than the 900% superiority in lure load. Catches by traps using water as a carrier were 89% larger (*P*<0.0001) than by those using the same methyl-eugenol load in cotton-wool wicks, which may be important in the light of their similar costs.

Introduction

Parapheromone lure traps as assessed by the IMFFI Project are of plywood squares of approximately 5x5x1.2cm soaked in ethanol solvent : lure : insecticide in a volume ratio of 6:4:1. These absorb 15-18ml of soakate and last about 6 to 10 weeks. They are not necessarily more cost-effective than traps with lower doses, replenished more frequently, and this study aimed to compare the soaked-plywood "IMFFI Block" with some traps recommended at present for control use. Recommendations have included:-

- 0.1% methyl-eugenol with insecticide in water; 100ml in a jar (Uttar Pradesh)
- 1% methyl-eugenol with 1% malathion or dichlorphos in water; 150ml in jar (Karnataka)
- 4-5 drops, each of 0.056ml, of methyl-eugenol, with the same amount of DDVP, dropped onto a 2x2cm square of sponge or cotton wool (Gujarat).

Materials and Methods

The experiment compared the IMFFI block with traps using water and cotton wool carriers, to obtain five treatments altogether:-

A1 - 0.1ml methyl-eugenol and 0.1ml malathion in 100ml water, replaced every week
A2 - 1.0ml methyl-eugenol and 0.1ml malathion in 100ml water, replaced every week
B1 - 0.1ml methyl-eugenol and 0.1ml malathion on cotton wool, replaced every week
B2 - 1.0ml methyl-eugenol and 0.1ml malathion on cotton wool, replaced every week
C - IMFFI soaked-plywood block (not replaced)

Table 1. Fixed and recurring costs in rupees of components of five methyl-eugenol traps as described in the text.

Carrier	Wick		Water		Soaked
Dose	0.1ml	1.0ml	0.1ml	1.0ml	block
Fixed (initial) costs					
Bottle	2.00	2.00	2.00	2.00	2.00
Wood block	0.00	0.00	0.00	0.00	2.00
ME	0.46	4.60	0.46	4.60	20.00
Cotton/thread	0.00	0.00	0.10	0.10	0.10
Insecticide	0.30	0.30	0.30	0.30	0.33
Labour	0.75	0.75	0.75	0.75	1.00
Solvent	0.00	0.00	0.00	0.00	1.77
Total	3.51	7.65	3.61	7.75	27.20
Recurring costs per week					
ME	0.46	4.60	0.46	4.60	0.00
insecticide	0.30	0.30	0.30	0.30	0.00
Cotton	0.00	0.00	0.10	0.10	0.00
Labour	0.75	0.75	0.75	0.75	0.00
Total	1.51	5.65	1.61	5.75	0.00

Traps were hung in fields outside Bhubaneswar in four complete randomised blocks; all the traps in each block were visited weekly, and at each visit the catch was counted and the water and cotton wool removed and replaced.

The optimisation of trap technology for farmers will depend not only on the performance of the various traps, but their fixed and recurring costs. These are given for each trap in Table 1, and these values were used to model the changes in relative costs over time, between the initially-expensive but unreplenished block and the initially-inexpensive but replenished traps, with the results summarised in Table 2.

Table 2. Projected cumulative costs of traps over a number of weeks, using the values from Table 1. In *bold underlined italics* are the points at which the costs of the four replenished traps rise to equal the total cost of the unreplenished but initially-costly soaked-block trap.

	Wick		Water		Soaked
Week	0.1	1.0	0.1	1.0	block
1	3.5	7.7	3.6	7.8	27.2
2	5.0	13.3	5.2	13.5	27.2
3	6.5	19.0	6.8	19.3	27.2
4	8.0	24.6	8.4	25.0	27.2
5	9.6	***30.3***	10.1	***30.8***	27.2
6	11.1	35.9	11.7	36.5	27.2
7	12.6	41.6	13.3	42.3	27.2
8	14.1	47.2	14.9	48.0	27.2
9	15.6	52.9	16.5	53.8	27.2
10	17.1	58.5	18.1	59.5	27.2
11	18.6	64.2	19.7	65.3	27.2
12	20.1	69.8	21.3	71.0	27.2
13	21.6	75.5	22.9	76.8	27.2
14	23.1	81.1	24.5	82.5	27.2
15	24.7	86.8	26.1	88.3	27.2
16	26.2	92.4	***27.8***	94.0	27.2
17	***27.7***	98.1	29.4	99.8	27.2

It was anticipated that the catches by the replenished traps, while initially inferior to those by the unreplenished soaked block, would persist longer as the trap ingredients were regularly replenished. Table 2 shows that for the soaked block to be as cost-effective overall, over a period of time, as the high-strength replenished traps, they would have to be at least as effective as them for at least five weeks; to be as cost-effective as the low-strength replenished traps they would have to be as effective for at least sixteen weeks. These dates therefore represent cutoff points where the blocks' cost-effectiveness will dip below that of the replenished traps if the performance declines too fast.

Results

Table 3 summarises the catches by the different traps, and Table 4 the analysis of the water and wick traps. The catches by larger doses were significantly larger than those by smaller, but this superiority, of (508-221)/221=130%, was less than the 900% superiority in lure load. Catches by traps using water as a carrier were significantly larger than by those using the same methyl-eugenol load in cotton-wool wicks, by (477-252)/252=89%.

Table 3. Means and standard deviations (<SD>; N=4) of catches of flies by five traps each week, totals after eleven weeks, and half-lives in days of the decay of catches from a regression model of exponential decay. There were significant differences between the five treatments in total catches(*F*=39.2777[4.12]* {*P*<0.0001}) and their half-lives(*F*=3.3252[4,12]* {*P*=0.0473}); in comparisons of the block with the four replenished traps as a group, values for total catches did not differ (self-evidently, as the block value lay within the spread of the others), but the decline of the block was significantly slower than that of the other four (ANOVA for non-orthogonal contrasts *F*=8.4390[1,12]* {*P*=0.0132}). (The analysis obtained a significant difference among the four replenished-trap persistence values (*F*=4.4041[3,9]* {*P*=0.0363}) but this was considered to be a random sampling outcome rather than a systematic difference, as most of the variation was due to interaction between carrier and dose, not main effects (for carrier *F*=1.8086[1,9]ns {*P*=0.2116}; for dose *F*=1.7186[1,9]ns {*P*=0.2223}; for interaction *F*=9.6849[1,9]* {*P*=0.0125}) for which no explanation was apparent).**

	0.1ml water		0.1ml wick		1.0ml water		1.0ml wick		Wood block	
Week	Mean	<SD>	Mean	<SD>	Mean	<SD>	Mean	<SD>	Mean	<SD>
1	109	<15>	24	<4>	144	<42>	83	<16>	39	<12>
2	90	<9>	22	<4>	130	<45>	74	<21>	12	<7>
3	30	<6>	17	<11>	66	<36>	46	<23>	25	<18>
4	20	<4>	15	<4>	50	<37>	38	<13>	50	<16>
5	14	<6>	17	<9>	27	<10>	25	<10>	25	<11>
6	7	<2>	3	<1>	12	<6>	10	<2>	9	<8>
7	1	<2>	1	<1>	4	<3>	3	<2>	2	<1>
8	24	<5>	10	<3>	102	<13>	53	<9>	78	<13>
9	17	<4>	9	<1>	78	<10>	36	<8>	58	<12>
10	6	<5>	5	<5>	19	<8>	12	<6>	7	<3>
11	1	<1>	2	<1>	4	<2>	2	<2>	0	<1>
Total	319	<33>	123	<12>	635	<134>	381	<69>	303	<58>
½ life	15	<1>	24	<6>	24	<10>	21	<7>	32	<8>

Table 4. The four trap-treatment means from Table 3 recast as a two-way table with marginal means. The water carrier was significantly superior to the cotton wick (*F*=61.2999[1,12]* {*P*<0.0001}) and the stronger dose superior to the weaker (*F*=99.6658[1,12]*** {*P*<0.0001}; there was no significant interaction between them (*F*=1.0414[1,12]ns {*P*=0.3341}).**

	Dose		Row
	0.1	1	means
Wick	123	381	252
Water	319	635	477
Column means	221	508	

Traps were also assessed by the persistence of their catches over time. Table 5 summarises the catches at the "break-even points" as discussed above, of five weeks for high-strength traps and seventeen weeks for low-strength traps, and comparisons among them. Per unit of expenditure, at the five-week break-even point all replenished traps caught significantly more flies than wooden blocks; after seventeen weeks the difference was less clear, as blocks caught significantly more than wick traps and fewer, but not-significantly, than water traps. Declines in catches were also measured by half-lives of their decay, calculated from exponential (logarithmic) regressions of catches against time: contrary to expectation, catches by the unreplenished soaked blocks declined significantly more slowly than those by the replenished traps. As the traps were replenished and the blocks not so, no explanation is apparent. It may be that the replenishment itself was for some reason inadequate to restore the trap to its initial catching power, or that the effects of differential "trapping-out" - particularly when first deployed - influenced the sequence of trap catches through time in such a way as to flatten the decay curve of the soaked-block trap.

Table 5. Catches by wooden blocks and replenished-traps at the “Break-even points” of five weeks for high-dose traps and seventeen weeks for low-dose traps. Catches for weeks 12 to 17, after data-gathering ended, were modelled from the exponential regression of catches against time. Given at the two dates are the total catch by wooden blocks and by each of the two replenished traps, and the outcome of planned, related *t*-tests comparing the block with each trap.

	High-dose traps at 5 weeks			Low-dose traps at 17 weeks		
	Water	Wick	Block	Water	Wick	Block
Mean	417	266	150	619	231	468
<SD>	<129>	<59>	<29>	<79>	<31>	<112>
t(block)[3]	3.7704*	3.2908*		2.3368+	4.5052*	
{*P*(block)}	{0.0327}	{0.0461}		{0.1015}	{0.0204}	

Discussion

Overall, replenished traps were found to be significantly superior to wooden blocks in terms of the numbers of flies each had caught by the point in time when their cumulative costs were the same. The water carrier of methyl-eugenol in replenished traps caught significantly more flies than the cotton-wool wick - a potentially important finding where cotton-wool wicks are still in use, given the close similarity in their costs. The significantly larger catches by high-strength (1.0ml) traps than low-strength (0.1ml) were in a ratio of 508/221=2.3, less than the ratio of ten times between their doses, indicating that per unit volume of attractant weaker traps are more economically efficient than stronger.

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~04/11[SDP]: Substrates and Doses for Melon Fruit Fly MAT in Northern Gujarat

Patel, RK, Joshi, B, Stonehouse, JM, Mumford, JD, Verghese, A

Abstract

Catches of melonflies by five different cue-lure MAT blocks, of soaked plywood and two synthetic “wood” boards - straw board and medium density fibreboard (MDF) each with 4 and 8 drops of mixture - were assessed in traps (N=4) in fields near Palanpur. Despite having a lure load estimated as 24 times greater, the plywood block caught fewer flies (5.5) than the synthetic boards. Strawboard caught significantly (*P*=0.0137) more flies (14.4) than MDF (8.5) and eight drops significantly (*P*=0.0258) more (14.0) than four (8.9) - a ratio (1.57) lower than that between their doses (2) - but there were no significant interactions between board type and drop number (*P*=0.2977). There were no significant differences among treatments in estimated half-lives of duration (*P*=0.5871).

Introduction, Materials and Methods

The aim of this experiment was the assessment of the size and persistence of killing effect of blocks of soft, synthetic “wood” boards as an alternative to soaked-plywood blocks for the control of fruit flies by male annihilation technique (MAT) to save the use of ethanol or ether as a soaking solvent where they may be difficult to obtain. Catches of melonflies by five different cue-lure MAT blocks, of soaked plywood and two synthetic “wood” boards - straw board and medium density fibreboard (MDF) each with 4 and 8 drops of mixture - were assessed in traps in four complete randomised blocks in fields near Palanpur.

Results and Discussion

Table 1. Means and standard deviations (as <SD>; N=4) of totals and half-lives of duration in days, of catches by blocks of plywood and two synthetic boards, the latter two with either four or eight drops of lure mixture. Half-lives were calculated on the assumption of a weekly increase in the resident fly population of 25% (in fact catch numbers increase over time for all five treatments). There were significant differences between catch totals (*F*=5.3125[4,12]* {*P*=0.0107}) but not among half-lives (*F*=0.7477[4,12]ns {*P*=0.5781}).

	Ply-	Strawboard		MDF	
	wood	4	8	4	8
Totals	5.5	10.8	18.0	7.0	10.0
	<4.0>	<4.3>	<6.2>	<1.4>	<1.8>
1/2-lives	29	44	42	34	40
	<6>	<26>	<21>	<11>	<9>

Table 1 shows the catches by the five types of blocks, as total catches and as the estimated persistence of these as half-lives in days (estimated from a local fly population assumed to be steadily increasing, and thus not treatable as realistic indications of persistence). The plywood block was estimated to absorb approximately 16ml of liquid, or 16/11=1.45ml of lure; four "drops" were estimated to comprise a volume of 0.06ml (and eight drops 0.12ml) so the much lower catches by plywood blocks than by the dropped board treatments was mysterious.

Table 2. The figures for total catches for the two soft boards in Table 1 recast as a 2x2 table. ANOVA analysis (all d.f.=[1,9]) found significant effects due to board types (*F*=9.3382* {*P*=0.0137}) and to drop number (*F*=7.1062* {*P*=0.0258}) but not to interaction between them (*F*=1.2217ns {*P*=0.2977}).

	4	8	Row means
Straw	10.8	18.0	14.4
MDF	7	10	8.5
Column means	8.9	14	

Table 2 shows the catch total data from Table 1 recast to show differences between boards and drop doses. Strawboard caught more flies than MDF and seemed a more suitable substrate. Eight drops more than four, though the ratio of this superiority (14.0/8.9=1.57) was less than that between the size of their doses (8/4=2). Table 3 shows the half-life data from Table 2 similarly analysed - no differences were apparent, though there was no evidence of a longer persistence of the harder MDF than the softer strawboard.

Table 3. The figures for half-lives for the two soft boards in Table 1 recast as a 2x2 table. ANOVA analysis (all d.f.=[1,9]) found no significant effects due to board types (*F*=0.6454ns {*P*=0.4425}), drop number (*F*=0.0383ns {*P*=0.8493}) or interaction between them (*F*=0.2915ns {*P*=0.6023}).

	4	8	Row means
Straw	44	42	43
MDF	34	40	37
Column means	39	41	

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~04/13[SRK]: Wood, Board and Commercial Lure Traps in Northern Gujarat

Patel, RK, Joshi, B, Stonehouse, JM, Verghese, A, Mumford, JD

Abstract

Three traps containing cue-lure - a soaked-plywood block with insecticide containing an estimated 1.45ml of lure, a dripped-board block in a "lobster pot" trap containing an estimated 0.075ml of lure and a McPhail trap containing a commercial lure plug - were hung in a field outside Palanpur for five weeks (N=1). The ply trap caught 5449 flies, the board 566 and the McPhail 349. The ratio between the catches of the two wood traps (5449/566=9.6) was less than half that between their doses (1.45/0.075=19.3). Estimated half-lives of catch decays were for plywood 16 days, for board 18 and for the McPhail 28.

Introduction, Materials and Methods

The aim of this experiment was to study the size and persistence of catching power among different candidate male annihilation (MAT) lure delivery systems. The first trap contained a plywood block of 5x5x1.2cm soaked in ether:cue-lure:DDVP at a v:v:v ratio of 6:4:1 for a week and hung in a 1L plastic bottle trap; the block was estimated to absorb approximately 16ml of liquid, or 16/11=1.45ml of lure. The second was a 5x5x1.2cm block of "nu-wood" with five drops (approximately 0.075ml) of cue-lure, with no insecticide, contained in a "Patel fruit fly trap" with "lobster-pot" entrances to allow flies to enter but prevent them from leaving. The third was a "McPhail" trap containing a cue-lure plug from Pest Control India Ltd (lure strength unknown), with water in the yellow bottom as the catching medium. One of each trap was hung in a melonfield near Palanpur, spaced 10m away from each other and all 1m above the ground. Fruit flies were collected weekly from November 8th 2003 until December 6th, and counted by species.

Results and Discussion

All flies were melonflies *B. cucurbitae.* Table 1 shows the numbers caught, totals and half-lives of persistence. The ratio of catches by the two home-made preparations (5449/566=9.6) was less than half that inferred between their strengths (1.45/0.075=19.3).

Table 1 : Number of males *B. cucurbitae* trapped week-by-week from 8-11-2003, by three different cue-lure traps, along with the totals and the estimated half-life of effects in days.

Date	Plywood	Cotton	McPhail
15-11-03	4375	354	230
22-11-03	880	155	77
29-11-03	189	57	3
37783	5	0	10
Total	5449	566	349
Half-life (days)	16	18	28

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~02/08[RBK]: Persistence of a Methyl-Eugenol Soaked Block in Central Kerala

Thomas, J, Vidya, CV, Stonehouse, JM, Verghese, A, Mumford, JD

Abstract

The pattern of catches by a methyl-eugenol block trap near Thrissur was analysed for its fit to various models. Correction of the data, to allow for fluctuations in the local fly population, by division by actual population estimated by a regularly-replenished trap nearby, substantially improved the fit to a model of declining effectiveness. There was little difference between the fit obtained by models of arithmetic and exponential decay.

Introduction, Materials and Methods

The assessment of the performance of MAT blocks in attracting and killing fruit flies is sometimes complicated by fluctuations in the surrounding fly population, and by ambiguities in the shape of the decay of catches over time. This study analysed the patterns of catches by a block hung in a mango orchard outside Thrissur throughout the mango season.

Results and Discussion

Table 1. Weekly fly catches of a soaked block, beginning on March 1st 2002. Values are given both as the data obtained ("Raw") and as corrected values obtained by dividing weekly catch data by those from a replenished trap nearby, which obtained monthly catches of 94.7 in March, 41.3 in April and 74.0 in May ("Corrected"). The distribution was assessed against both an arithmetic decay (regression of catches against time) and geometric or exponential decay (regression of logarithm of catches against time). For both raw and corrected sets, data were compared against the arithmetic and geometric models by the Kolmogorov-Smirnov *D* test (procedure from Siegel and Castellan, 1988; critical *D*(1% [N=4660])=0.0238).

Data	Raw			Corrected		
Week	Catch	Arithmetic	Geometric	Catch	Arithmetic	Geometric
1	1472	899	902	1052	706	748
2	978	804	760	699	654	666
3	264	710	640	189	602	593
4	231	616	539	165	550	528
5	371	522	454	608	497	470
6	252	428	382	413	445	419
7	483	334	322	792	393	373
8	259	240	271	425	341	332
9	203	146	228	186	289	296
11	147	-42	162	134	184	234
Sum	4660	4660	4659	4661	4661	4660
D		0.1603	0.1690		0.0875	0.0929

The catches of the block through the season are given in Table 1. Values are given both as the data obtained and, to allow for fluctuations in the actual local insect population, also as corrected values obtained by dividing weekly catch data by those from a replenished trap nearby. The distribution was assessed against both an arithmetic and geometric (exponential) decay. The replenished-trap-correction considerably improved the fit of the catch data to both models. There was little to choose between the arithmetic and geometric decay models.

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~03/06[VSG]: The Persistence of Fruit Fly Lures of Wood, Cotton and Sponge in Eastern Uttar Pradesh

Rai, S, Swamy, S, Satpathy, S, Stonehouse, J, Verghese, A, Mumford JD

Abstract

Wooden blocks soaked in cue-lure were hung alongside regularly-replenished traps of lure soaked into cotton wool and sponge for comparison in fields outside Varanasi. Due to their replenishment the non-wood substrates caught flies for longer periods than the wood blocks. The half-life of decay of the soaked-wood blocks was calculated as 23 days.

Introduction, Materials and Methods

Lures for attracting and killing fruit flies are commonly soaked into plywood blocks, although lures of cotton wool and sponge have also been recommended. This experiment aimed to compare the effectiveness and persistence of these three substrates, soaked in the melonfly parapheromone cue-lure, with insecticide, placed inside 1L plastic-drinking-water-bottle traps and hung in the field outside Varanasi, Uttar Pradesh. Plywood and cotton wool traps were replicated four times, and sponge traps twice, arranged in a completely randomised design. The wooden block was a 5x5x1.2cm block of plywood soaked in a mixture of ethanol:cue-lure:malathion in a volume ratio of 6:4:1, and replaced after 45 days. Other lures were replaced weekly. Traps were hung from May 31 to August 15, 2003, and the wooden blocks were therefore replaced once, July 22.

During the run of the experiment, fly populations in the field continually increased, so that catches generally increased as the lures aged. To correct for this, catches were weighted by assuming a daily increase in the field population of 1% (this approximated estimates of population dynamics from local fieldworkers - of relative populations sizes of 100 in June, 200 in July and 300 in August - rising from 100 on May 31 to 213 by August 15). Data were compared as half-lives of decay in fly catches, obtained from the exponential regression of weighted catches against time. The runs of data before and after the wooden blocks were replaced were separated, and each trap had as its datum the mean of the slopes of its first and second runs.

Results and Discussion

Table 1. Means, standard deviations <SD> and sample sizes [N] of half-lives of melon fly catch decay by different substrate traps soaked in parapheromone lure, in days, calculated from exponential regression of weighted catches against time, each as the mean of those obtained before and after wooden blocks were replaced in mid-season. The half-lives for wood were compared with those of the two others by pre-planned *t*-tests (for unequal sample sizes) with the outcomes given as *t*, degrees of freedom [df] and significance level {*P*}.

	Wood	Cotton	Sponge
Mean	23	37	74
<SD>	<10>	<16>	<23>
[N]	[4]	[4]	[2]
Compared with wood	*t*	1.4686ns	4.0569*
	[df]	[6]	[4]
	{*P*}	{0.1923}	{0.0154}

The half-lives of decay by the different blocks are summarised in Table 1. The decay of the wood block was appreciably more rapid than that of the other substrates which were more regularly replenished.

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~02/02[SAC];02/03[RAC];03/24[MAC]:
Acacia and Plywood Soaked Blocks for Male Annihilation
in Northern Gujarat, Central Kerala and Southern Kerala

Stonehouse,JM, Patel, RK, Thomas, J, Jiji, T, Joshi, B, Vidya, CV, Napoleon, A

Abstract

Methyl-eugenol MAT soaked blocks of plywood and acacia were compared in traps in the field in three locations in India. Near Palanpur, Gujarat (N=6), plywood caught a mean of 415 flies and acacia 53, a significant difference (*P*<0.0001); plywood blocks also indicated longer persistence but this was not significant (*P*=0.4959). Near Thrissur, Kerala (N=4), plywood blocks caught a mean of 954 flies and acacia blocks 553, a significant difference (*P*=0.0070); acacia blocks indicated longer persistence of effect but this was not significant (*P*=0.6271). Near Thiruvananthapuram, Kerala (N=4), plywood blocks

caught a mean of 1533 flies and acacia blocks 914, a significant difference (*P*=0.0004); plywood blocks also indicated longer persistence with a half life of 3.1 months to one of one month by acacia, which was statistically significant (*P*=0.0038).

Introduction

Fruit fly males are caught for both research and control by wooden blocks soaked in parapheromone lure and insecticide. Research blocks are commonly of plywood. Farmers and resource-poor researchers, however, may have readier access to local unprocessed woods. In this study the efficacy of plywood was compared with that of blocks of acacia, a cheap and widely-available wood in India.

Materials and Methods

All blocks were 5x5x1.2cm and soaked in a 6:4:1 mixture of ethanol:methyl-eugenol:insecticide. Blocks made of plywood or local acacia were hung in complete randomised blocks (pairs) in trees in mango orcahrds and catches counted at regular intervals. The experiment was conducted in Palanpur, Gujarat (N=6) from May 8, 2002 (“marble-sized” fruits), Thrissur, Kerala (N=4) from March 14, 2002, and Thiruvananthapuram, Kerala (N=4) from May 1, 2003 (emptied monthly on the last days of May, June, July, August and September). In Palanpur, the mean mass of an acacia block was 27.29g, absorbing 3.33ml of soakate in 48 hours, and the mean mass of a plywood block 20.20g, absorbing 12.5ml in 48 hours.

Results and Discussion

The data obtained in Palanpur are summarised in Table 1, those from Thrissur in Table 2 and those from Thiruvananthapuram in Table 3.

Table 1. Persistence of MAT soaked-blocks of plywood and acacia wood in Northern Gujarat, as weekly catch totals, as means and standard deviations (<SD>; N=6). The fit of the decay of catches over time was very slightly closer to an arithmetic than to a geometric model. Over all twelve blocks (pooling the two treatments) the average Kolmogorov-Smirnov *D* for departure from the modelled distribution was 0.0489 <±0.0227> for arithmetic and 0.0524 <±0.0279> for geometric; the difference between the two values was not significant (related *t*=1.0632ns[5] {*P*=0.3105}). Accordingly, the arithmetic model was used for the calculation of “persistence” (the number of days for the daily catch to be reduced to one fly, as estimated by regression of catches against time). The slope of catches against time for the plywood block was positive, as catches increased, resulting in the nonsensical outcome of a negative value for days of persistence (i.e. intercepting when daily catch was in negative time - before the experiment began): this was taken to be a function of fluctuations in the abundance of the surrounding population, building up over the growing season, and not to affect the ability of the trial accurately to reflect the relative persistence of the two woods. In spite of the large size of this difference, it was not significant due to high internal variation among replicates. In terms of total catch, ply was significantly superior to acacia (related *t*=17.6229[5]* {*P*<0.0001}) but not in terms of persistence (related *t*=0.7341[3]ns {*P*=0.4959}).**

Day	Plywood		Acacia	
7	98	<20>	12	<2>
14	74	<12>	9	<3>
21	65	<12>	10	<3>
28	89	<17>	11	<4>
35	89	<17>	11	<4>
Total	415	<56>	53	<9>
Persistence	-79	<359>	68	<271>

Table 2. Weekly catches of orchard fruit flies by soaked MAT methyl-eugenol blocks of plywood and acacia in central Kerala, as means and standard deviations (<SD>; N=4). The fit of the decay of catches over time was closer to an arithmetic than to a geometric model. Over all eight blocks (pooling the two treatments) the average Kolmogorov-Smirnov *D* for departure from the modelled distribution was 0.0645 <SD±0.0364> for arithmetic and 0.1338 <±0.0622> for geometric; the departure from arithmetic was significantly smaller (related *t*=3.5754[3] {*P*=0.0090}). Accordingly, the arithmetic model was used for the calculation of "persistence" (the number of days for the daily catch to be reduced to one fly, as estimated by regression of catches against time). In terms of total catch, ply was significantly superior to acacia (related *t*=6.6334[3]* {*P*=0.0070}) but not in terms of persistence (related *t*=0.5394[3]ns {*P*=0.6271}).**

Day	Plywood		Acacia	
7	167	<101>	150	<52>
14	129	<18>	108	<17>
21	104	<45>	71	<18>
28	181	<38>	91	<20>
35	143	<24>	57	<21>
42	92	<29>	41	<27>
49	76	<61>	13	<10>
56	126	<71>	5	<3>
Total	954	<150>	533	<72>
Persistence	113	<1000>	383	<31>

Table 3. Performance of MAT blocks of plywood and acacia in Southern Kerala, as means and standard deviations (<SD>; N=4) of total catches per block over five months (April 1 to August 31) and the half-lives in months of their decay, with the outcome of related *t*-test comparisons.

Value	Acacia	Ply		*t*, [df], {*P*}
Total	914	1533	0	17.5158[3]***
(Count)	<148>	<83>		{0.0004}
Half-Lives	1.0	3.1	0	8.2289[3]** {0.0038}
(Months)	<0.1>	<0.6>		

Overall, acacia catches as a fraction of plywood catches were in Northern Gujarat 53/415=13%, in Central Kerala 533/954=56% and in Southern Kerala 914/1533=60%.

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~03/36[GBK];03/43[AWD]: Different Woods for Soaked-Block Fruit Fly MAT in Southern and Central Gujarat

Patel, ZP, Jhala, RC, Jagadale, VS, Sisodya, D, Stonehouse, JM, Verghese, A, Mumford, JD

Abstract

These studies evaluated the performance of different woods for MAT fruit fly control, hung in traps in farm fields to compare the volume and persistence of catch effectiveness. In Gandevi, 25cm2 ethanol:methyl-eugenol:malathion (6:4:1) blocks of eighteen different woods were assessed in mango orchards (N=6; with blocks arranged in "nested rings" to allow between-block variance to comprise differences due to "edge-effects"). The largest catches were by locally-sourced and Delhi-sourced plywood, with mean catches of respectively 710 and 709; other woods ranged from 644 by black plum to 52 by rosewood. Two thirds of the woods tested (twelve out of eighteen) caught less than half the largest catch including mango (355), acacia (249), teak (87) and sapota (71). Half-lives were calculated by the exponential regression of catches against time elapsed, but due to population fluctuations were not considered accurate measures of actual duration: the longest(16 days) was for black plum; those for plywoods were between 8 and 9 days. In Anand, 37.5cm2 ethanol:cue-lure:methyl-eugenol:DDVP (6:4:4:1) blocks of eight different woods were assessed in fields of little gourd (N=3). Take-up volumes

were largest for strawboard (21.7ml per block) followed by plywoods, *chil* and *maraso* (all between 13.3 and 15) and *babul*, *jambu* and neem (all below 12.5). In unadjusted catches, strawboard caught many more flies than the other woods; when catches were adjusted to allow for the different volumes taken up, for both guilds, significantly larger catches (overall $P<0.0001$) were obtained by *chil* (1556 flies caught overall), *maraso* (1471), strawboard (1451) and plywoods (1312 by Delhi ply, 1164 by local), and less so by *babul* (1056), *jambu* (906) and neem (672). There were no significant differences between orchard and melon species ($P=0.1228$). Half-lives of decays did not significantly differ - for melon flies between 41 and 388 days ($P=0.3601$), for orchard flies between 34 and 86 days ($P=0.1458$). Overall, even after discounting the volume of soakate taken up, the woods which took up the most caught the most flies.

Introduction, Materials and Methods

Male Annihilation Technique (MAT) blocks for fruit fly control may be made of any number of different woods. It may be anticipated that the type of wood may affect the performance of the block. This experiment aimed to compare the catch and persistence of blocks of different woods available to Indian farmers.

In orchards outside Gandevi, eighteen different woods, listed in Table 1, were deployed as MAT blocks in traps in six complete randomised blocks. The large number of treatments led to concerns about the incidence of “edge-effects”, whereby traps on the edges of complete randomised blocks are assumed to catch flies more readily than those inside them. This was addressed by the grouping of all experimental blocks into pairs - one full set of 18 treatments were arranged in a regular ring in an “outer” block, and another full set of 18 treatments in an “inner” block grouped in concentric rings inside this. The outer block was of 18 in a ring, the inner of three concentric rings, containing from the inside to outside 1, 6 and 9 traps to obtain a total of 18. All rings in the nested-ring design therefore had threefold radial symmetry, to allow all traps in the nested rings to be spaced as evenly as possible away from each other. Each trap in an outer ring block presented an equal length of face to the exterior, and no trap in an inner block presented any face to the exterior, so that variation due to edge effects would be subsumed into the term for variation between blocks.

Each block was assessed by its total catch, and half-life of catch decay. Half-lives were calculated from regression slopes of logged data, corrected for fluctuations by division by the relevant catches from the survey grid traps, against days elapsed. Survey trap data for the whole year were first hand-smoothed to obtain a single curve, then for the period of the experiment the relevant weekly figures were read from the curve. From each of these were subtracted the minimum value to obtain a ratio scale, and the experimental data were divided by these to obtain slopes of catch decay with compensation for fluctuations in the general population. It is not claimed that the half-lives estimated in this way are in fact accurate estimates of the durability of blocks; but they do permit the comparison of treatments for differences in their performance relative to each other.

In farm fields of little gourd outside Anandblocks of 37.5sqcm, soaked in a mixture of ethanol:cue-lure:methyl-eugenol:insecticide (DDVP) in the ratio of 6:4:4:1 by volume for 6 days. The blocks were made of the eight woods listed in Table 1. Traps were installed 20m apart in three complete randomised blocks, each block in a separate field between August 2002 and March 2003. Observations were taken of the volume of mixture absorbed by each set of three treatment blocks, and of the numbers of fruit flies caught at weekly intervals for 33 weeks. Flies were identified as either the melonfly *Bactrocera cucurbitae*, attracted to cue-lure, or members of the local complex of orchard fruit flies, attracted to methyl-eugenol, principally *B. dorsalis* and *B. zonata*.

Results and Discussion

A preliminary analysis of the Gandevi data compared the catches in the traps which formed the inner and outer blocks in the design, to assess the impact of edge-effects. This comprised a two-way analysis of variance, of catches by the 18 treatments in the inner and outer rings, with the three ring pairs as blocks, and found highly significant effects for treatments (ANOVA F=18.3035[17,70]*** {P<0.0001}) and between inner and outer rings (F=10.2759[1,70]** {P=0.0020}) but not for interaction between the wood treatments and the inner/outer rings (F=0.5807[17,70]ns {P=0.8953}). It was concluded that the nested-ring design was successful in absorbing edge-effects into the between-block variation term, and that there was no interaction between edge-effects and wood treatments, and so the analysis was recast as a conventional ANOVA comparing the 18 treatments across all six blocks, comprising both inner and outer rings. Table 1 gives the data as catches of flies over the length of the experiment and as half-lives of block catch decays in days. The differences between woods were very marked, but the relative effectiveness of the plywoods and inferiority of acacia confirm earlier findings. Plywood emerged as significantly superior in its catches to all other woods except jamun and neem. Plywood from two different sources - Delhi and the locality - did not significantly differ. The calculation of half-lives and their use for the assessment of durability remained inconclusive.

Table 1. Means and standard deviations (<SD>; N=6) of fly catches, and half-lives of catch decays, by MAT blocks of different woods outside Gandevi. Woods differed in total catches (ANOVA F=19.5420[17,85]* {P<0.0001}) and in half-lives (F=2.4481[17,85]** {P=0.0037}); catch means followed by differing letters differed significantly (P<0.05; for total catches Tukey's HSD=252.06, for half-lives HSD=7.80).**

		Total catch (insects)		Half-life (days)	
Linnean name	Local name	Mean	<SD>	Mean	<SD>
Plywood	Local-source	710a	<172>	8.8ab	<2.1>
Plywood	Delhi-source	709a	<208>	8.3b	<2.0>
Syzygium cumini L.	Black plum	644ab	<170>	16.2a	<12.4>
Azadirachta indica Juss.	Neem	520abc	<286>	10.6ab	<2.5>
Zizyphus mauritiana Lam.	Indian plum	439bcd	<111>	10.0ab	<5.1>
Morinda tomentosa Heyne	Aliyo	369cde	<192>	8.7ab	<2.6>
Mangifera indica L.	Mango	355cdef	<185>	9.7ab	<3.0>
Tamarindus indica L.	Tamarind	251defg	<131>	8.1b	<2.5>
Acacia nilotica (*indica*) L. (Bren.)	Acacia	249defg	<111>	9.4ab	<1.4>
Grewia titiaefolia Vahl.	Dhaman	223defg	<135>	7.6b	<2.1>
Gmelina arboria Roxb.	Seven	213defg	<111>	7.4b	<1.7>
Pterocarpus marsupium Roxb.	Malbar kino	152efg	<92>	5.8b	<0.9>
Tectona grandis L.	Teak	132efg	<87>	7.1b	<0.8>
Manilkara zapota L.	Sapota	119efg	<71>	8.6ab	<2.5>
Thespesia populnea L.	Tulip tree	105fg	<34>	6.0b	<1.0>
Shorea robusta Gaertn.	Sal	101g	<41>	10.2ab	<5.2>
Pithecolobium dulce Benth.	Monkey's bread	96g	<55>	6.1b	<1.6>
Dalbergia latifolia Roxb.	Rosewood	52g	<21>	6.9b	<0.6>

Catches outside Anand were evaluated as total catches, as the half-lives of catch decays, calculated by exponential regression of catch against weeks until the catch remained at zero for two successive weeks, and as total catches adjusted to disallow the effects of different volumes of soakate absorbed, by division by the volume recorded as absorbed by the three blocks of each type of wood. Catches were initially evaluated separately for melon flies and orchard flies, and are summarised in Table 2.

Table 2. Catches of fruit flies by MAT blocks made of different woods in field conditions outside Anand. “Take-up” is the volume in ml of soakate absorbed by each block. For melonflies, orchard flies and all flies, given are the means and standard deviations (<SD>; N=3) of total catch, the half lives of catches in days (calculated by exponential regression of catch against time until the catch remained at zero for two successive weeks) and total catches adjusted for the take-up of soakate absorbed (by the division of each unadjusted value by its volume of soakate absorbed, multiplied by the geometric mean of all volumes absorbed). Also given are *F* and *P* for analysis by two-way ANOVA (in all cases d.f.=[7,14]). Means not followed by the same letter differed significantly (*P*<0.05; Tukey’s Honestly Significant Difference for melonflies HSD=560.2, for orchard flies HSD=72.7, for all flies HSD=588.2). Interaction between species and woods was significant for unadjusted (*F*=4.1976[7,30] {*P*=0.0025}) but not for adjusted values (*F*=1.8058 [7,30]ns {*P*=0.1228}).**

	Take	Melonflies			Orchard flies			All flies	
Value	-up	Total	Half-life	Adjusted	Total	Half-life	Adjusted	Total	Adjusted
Chil	13.7	1410	68	1405a	152	62	151bc	1562	1556a
		<453>	<49>	<451>	<56>	<38>	<56>	<508>	<506>
Maraso	13.3	1277	156	1304ab	164	66	167ab	1441	1471ab
		<762>	<81>	<778>	<75>	<10>	<77>	<827>	<845>
Strawboard	21.7	1930	52	1213ab	379	45	238a	2309	1451ab
		<549>	<5>	<345>	<167>	<13>	<105>	<704>	<442>
Delhi ply	15	1263	105	1146ab	184	66	167ab	1446	1312ab
		<294>	<57>	<267>	<72>	<12>	<65>	<336>	<305>
Local ply	13.3	1000	388	1021abc	141	86	144bc	1140	1164abc
		<347>	<530>	<354>	<60>	<39>	<61>	<400>	<408>
Babul	11	755	42	935abc	98	34	121bc	853	1056abc
		<300>	<11>	<371>	<43>	<18>	<54>	<343>	<425>
Jambu	11	645	42	798bc	87	43	108bc	732	906abc
		<302>	<13>	<373>	<41>	<20>	<50>	<341>	<422>
Neem	12.3	526	41	581c	83	43	92c	609	672c
		<315>	<4>	<348>	<34>	<21>	<38>	<349>	<386>
F		15.9701 ***	1.2081 ns	5.9352 **	13.3825 ***	1.8971 ns	9.6579 ***	8.9559 ***	2.8945 *
{*P*}		<0.0001	0.3601	0.0024	<0.0001	0.1458	0.0002	<0.0001	0.0195

The largest number of melon flies were caught by strawboard when unadjusted for soakate take-up, but this was reduced relative to the others when take-up volume was taken into account. Strawboard had a shorter half-life than some though not all of the other woods, though these differences were not significant. For a combination of catching power adjusted for take-up volume and persistence in time, the plywoods emerged as attractive choices, though Maraso may be a plausible alternative. Apart from the change in rank-ordering of strawboard, the adjustment for soakate take-up did not alter the rank-order of the other woods - the implication is that the take-up of the “timber woods” other than strawboard was largely equivalent. In evaluation by catches of orchard flies, strawboard remained the wood with the largest catch even after adjustment to discount soakate take-up. The total number of orchard flies caught was substantially smaller than those of melon flies (attributable to the cucurbit-cultivating nature of the locality).

Overall, there was no evidence that woods differed in the decay rates of effectiveness as assessed by half-lives. Assessed by total catch, there was evidence that strawboard delivered the largest catches even after adjustment to allow for differences in volume of soakate taken up. There were no significant interactions between woods and insect species, once catches were discounted for soakate volume taken up. Overall, *chil*, *maraso*, strawboard and plywoods obtained satisfactory and broadly equivalent controls, and *babul*, *jambu* and neem woods less so. Even after discounting the volume of soakate taken up, the woods which took up the most caught the most flies.

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~03/17[BBL]: The Influence of Wood and Soaking Time on Cue-Lure MAT Blocks in Orissa

Singh, HS, Mohantha, A, Stonehouse, JM, Verghese, A, Mumford, JD

Abstract

Blocks of four woods - acacia, mango and “local” and “Delhi” plywoods - were soaked in a cue-lure MAT mixture for periods of five seconds, five minutes and two days, before being hung in fields outside Bhubaneswar to assess their power to attract and kill melonflies. Blocks soaked for longer times absorbed significantly more soakate mixture, although those soaked for five seconds caught more flies than those soaked for five seconds. Acacia wood absorbed significantly less than the others, and caught fewer flies, although this was not significant (P=0.6414). There were no significant differences in size or persistence of catches.

Introduction

MAT blocks offer promising control of orchard fruit flies in India. In order to maximise usefulness to farmers, the cost-effectiveness of blocks should be optimised, by obtaining maximum fly kill for minimum cost. The type of wood used, and duration of soaking time, may be manipulated to assist to optimise this.

Materials and Methods

Influence on the effectiveness of MAT blocks was assessed by counts of flies caught in traps containing blocks of different woods and soaked for different lengths of time. Woods used were local plywood, standard plywood from Delhi (for comparison with different local woods at other parts of India), mango and acacia. They were dipped in soaking solution (ethanol:cue-lure:malathion at 6:4:1 by volume) for either 5 seconds, 5 minutes (300 seconds) or 48 hours (172800 seconds). The treated blocks were hung in traps in bitter gourd fields outside Bhubaneswar on March 24, 2003, and five counts made of flies caught over a period of 14 days.

Results and Discussion

The volumes absorbed are shown in Table 1. Unsurprisingly, volumes increased with time immersed in the soaking mixture. Acacia absorbed significantly less than the other woods, which may explain its poor performance in field comparisons with plywood. Absorption by the two plywoods differed significantly, showing that not all plywoods may be the same in this regard.

Table 1. Means and standard deviations (<SD>; N=5) of the volume in ml of soaking liquid (ethanol:cue-lure:malathion at 6:4:1) absorbed by blocks of different woods immersed for 5 seconds, 5 minutes and 48 hours. There were highly significant differences attributable to woods (ANOVA F=204.4649[3,44]* {$P<0.0001$}), soak timing (F=1209.5729[2,44]*** {$P<0.0001$}) and interactions between them (F=82.8898[6,44]*** {$P<0.0001$}). Means not followed by the same letter differed significantly ($P<0.05$; Tukey’s HSD=1.379).**

Soak time	Mango	Delhi plywood	Local plywood	Acacia	Row means
5s	1.2 <0.2>	2.6 <0.3>	2.2 <0.2>	1.0 <0.2>	1.8
5m	2.0 <0.3>	3.5 <0.3>	2.6 <0.3>	1.0 <0.2>	2.3
48h	11.3a <1.0>	11.6a <0.7>	9.0b <0.8>	2.8c <0.3>	8.7
Column means	4.8	5.9	4.6	1.6	

The results were assessed in two ways. The first was as the total catches by each trap over two weeks, with the results shown in Table 2. The second was the rate of decline of catches over time, as half-life of persistence, calculated by least-squares exponential regression of catches against time. These regressions were carried out with data both unlogged and logged, and the fit obtained in the two ways compared by a related t-test of their correlation coefficients (CC), over the regression slopes of catch against time by all 60 blocks. The mean CC for arithmetic decay was 0.3300 <SD±0.3034> and that for geometric 0.3472 <±0.3068>; the fit to the geometric model was significantly superior (related t=2.4357[59]*), and accordingly the geometric-model regression slopes were used for the analysis, with the results shown in Table 3. As most block catches increased over the experimental period, all catches were weighted to a presumption that the population increased by a factor of 200% over the experimental period - as a result the half-lives estimated should be viewed as only meaningful relative to each other and not indicative of actual persistence times.

Table 2. Means and standard deviations (<SD>; N=5) of the total catches over the run of the experiment. No differences were significant (among woods ANOVA F=0.5644[3,44]ns {P=0.6414}, among soak times F=2.3062[2,44]ns {P=0.1116}, for interaction F=0.1105[6,44]ns {P=0.9948}).

Soak time	Mango	Delhi plywood	Local plywood	Acacia	Row means
5s	20.6 <20.1>	18 <14.1>	14.6 <5.9>	14.8 <13.8>	12.3
5m	12.4 <4.0>	10.4 <8.6>	11.2 <6.7>	6 <3.5>	10.0
48h	14 <10.1>	12 <8.9>	11.4 <4.4>	11.6 <9.6>	17.0
Column means	15.7	13.5	12.4	10.8	

Table 3. Means and Standard Deviations (<SD>; N=5) of half-lives of the geometric progression of catches over time. No differences were significant (among woods ANOVA F=1.3849[3,43]ns {P=0.2602}, among soak times F=1.3954[2,43]ns {P=0.2587}, for interaction F=0.2108[6,43]ns {P=0.9715}; in the ANOVA one cell missing due to absence of data - acacia at 5m - was filled with the mean of the other replicates in its cell and one residual degree of freedom deducted).

Soak time	Mango	Delhi plywood	Local plywood	Acacia	Row means
5s	0.5 <13.1>	9.9 <31.0>	-6.4 <10.7>	9.8 <55.0>	3.4
5m	14.2 <11.1>	26.0 <14.3>	1.3 <12.3>	28.5 <22.4>	17.5
48h	11.1 <54.8>	17.9 <11.8>	3.8 <13.7>	6.2 <25.3>	9.7
Column means	8.6	17.9	-0.4	14.8	

No differences were detectable among the experimental treatments for either catch or persistence. While possibly indicating that there may be no difference between costlier and cheaper woods, and that briefly-soaked blocks may perform as well as those soaked for longer periods, these results do not allow conclusions to be drawn. There may be difficulties in the adjustment of soaking time to manipulate catches, as in all cases blocks soaked for five seconds caught more flies, on average, than those soaked for five minutes.

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~03/05[VTB]: Rubber Septa as Soaking Substrates for Fruit Fly Lures in Eastern Uttar Pradesh

Satpathy, S, Swamy, S, Rai, S, Stonehouse, JM, Verghese, A, Mumford, JD

Abstract

The catching power of cue-lure with insecticide soaked into substrates of three different rubbers was assessed, by slopes of decay in comparison with those of wooden blocks hung alongside, in traps in fields outside Varanasi. No differences between rubbers were apparent, and the three rubbers as a group indicated a shorter duration than corresponding woods (slope of progression for woods 0.28, for all rubbers 0.05) though this was not significant (*P*=0.1111).

Introduction, Materials and Methods

Many commercial formulations of blocks soaked in lures and insecticides for insect control by male annihilation use as a soaking substrate blocks of rubber which dispense vapour more smoothly and slowly than more primitive substrates such as plywood. This experiment assessed the persistence, relative to wooden blocks, of three commercially-available synthetic rubbers, of types similar to those used in commercial lure dispensers, in farm fields around Varanasi, Uttar Pradesh. Each attractant was placed in a 1L plastic-water-bottle trap and hung in the field for 109 days from July 27 to November 12, 2003. Each rubber septum was accompanied by a conventional soaked-plywood block, to allow its persistence to be precisely calibrated. Pairs of rubber-and-wood dispensers were soaked in ethanol, cue-lure and malathion insecticide, and hung in the field in two complete randomised blocks.

The first analysis was the linear regression of decay of catches in all traps, and the comparison of all rubbers as a group against the corresponding wood blocks. The second was the calculation of the catch of each rubber septum as a fraction of its wooden companion. As daily wooden block catches were often zero, to avoid division by zero all catch data were pooled into weekly totals (even so one week obtained zero catches in one wooden block - with white rubber - for all seven days; this was addressed by moving to this week, for this one cell, the single day's data from the last day of the preceding week). Data records in each block were ended two days after all its daily rubber septa lure catches had settled to zero. This obtained for one block sixteen weekly data points, and for the other eight. Comparison of half-lives was not possible as two of the six cells had positive slopes, and therefore negative half-lives which could not be statistically combined with the other values. As a result, rubber septa were compared by the slope of the daily decline of the natural logarithm of their catches as a fraction of catches by wooden blocks (i.e. as LN[RubberCatch/WoodCatch]). These logarithmic slopes were calculated for each rubber type in each of the two blocks.

Results and Discussion

Due to rising fly populations, catches in general rose over the duration of the experiment. The mean slopes of catch progress over time were for wood 0.28 <SD=0.23> and for all rubbers 0.05 <SD=0.07> though this difference was not significant (related *t*=1.9327[5]ns {*P*=0.1111}).

Table 1. Means and standard deviations (<SD>; N=2) of slopes of logarithmic decay of daily catches of fruit fly parapheromone lures of synthetic rubber, as percentages of those obtained by wooden blocks hanging nearby. Compared by ANOVA for complete randomised blocks, and including values of zero for the wooden blocks alongside, differences were not statistically significant (*F*=1.6549[3,3]ns {*P*=0.3446}).

Brown	Black	White
-0.03	-0.011	-0.014
<0.019>	<0.024>	<0.033>

Table 1 gives the means and standard deviations of the slopes of logarithmic decay of catches by rubber septa as fractions of those of their accompanying wooden blocks. ANOVA comparison of these with wooden-block values (included as zero as wood-block relative decay slopes were zero by definition) no significant differences could be seen. The implication, though not conclusive, was that rubber septa were neither superior nor inferior to the wooden blocks.

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6C. Parapheromone Lures: Soaking Solvents and Additives

~03/49[SSL];04/16[ASL;ASM]: Effectiveness of Different Solvents for Soaked-Block Annihilation of Male Fruit Flies in Northern and Central Gujarat

Patel, RK, Jhala, RC, Joshi, B, Sisodya, D, Stonehouse, JM, Verghese, A, Mumford, JD

Abstract

The usefulness of alternatives to the conventional ethanol, as solvents for soaking plywood methyl-eugenol MAT blocks for fruit fly management, was assessed by placing blocks soaked in four different solvents in orchards near Palanpur (N=4). In terms of total numbers of flies caught, there was significantly different interaction between fly species and the four solvents (P=0.0001) though this was hard to interpret. Among species, catches of *zonata* were substantially greater than those of *dorsalis*; among solvents, the largest catches were by ether (122 flies), and ethanol (101), followed by kerosene (81) and petrol (76) and these differed significantly (P<0.0001). In terms of the half-lives of catch duration, petrol (101 days) and kerosene (76 days) were significantly more persistent than ether (56) and ethanol (51), but these differences were not enough to discount the superior catch totals of ethanol and ether. Ethanol and ether performed similarly, and the selection of which as the most suitable solvent in any individual case will depend on considerations of availability, cost and safety. In a similar study in fields near Anand, candidate solvents were assessed by hanging blocks soaked in lure, DDVP insecticide and solvent in traps(N=3) and counting weekly catches. There were significant differences in catches by cue-lure over twenty weeks (P=0.0101) - ethanol caught 423 flies, hexane 350, ether 296, benzene 293, water 256, petrol 254, diesel 252, acetone 251, kerosene 241 and country wine 192; persistence also differed (P=0.0002) the longest being obtained by kerosene (with a half life of 81 days), followed by ethanol (64 days), hexane (63), ether, (52) and benzene (47); all other half-lives were 35 days or less. Using methyl-eugenol over three weeks, the largest mean total catch was by ethanol (75), followed by petrol (64), water (59), kerosene (46) and diesel (26), but there were no significant differences among catch totals (P=0.1125) or persistence rates (P=0.7265). Methyl-eugenol traps caught 147 *Bactrocera dorsalis*, 8 *B. correcta* and 6 *B. zonata*. In terms of catch the best alternatives to ethanol were hexane (83% of ethanol) and ether (70%); the best of the readily available alternatives were petrol (73% of ethanol) and water (70%).

Introduction, Materials and Methods

These experiments compared the catch and persistence of MAT blocks made with different solvents, to assess the feasibility of alternatives which may be cheaper or easier to obtain than the conventional ethanol. Plywood MAT blocks of 5x5x1.2cm were soaked in a mixture of solvent:lure:insecticide at 6:4:1 by volume, and hung inside traps in farm fields, and the catch of flies recorded weekly to allow the size and persistence of fly catches to be quantified.

In a study near Palanpur in the mango season of 2003, using methyl-eugenol and commercially-available malathion EC, the test solvents were ethanol, ether, kerosene and petrol. Blocks soaked in each of the four solvent mixtures were hung in traps in four complete randomised blocks in fruit orchards. Treatments were initially evaluated as total numbers of flies caught, by species, over the trapping period. Treatments were also evaluated for the persistence of effectiveness. First, the catches for fly species were combined, as numbers of *B. dorsalis* were insufficient for regression analysis, and it was not considered likely that catch efficiency would decline differentially for the different species. Second, catch data were weighted to adjust for the (very large) fluctuation in the surrounding population over the trapping period: catches from a parallel trapping survey, using methyl-eugenol traps which were regularly replenished, were converted into weekly population estimates by hand-smoothing the curve of catches over time; each catch datum was then weighted by division by the corresponding population estimate and multiplication by the geometric mean of all the population estimates. Third, data were converted to natural logarithms (with the addition of one to forestall calculating the logarithm of zero) and regressed against days elapsed. Fourth, from this the half-life of catch efficiency of each trap, in days, was calculated as the natural logarithm of 0.5 divided by this regression slope.

In two studies in farm fields near Anand in 2004 using DDVP, soaked blocks were hung in the traps in three complete randomised blocks. Cue-lure was assessed in cucurbit fields, with ten candidate solvents for twenty weeks from July; methyl-eugenol was assessed in fruit orchards, with five solvents for three weeks in December.

Results and Discussion

Catches by blocks made with various solvents in Palanpur, and the half-lives of the decay of these catches, are given in Table 1. Ethanol and ether were superior to both kerosene and petrol in terms of total numbers of flies killed. The significantly superior persistence of petrol was not adequate to compensate for its significantly inferior killing power.

Table 1. Means and standard deviations (<SD>; N=4) of total catch numbers and half-lives of catches in days, between June 4 and November 4 2003 by MAT blocks using different solvents, near Palanpur. For total catches by each species, all differences were highly significant (for solvents F=16.6295[3,21]* {P<0.0001}; for species F=1163.0883[1,21]*** {P<0.0001}; for interaction F=11.0694[3,21]*** {P=0.0001}); subsequent mean-separation tests were performed for each species separately. For catch half-lives (with species pooled), F=16.7596[3,9]*** {P=0.0005}). Means not followed by the same letter differed significantly (P<0.05; for *zonata* catch Tukey's HSD=20.6, for *dorsalis* HSD=3.4, for half-lives HSD=44.9).**

		Ethanol	Ether	Kerosene	Petrol
Catch total (number of insects)	*B. zonata*	97ab	116a	79b	75bc
		<10>	<11>	<15>	<8>
	B. dorsalis	4ab	6a	3ab	1b
		<3>	<2>	<2>	<1>
	Total	101	122	81	76
Catch half-life (days)		51b	56b	76ab	101a
		<5>	<7>	<15>	<41>

Table 2 shows the solvents assessed, and the mean volume of material absorbed per plywood block by different solvents containing the two lures in Anand. Table 3 summarises the catches by cue-lure and Table 4 those by methyl-eugenol, divided among the three orchard species found.

Table 2. The mean volumes of soakate liquid absorbed by each individual plywood block in Anand, for mixtures containing candidate solvents, two different lures, and DDVP insecticide in 6:4:1 v:v:v ratio, in ml per block.

Candidate solvent	Cue-lure	Methyl-eugenol
Ethanol	11.8	11.7
Hexane	15.3	-
Ether	15.3	-
Benzene	12.7	-
Water	11.8	10.0
Petrol	15.3	12.7
Diesel	9.8	10.0
Acetone	14.0	-
Kerosene	9.7	8.7
Country wine	11.8	-

Table 3. Means and standard deviations (as <SD>: N=3) of catches by cue-lure as total catches per trap per week and half-life in days. There were significant differences among total catches (*F*=3.5892[9,18]* {*P*=0.0101}) and half-lives (*F*=7.1399[9,18]* {*P*=0.0002}). Means followed by different letters differed significantly at the 0.05 level (for total catch Tukey's HSD=174, for half-life 34).**

	Total catch		Half-life	
Ethanol	423a	<64>	64ab	<16>
Hexane	350ab	<65>	63ab	<8>
Ether	296ab	<48>	52abc	<16>
Benzene	293ab	<81>	47bc	<9>
Water	256ab	<35>	35bc	<3>
Petrol	254ab	<52>	34bc	<2>
Diesel	252ab	<72>	33bc	<9>
Acetone	251ab	<109>	32bc	<3>
Kerosene	241b	<28>	81b	<33>
Country wine	192b	<20>	27c	<7>

Table 4. Means and standard deviations (as <SD>; N=3) of total catches by methyl-eugenol of three orchard *Bactrocera* species, and mean half-lives in days. (Half-lives are given as means without standard deviations as, because some slopes were positive, these could not be calculated for all individual cells; when assessed by ANOVA of slopes there were no significant differences among treatments - *F*=0.7317[14,28]ns {*P*=0.7265}). Among total catches, there were significant differences among species (*F*=63.5995[2,28]* {*P*<0.0001}) but not due to solvents (*F*=2.0636[4,28]ns {*P*=0.1125}) or to interaction between them (*F*=1.9295[8,28]+ {*P*=0.0949}).**

Bactrocera	*dorsalis*			*zonata*			*correcta*			Row means
Variable	Total		½ life	Total		½ life	Total		½ life	(Total)
Ethanol	208.7	<91.5>	46	8	<2.6>	26	8	<2.6>	24	75
Petrol	176.3	<107.0>	45	6.3	<2.9>	17	9.3	<2.5>	24	64
Water	163.3	<73.4>	38	5.3	<3.1>	30	7.3	<3.2>	23	59
Kerosene	123.3	<62.1>	34	6.0	<2.6>	22	7.3	<1.2>	51	46
Diesel	65.0	<19.7>	37	5.0	<2.0>	16	7.7	<1.5>	28	26
Column means	147			6			8			

Table 5 compares the rank performances of those solvents common to all three assessments, and indicates the consistency of the general superiority of ethanol.

Table 5. Comparative rank performances of those solvents common to the assessments with all three lures.

	Palanpur	Anand	
Solvent	Methyl-eugenol	Cue-lure	Methyl-eugenol
Ethanol	2	1	1
Ether	1	2	-
Petrol	4	4	2
Water	-	3	3
Kerosene	3	6	4
Diesel	-	5	5

In Palanpur ethanol and ether performed similarly, and the selection of which as the most suitable solvent in any individual case will depend on considerations of cost and safety. In Anand the only plausible alternatives to ethanol, though less effective, were hexane (with a catch of 350/423=83% of ethanol) and ether (296/423=70%). Of more readily-available candidates the best performances were by petrol (254/423=60% and 64/75=85%, with a mean of 73%) and water (256/423=61% and 59/75=80%, with a mean of 70%) but these were not credibly close to the performance of ethanol. In conclusion, where ethanol, the conventional solvent, is not available (as in Islamic and other regimes, including Gujarat) ether may be used as a substitute with very similar levels of performance.

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~03/41[ABT]: Persistence of Fruit Fly Catches by Soaked Blocks with and without Butylated Hydroxy Toluene in Central Gujarat

Jhala, RC, Sisodya, D, Stonehouse, JM, Verghese, A, Mumford, JD

Abstract

Wooden MAT blocks soaked in lures - both methyl-eugenol and cue-lure - and insecticide were hung in traps near Anand (N=1) to assess the effects of the addition of Butylated Hydroxy Toluene (BHT), which is sometimes useful in enhancing the persistence of MAT blocks. The presence of BHT reduced the volume of lure taken up by each block, and with it total catches were lower than without, by a larger ratio than the reduction in lure content as a consequence of the BHT addition. The half-lives of catches by BHT and no-BHT blocks, as, respectively, 37 and 41 days, were not noticeably different.

Introduction, Materials and Methods

Wooden blocks soaked in lure and insecticide for the control of fruit flies by Male Annihilation Technique (MAT) have in some cases shown to have their persistence enhanced by the addition of Butylated Hydroxy Toluene (BHT). The effect of this additive was assessed using plywood MAT blocks. Blocks were soaked in a mixture of lure and insecticide, with and without BHT, and hung in the field outside Anand, Gujarat, between May and November, 2003, with weekly catches counted to allow the comparison of the persistence of effects. Treatments were blocks of 5x5x1.2cm of ply wood, soaked in ethanol solvent, "Cue-Lure" attractant (CL) for *Bactrocera cucurbitae*, methyl-eugenol attractant (ME) for *B. dorsalis* and *B. zonata*, and a commercial emulsifiable concentrate preparation of insecticide (DDVP) in the ratios of Solvent:CL:ME:DDVP of 6:4:4:1 by volume.

Due to the small quantities of BHT available, the treatments were not replicated. One block of each type was soaked in this liquid for seven days, with or without the addition of BHT; the quantities of materials absorbed were recorded, and the blocks were hung in the field in 1L plastic traps on May 1, 2003, and the catches of flies recorded weekly from May 8 for 30 weeks.

Results and Discussion

The BHT Block absorbed 15ml of soaking liquid and 12g of BHT, and the no-BHT Block 20ml. Table 1 shows the comparison of the two blocks, in catches of both *B. cucurbitae* and orchard flies, as total catches and half-lives of persistence. The BHT gave no indication of enhancing the persistence of block catches. The reduction in catch totals, inferred from the addition of BHT, was greater than that indicated by the lower levels of attractant in the BHT block due to its uptake of a smaller volume: the catches expected from this would have been, for melonfly catches 1342x15/20=1007, and for orchard fly catches 542x15/20=407, both larger than those obtained. The experiment gave no indication that the addition of BHT may lengthen the persistence of MAT blocks, and it may reduce the numbers of flies caught.

Table 1. Catches of fruit flies by wooden blocks soaked in lure, solvent and insecticide with and without BHT. Each value is the performance of a single trap as treatments were unreplicated. Given are total catches of individual flies after 200 days, and the half-lives of catches in days, calculated from an exponential regression until the catch of each trap had remained at zero for two weeks. Values "together" are totals of catches and means of half-lives for the two.

	Melonfly		Orchard flies		Together	
	With BHT	Without BHT	With BHT	Without BHT	With BHT	Without BHT
Totals	630	1342	402	542	1032	1884
Half-lives	45	48	29	33	37	41

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6D. Parapheromone Lures: Shelf-Life and Persistence

~04/15[ASF;ASG]: The Keeping Properties in Storage of Wooden MAT Blocks in Central Gujarat

Sisodya, D, Jhala, RC, Stonehouse, JM, Verghese, A, Mumford, JD

Study conducted as part of the IMFFI-associated project

Biology and Management of Bactrocera cucurbitae *Infesting Bitter Gourd*

Abstract

The effects on the performance of plywood MAT blocks of time spent in storage before use was assessed by storing blocks for different lengths of time. Soaked blocks were wrapped tightly in aluminium foil and plastic bags and then stored for 0,1,2,3,4 and 5 months before being hung in the field in traps to assess their performance (for methyl-eugenol N=4, for cue-lure N=2). The catching power of methyl eugenol blocks declined with a half-life of 99 days in storage, and that of cue-lure blocks with a half-life of 100 days in storage; the decay of methyl-eugenol blocks in terms of catch persistence could not be concluded, but the persistence of cue-lure blocks was inferred to decay with a half-life of 377 days in storage.

Introduction, Materials and Methods

This study evaluated the performance in the field of blocks of different ages in order to assess their shelf-lives. Blocks were wrapped tightly in aluminium foil, then plastic bags, then left for 0,1,2,3,4 and 5 months. Blocks were then hung in gourd fields near Anand in complete randomised blocks, cue-lure in four replicates between March 15 and November 15 and methyl-eugenol in two replicates between March 15 and October 7. Numbers of flies caught were recorded weekly.

Results and Discussion

1. Methyl-eugenol blocks

Table 1 summarises the numbers of flies caught by methyl-eugenol blocks aged for different periods of time. It was clear that over time in storage the power of blocks was undermined, losing half their effectiveness over a mean of 99 days.

Table 1. Means and standard deviations (as <SD>;N=2) of the catches of three *Bactrocera* species by methyl-eugenol blocks stored for different numbers of months, and of half-lives in days of the decay of catching efficiency of blocks during storage. Catches by each block were regressed against the time they had been stored, separately for the two replicates and three species caught, with data untransformed and as logarithms. The fit for the logged-data model (r^2=0.8002 <SD=0.3118>) was slightly superior to that for the untreated-data model (mean r^2=0.7830 <SD=0.2914>); this difference was not significant (related *t*=0.7990[5]ns {*P*=0.4606}). The logged model was chosen for regression analysis which obtained the estimations of the half-lives of the decay of catching power, under storage conditions, shown at the foot of the table. There were no significant differences among values for the three species (*F*=0.8124[2,2]ns {*P*=0.5518}).

Months	*Bactrocera*			All
aged	*dorsalis*	*correcta*	*zonata*	three
0	838 <575>	53 <20>	116 <1>	336
1	696 <524>	25 <8>	80 <7>	267
2	586 <436>	20 <11>	72 <3>	226
3	482 <385>	21 <1>	61 <4>	188
4	406 <335>	16 <13>	46 <5>	156
5	350 <310>	21 <3>	30 <8>	133
½ life (days)	102 <28>	115 <28>	79 <19>	99

The data also permitted comparison among blocks stored for different periods of the decay of catching power over time once deployed in the field. Table 2 summarises the relationships between the storage time of blocks and the subsequent decay of catches when the blocks were in the field. No relations were apparent.

Table 2. Means and standard deviations (as <SD>: N=2) of the slopes of the association between the number of months of storage of methyl-eugenol MAT blocks and the slope of the subsequent decay of catches when the aged blocks were hung in the field, given for three *Bactrocera* species, with the output of *t*-tests of each slope against zero (i.e. no relationship). A positive slope indicates that as blocks were stored for longer times the slopes of the decay of their subsequent catches (which were negative as catches declined), became less negative (shallower) entailing a slower decay of effect, i.e. a positive association indicates that older blocks may have caught fewer flies but their powers decayed more slowly.

Bactrocera	Mean	SD	$t_{(slope=0)}$[5]	*P*
dorsalis	0.001	<0.0007>	0.9769ns	{0.3735}
correcta	0.0019	<0.0002>	7.8310***	{0.0005}
zonata	0	<0.0006>	0.4799ns	{0.6515}

2. Cue-lure blocks

Table 3. Means and standard deviations (as <SD>; N=4) of catches of melonflies by cue-lure blocks soaked in lure and insecticide and then aged in storage for between zero and five months. Catches and half-lives for each block were regressed against the time they had been stored, separately for the four replicates, with data untransformed and as logarithms. For both variables the fit for the logged-data model was slightly superior to that for the untreated-data model (for total catch, logged model mean r^2=0.9699 <SD=0.0295>, untreated model mean r^2=0.9411 <SD=0.0304>, related t[3]=3.6563* {P=0.0353}; for half-lives logged model mean r^2=0.9037 <0.0573>, untreated model mean r^2=0.8975 <0.0464>, t[3]=0.9697ns {P=0.4037}). The logged models were chosen for regression analysis which obtained the estimations of the half-lives of the decays of catching power, under storage conditions, shown in the final column of the table.

Months aged	0	1	2	3	4	5	Half-life (days)
Total catch	862 <201>	669 <178>	560 <110>	464 <116>	358 <62>	318 <41>	100 <18>
Half -life	51 <4>	46 <1>	45 <2>	43 <2>	41 <2>	38 <1>	377 <102>

Table 3 summarises the performance of cue-lure blocks stored for different periods of time. Over time in storage, both the catching power and the persistence of blocks decayed significantly, catching power with a half-life of 100 days in storage and persistence with a half-life of 377 days in storage

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~03/01[LWT]: Effects of Simulated Rainwater on MAT Blocks in Central Uttar Pradesh

Stonehouse, JM, Shukla, R, Manzar, A, Verghese, A, Mumford, JD

Abstract

The effects of simulated rain on MAT blocks were studied by the regular application of precise volumes of water to individual blocks, and the assessment of the effects by recording their subsequent catches of flies when placed in traps in six complete randomised blocks in the field near Lucknow. The efficacy of blocks, of plywood soaked in methyl-eugenol, insecticide and solvent, was significantly reduced by regular wetting. Heavier "rain" had more serious effects than lighter, and the same amount in daily "showers" had effects more serious than in a weekly "downpour".

Introduction

Male annihilation technique (MAT) by wooden blocks soaked in insecticide and parapheromone lure offers promise for the large-scale management of orchard fruit flies in India. A concern about the suitability of these blocks centres on their vulnerability to rain, which may reduce their effectiveness by leaching out the soakate or inhibiting its freedom of evaporation from the surface. This experiment aimed to simulate the rain-wetting of blocks, by different regimes of rainfall intensity and pattern, and to assess the reduction of their effectiveness at killing flies in a mango orchard outside Lucknow, Uttar Pradesh.

Materials and Methods

Identical MAT blocks were dripped with different levels of fresh water in the laboratory and then hung out in the field for the assessment of their catching efficacy, on a weekly rotational basis (wetting – field assessment – wetting – field assessment – etc). They were hung in traps in the afternoon on Fridays, and collected and assessed by counting the trap catch in the late morning the following Monday. As flies are active at twilight this allowed for three twilight "days" per week in the field. Blocks wetted five times weekly were wetted at midday on Mondays, Tuesdays, Wednesdays, Thursdays and Fridays. Blocks wetted once weekly were wetted at midday on Tuesdays.

Blocks were 5x5x1.2cm blocks of plywood, soaked for a week in ethanol solvent, methyl-eugenol and malathion EC in a 6:4:1 volume ratio for one week. Wetted blocks received a simulated rain dose which was either “Light” (5mm of rain weekly), “Medium” (25mm weekly) or “Heavy” (125mm weekly). Half of the wetted blocks received their weekly dose of rain in one single wetting, the other half on five successive days (in five daily wettings of respectively 1, 5 and 25mm of rain equivalent). There were thus six different wetted treatments (deployed in the field alongside an unwetted block). During the five-day wetting period, blocks were kept indoors, protected from the rain, below a grid of drippers to apply the wetting regime, each individual block below one dripper. Each individual dripper was made of a 2L soft drink bottle, its base cut off and a narrow hole made in its screwtop with a heated needle, inverted so that a volume of water poured into the upward-facing open base emerged as a thin dribble through the hole in the screwtop onto the block placed just below. Individual drippers were used in a battery of 36 lashed together. Drippers were bound together with sticky-tape and lashed with string to a bamboo frame mounted on stands on a laboratory bench. Blocks were placed, each below its dripper, on a wire mesh grid (to allow the dripping water to drain off the blocks) lashed on a second bamboo frame below the drippers, so that each block was 3cm below its dripper. Below the wire grid were placed drip trays so that fallen water (also containing considerable numbers of fruit flies attracted into the laboratory and killed by the blocks) could be collected and poured away. Once each block was placed below its dripper on Monday, the wetting regime was implemented by pouring the specified volume of water into the top of each dripper and allowing it to dribble through onto the block below. The blocks were positioned flat and so presented 5x5=25sqcm to the rain. So 5mm of rain was represented by 0.5x25=12.5ml of water, 25mm of rain by 2.5x25=62.5ml, and 125mm of rain by 12.5x25=312.5ml. Collection and measurement of water having dribbled through the drippers confirmed that small quantities were lost, as drops adhering to the vessel sides which then dried, so the three application volumes (12.5, 62.5 and 312.5ml) were increased slightly in the volumes added to each dripper (to 13, 63 and 313ml respectively).

Blocks were hung in mango trees weekly to assess their effectiveness in the field in traps of 1L plastic drinking-water bottles, which protected them from the (real) rain and allowed the collection and counting of killed flies before they were relocated to the laboratory every Monday morning. They were deployed in six complete randomised blocks (for the seven treatments a total of 6x7=49 traps) and each block was placed in the same location every Friday afternoon. The experiment was started at the beginning of June 2004 and continued for fourteen weeks.

Results and Discussion

Table 1. Means and standard deviations (<SD>; N=6) of catches by blocks soaked for different regimes weekly in the mango season of 2004 outside Lucknow.

	Wet daily			Wet weekly			
Week	Light	Medium	Heavy	Light	Medium	Heavy	Dry
1	40.7	33.3	24.8	41.7	41.3	38.8	78.3
	<9.8>	<18.9>	<26.8>	<14.4>	<14.9>	<21.9>	<34.5>
2	45.5	31.3	29.2	56.7	46.7	38.0	65.0
	<22.3>	<14.5>	<26.6>	<28.0>	<24.3>	<26.3>	<37.0>
3	37.3	36.5	22.7	79.0	73.3	67.5	128.5
	<4.9>	<6.5>	<8.9>	<10.0>	<14.3>	<14.0>	<11.5>
4	6.5	6.2	5.7	15.5	11.7	7.3	22.3
	<2.4>	<1.2>	<1.6>	<4.1>	<2.2>	<4.5>	<2.5>
5	23.5	20.8	13.8	45.8	30.5	25.3	136.3
	<5.1>	<2.0>	<2.5>	<3.3>	<7.6>	<3.2>	<27.6>
6	39.5	31.0	15.5	41.0	38.0	29.8	73.3
	<6.2>	<6.8>	<3.1>	<8.2>	<14.3>	<8.5>	<8.7>
7	8.7	8.0	4.0	16.7	10.7	7.2	27.0
	<3.3>	<2.4>	<2.4>	<1.8>	<2.2>	<3.7>	<2.4>
8	0.5	0.3	0.2	0.8	0.7	0.5	1.8
	<0.8>	<0.5>	<0.4>	<1.0>	<0.8>	<0.5>	<2.0>
9	0.2	0.0	0.0	0.7	0.5	0.2	0.8
	<0.4>	<0.0>	<0.0>	<0.8>	<0.5>	<0.4>	<0.8>
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	<0.0>	<0.0>	<0.0>	<0.0>	<0.0>	<0.0>	<0.0>
11	0.2	0.0	0.0	0.5	0.0	0.0	0.5
	<0.4>	<0.0>	<0.0>	<0.8>	<0.0>	<0.0>	<0.8>
12	0.2	0.0	0.0	0.5	0.2	0.0	0.7
	<0.4>	<0.0>	<0.0>	<0.8>	<0.4>	<0.0>	<0.8>
13	0.0	0.0	0.0	0.2	0.0	0.0	0.3
	<0.0>	<0.0>	<0.0>	<0.4>	<0.0>	<0.0>	<0.5>
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	<0.0>	<0.0>	<0.0>	<0.0>	<0.0>	<0.0>	<0.0>

Table 1 shows the catches by all seven treatments over fourteen weeks. From the first week the catches by all six wetted blocks was roughly half that of the dry blocks; but they remained at about half the dry block catches for several weeks, instead of immediately continuing to decline. There was an abrupt collapse of catches by all blocks between Weeks 7 and 8, indicating a crash in the local fly population, possibly related to a downpour of real rain on July 25th (the blocks in traps were protected from real rain to ensure the applied wetting was all they received), although more intense rainfall had fallen in the third week in June. Table 2 shows catches as totals and those in the first seven and last seven weeks, and half-lives in days. Treatments were highly significantly different in terms of total catch *F*=59.2545[6,41] {*P*<0.0001} and half-lives (*F*=15.9812[6,41] {*P*<0.0001}). The shorter half-life for dry blocks was due to their very considerably superior catches in the first week: it may be inferred that the loss of power by wetting is more pronounced in the early stages of block deployment, while the soaking liquid is still damp.

Table 2. Catches by blocks under various wetting regimes, as totals and those in the first seven and last seven weeks, and half-lives in days.

		Daily			Weekly			Dry
	mm	12.5	62.5	312.5	12.5	62.5	312.5	0
Total catch	Mean	203	168	116	299	254	215	535
	<SD>	<24>	<35>	<53>	<34>	<31>	<49>	<76>
First half	Mean	202	167	116	296	252	214	531
	<SD>	<25>	<35>	<53>	<33>	<31>	<49>	<76>
Last half	Mean	1	0	0	3	1	1	4
	<SD>	<1>	<1>	<0>	<2>	<1>	<1>	<3>
Half-lives	Mean	14	14	16	13	13	14	11
	<SD>	<1>	<1>	<2>	<1>	<1>	<1>	<1>

Table 3 shows the data from the six wetted treatments recast with row and column means. Among the six wetted treatments were highly significant differences due to wetting weight (*F*=18.6577[2,25]*** {*P*<0.0001}) and frequency (*F*=67.0515[1,25]*** {*P*<0.0001}) but not to interaction between them (*F*=0.1178[1,25]ns {*P*=0. 8894}).

Table 3. Total catches by blocks under six wetting regimes cast as a factorial table.

mm	12.5	62.5	312.5	Row means
Daily	203	168	116	162
Weekly	299	254	215	256
Column means	251	211	165	

Further analysis of wetting regimes was by conversion of the catch data from the wetted blocks to percentages of those from the adjacent dry blocks (i.e. that in each experimental replicate block), to study the decline in power of wetted blocks as a fraction of dry ones. This conversion was impossible with dry block catches of zero, so the catches of the six weeks from Week 8 onwards were pooled (even so in one replicate block the catch for these six week was zero - a notional catch of one fly over these weeks in this one trap was inserted). The resulting figures for percentage catch by wetted blocks of that of adjacent dry blocks were converted to logarithms (after the addition of 1 to forestall the calculation of LN(0)) and the resulting slopes, and half-lives derived from these in weeks, are given in Table 4. The half-lives are recast as a factorial table in Table 5.

Table 4. Means and standard deviations (<SD>; N=6) of regression slopes of logarithms of fractional catches by wetted blocks as fractions of those by adjacent dry blocks. Below these are given half-lives in weeks of the decline of wetted block catches relative to dry block catches, calculated as LN(0.5)/slope.

	Wet daily			Wet weekly		
	Light	Medium	Heavy	Light	Medium	Heavy
Slope	-0.15	-0.23	-0.29	-0.02	-0.17	-0.19
	<0.24>	<0.22>	<0.21>	<0.10>	<0.17>	<0.27>
Half-life (weeks)	32	21	17	299	29	26

Table 5. The half-life data from Table 4 recast as a factorial table with marginal means.

	Light	Medium	Heavy	Row means
Daily	32	21	17	23
Weekly	299	29	26	118
Column means	166	25	21	

The marginal means in Table 5 suggest that the same weekly amount of water was less damaging to blocks' effectiveness when applied in one weekly downpour than in five daily showers; they also suggest that light weekly rain was considerably less damaging than any other regime. The slope data from Table 4 were subjected to a two-way factorial ANOVA for complete randomised blocks, but this found no statistically significant results: for wetting dose F=2.5280[2,25]ns {P=0.1000}; for wetting frequency F=2.8757[1,25]ns {P=0.1023}; for interaction F=0.1071[2,25]ns {P=0.8989}.

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~04/01[GWT]: Simulated Rain Wetting of MAT blocks in Southern Gujarat

Stonehouse, JM, Patel, ZP, Jagadale, VS, Verghese, A, Mumford, JD

Abstract

This study assessed the size and persistence of catches by methyl-eugenol MAT soaked plywood blocks in traps in mango orchards outside Gandevi, when subjected to different wetting regimes to imitate light and heavy rainfall, and oriented face-up or edge-up. Blocks wet heavily, to mimic weekly rainfall of 250mm, decayed catches approximately six times faster than lightly wet, to mimic 50mm weekly, though this was not significant (P=0.6030); blocks positioned face-up decayed more quickly than those edge-up, but this was not significant (P=0.3294).

Introduction, Materials and Methods

MAT blocks may be susceptible to wetting by the rain, which may affect their performance. Apart from the volume of rain itself, other factors may influence its effects on the performance of blocks. One of these is whether a unit volume of rain is experienced as frequent but mild "showers" or as infrequent but intense "downpours"; another is whether blocks are deployed in the field "face-up" or "edge-up" (for example, whether nailed to horizontal or vertical branch surfaces). This experiment examined the response of block effectiveness to these factors.

Blocks were identical 5x5x1cm plywood blocks, soaked in a mixture 6:4:1 v:v:v of ethanol, methyl-eugenol and malathion. Once hung in the field inside water bottle traps, they were treated in five different ways (wetted blocks were wet with either "light rain", calculated to mimic 25mm of rain, or "heavy rain" to mimic 125mm of rain):-

A. Dry
B. Positioned edge-up, wet twice weekly with "light rain" (3.124 ml)
C. Positioned face-up, wet twice weekly with "light rain" (31.25 ml)
D. Positioned edge-up, wet twice weekly with "heavy rain" (15.625 ml)
E. Positioned face-up, wet twice weekly with "heavy rain" (156.25 ml)

The experiment was set up in five complete randomised blocks. Blocks were installed on May 28, 2004, and catches counted at approximately four-day intervals between June 1 and July 7, a total of ten counts.

Results and Discussion

The catches are summarised as totals and decay slopes in Tables 1 and 2.

Table 1. Means and <standard deviations> of total catches, as percentages of the catch by the dry blocks, and of the slopes (multiplied by 10,000) of the regression of the logarithms against catches, as fractions of those by the dry blocks, against times.

	LE	LF	HE	HF
Totals	109	106	98	111
	<24>	<22>	<24>	<23>
Slopes	14	-27	-1	-70
	<226>	<196>	<142>	<253>

Table 2. Means of slopes from Table 1 recast to a 2x2 factorial with marginal means.

	Edge	Face	Row means
Light	14	-27	-6
Heavy	-1	-70	-35
Column means	7	-48	

In terms of number caught, the wetted blocks as a group were not inferior to the dry blocks (three of them catching more flies) and there were no differences among the four wetted treatments (*F*=0.6189[3,12]ns {*P*=0.6160}). In terms of slopes of decays, the wetted blocks as a group were not inferior to the dry blocks (one of them decaying more slowly) and there were no significant differences among the four wetted blocks (*F*=0.4610[3,12]ns {*P*=0.7147}). Table 2 suggests that edge-up blocks decayed more slowly than face-up, and lightly-wet blocks more slowly than heavily-wet, but this was not statistically confirmed (due to heavy/light wetting *F*=0.2854[1,12]ns {*P*=0.6030}; due to face/edge positioning *F*=1.0337[1,12]ns {*P*=0.3294}; due to interaction between them *F*=0.0638[1,12]ns {*P*=0.8048}).

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6E. Parapheromone Lures: Effects of Dose and Density

~03/18[BSK]: The Influence of Soaking Time and Soakate Concentration on Fruit Fly MAT Blocks in Orissa

Singh, HS, Mohantha, A, Stonehouse, JM, Verghese, A, Mumford, JD

Abstract

The influence on the size and persistence of attraction of fruit flies to wooden MAT blocks was assessed by hanging in orchards near Bhubaneswar traps containing a variety of blocks, of the same size but soaked for different periods of time and in soakate solutions of different strengths - five periods between 5 seconds and 6 days, and three concentrations of between 5% and 35% lure, as a total of fifteen combinations in all - and counting fly catches weekly for ten weeks throughout the growing season of 2003 (N=5). In terms of total catch, numbers increased with increasing time and concentration, levelling off to an inferred asymptote - both were highly significantly quadratic in response (both *P*<0.0001) - and there was a significant interaction between the two (*P*=0.0053). Solution of the quadratic curves found peaks in the effectiveness of response (as approximations of the saturation of effect) approximately at a soakate concentration of 30% and a soaking time of 4½ days. There were no significant differences among treatments {*P*=0.3817} in the persistence of effects as indicated by the decay of catches.

Introduction

The successful use of MAT blocks on farms requires the minimisation of costs. It may be possible to obtain cost-effective protection, particularly for a limited period of time, by reducing the amount of lure and other soaking liquid used per block. This experiment aimed to assess the attraction-and-killing power, and the rate of its decline, of blocks with varying levels of lure content, adjusted by modifying two parameters (a) the concentration of the lure methyl-eugenol (ME) in the soaking liquid and (b) the duration of soaking time.

Materials and Methods

Plywood blocks of 5x5x0.5cm were soaked for 5 seconds, 7 minutes (420s), 15 minutes (900s), 24 hours (86400s) and 6 days (518400s) in mixtures of ethanol:ME:malathion in the ratios by volume of 6:4:1 (36% lure), 9:1:1 (9% lure) and 9:½:1 (5% lure). Five complete randomised blocks each of all 15 treatments were installed in field conditions at three locations near Bhubaneswar for 70 days from September 17, 2003. Trap catches were recorded at weekly intervals.

Results and Discussion

Table 1 shows the mean total catches by blocks under various treatments. Catch numbers rose consistently with increases in both lure concentration and soaking time. Catch data were transformed to natural logarithms and then regressed against lure concentration and soaking time. Table 2 shows the outcome of statistical analysis of the data summarised in Table 1.

Table 1. Means and standard deviation (<SD>; N=5) of total catches per trap over 70 days, by blocks soaked in soakate liquids of different lure (ME) concentration and for different periods of time.

Soaking time	Percentage lure in soaking mixture						Row means
	36		9		5		
	Mean	SD	Mean	SD	Mean	SD	
5s	1	<1.4>	0.4	<0.9>	0.4	<0.6>	0.6
7m	3.8	<2.7>	2.2	<0.5>	0.8	<1.3>	2.3
15m	5.2	<2.8>	3.0	<2.9>	1.8	<0.8>	3.3
24h	7.4	<2.5>	3.4	<1.7>	1.6	<1.5>	4.1
6d	10.4	<3.1>	5.8	<3.4>	2.8	<1.5>	6.3
Column means	5.6		3.0		1.5		

Table 2. ANOVA table of the data summarised in Table 1, as *F*, degrees of freedom and *P* for soakate concentration and soaking time for total treatment variance, linear and quadratic regressions, the additional explanation offered by the quadratic equation, and interaction between the two.

Treatment	*F*	[df]	{*P*}
Soakate concentration (T=3)			
- Total	55.6763	[2,56]	{<0.0001}
- Linear regression	87.9240	[1,56]	{<0.0001}
- Quadratic regression	55.6763	[2,56]	{<0.0001}
- Quadratic (additional)	23.4286	[1,56]	{<0.0001}
Soaking time (T=5)			
- Total	32.0472	[4,56]	{<0.0001}
- Linear regression	70.6038	[1,56]	{<0.0001}
- Quadratic regression	44.3545	[2,56]	{<0.0001}
- Quadratic (additional)	18.1053	[1,56]	{0.0001}
Time/concentration interaction	3.1405	[8,56]	{0.0053}

Catch responses to both soak times and soakate concentration were significantly quadratic (for the linear component for time b_1=2.6758E-6, for concentration b_1=0.04899; for the quadratic component for time b_2=-3.5496E-12, for concentration b_2=-0.08262). Inserting slope values into the formula to find the value obtaining the peak catch (x{peak}=$-b_1/b_2/2$) derived peak catch values at a soakate concentration of 29.6% and a soaking time of 376915 seconds, or about 4 days, 9 hours.

Data for persistence are summarised in Table 3, as half-lives of catch persistence derived from the slopes of exponential regressions of catches against time. Due to small catches by blocks with smaller lure loads, many of the cells were empty. Regression slopes were compared by ANOVA (with data losses addressed by omitting all “5s” values, and replacing five other missing values by the products of their row and column means divided by the grand mean, with five subtracted from the residual degrees of freedom). Differences due to treatments were not significant (ANOVA F=1.1071[11,39]ns {P=0.3817}).

Table 3. Means, standard deviations <SD> and [N] of half-lives in days of the decays of catches, estimated by exponential regression of catches against time, by blocks soaked in different lure concentration and for different periods of time.

Soaking time	Percentage lure in soaking mixture									Row means
	36			9			5			
	Mean	<SD>	[N]	Mean	<SD>	[N]	Mean	<SD>	[N]	
5s	613	<11047>	[2]	419	-	[1]	400	<774>	[2]	477
7m	175	<170>	[5]	168	<238>	[5]	178	<431>	[2]	174
15m	111	<314>	[5]	255	<189>	[5]	210	<158>	[4]	192
24h	116	<105>	[5]	173	<322>	[5]	152	<175>	[4]	147
6d	86	<86>	[5]	135	<158>	[5]	199	<190>	[5]	140
Column means	220			230			207			

Discussion

The experiment indicated that with increases in both methyl-eugenol concentration and in soaking time the catches of flies increased up to a point and then levelled off. It does not seem likely that increasing doses of methyl-eugenol actually decrease catches, but that they flatten off in their effectiveness above a concentration of about 30% and a soaking time of about 4½ days. There was a significant interaction between concentration and soaking time. An aim of the experiment was to determine the effect of soaking time on the persistence of effects, but no differences in this were observed.

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~04/14[ASZ]: The Effects of Size of Wooden MAT Blocks in Central Gujarat

Sisodya, D, Jhala, RC, Stonehouse, JM, Verghese, A, Mumford, JD

Study conducted as part of the IMFFI-associated project

Biology and Management of Bactrocera cucurbitae *Infesting Bitter Gourd*

Abstract

The effects of their size on the performance of plywood cue-lure MAT blocks was studied by hanging blocks of five different sizes (edge lengths of 1,2,3,4 and 5cm) in traps over a growing season (N=4). Three clear and significant trends were apparent: (1) with increasing block size the catch increased; (2) with increasing block size the catch per unit volume of block decreased; (3) with increasing block size the persistence of catching power was extended. It may be that the bulk of the block, carrying its load of soakate, acted like a fuel tank, not only emitting more vapour (as a function of its surface area) but also persisting longer (as a function of its volume). This suggests it may be possible to “tune” block performance, selecting precise outcomes in daily killing power (by adjusting soakate concentration or block number) and persistence (by adjusting block size) independently of each other.

Introduction, Materials and Methods

This experiment studied the size and persistence of the catching power of plywood cue-lure MAT blocks different sizes. Blocks were made with edge lengths of 1,2,3,4 and 5cm, soaked in cue-lure, insecticide and solvent and hung in traps in gourd fields near Anand in five complete randomised blocks and checked daily for 154 days between July 1 and December 21 2004. The catches by each block were assessed as total catches and the half-lives of their decay over time.

Results and Discussion

Table 1 summarises the total catches, catches per volume of each block and half-lives of catch decays.

Table 1. Means and standard deviations (as <SD>; N=4) of the catches of melonflies by cue-lure MAT blocks of 1,2,3,4 and 5cm edge lengths. Given are the total catches per block over 154 days, the total catches divided by the area (respectively 1,4,9,16 and 25cm^2) and the half-lives in days of the decay of catches.

Size	1	2	3	4	5
Total	306	350	508	693	869
catch	<17>	<48>	<118>	<202>	<164>
Catch	306	88	56	43	35
/Area	<17>	<12>	<13>	<13>	<7>
Half	23	31	64	64	68
-life	<1>	<3>	<25>	<27>	<29>

Table 2. Significance of regression associations of total catch, catch per unit area of block and half-life of catch persistence, each regressed against the volume of the wooden block, as in Table 1.

	F[1,12]	*P*
Total catch	67.4458	{<0.0001}
Catch/area	567.0917	{<0.0001}
Half-life	21.2124	{0.0006}

Table 3. Fits of different models to the associations of total catch, catch per unit area and half-life to the volume of the wooden block, as in Table 1, given as the mean and standard deviation (<SD>; N=4) of r2 of the association with data untreated, as logarithms and as exponents, and the outcomes of planned related *t*-test comparisons [df=3] of the untreated r2 values to the two transformed ones. For each variable, the largest r2 value is given in bold and the second-largest in italics.

	r2 values of associations			t comparisons of transformations	
	Untreated	Logarithms	Exponents	Logarithms /untreated	Exponents /untreated
Total	**0.9382**	*0.9156*	0.7897	1.2864	3.5791
	<0.0246>	<0.0573>	<0.0678>	{0.2886}	{0.0373}
Total	*0.4896*	**0.6943**	0.3713	10.0412	6.8865
/area	<0.0458>	<0.0850>	<0.0124>	{0.0021}	{0.0063}
1/2-life	*0.6465*	**0.6586**	0.64	0.4465	0.4023
	<0.2156>	<0.1700>	<0.2408>	{0.6855}	{0.7144}

Three clear and significant trends were apparent. (1) with increasing block size the catch increased; (2) with increasing block size the catch per unit volume of block decreased; (3) with increasing block size the persistence of catching power was extended. The implication is that the bulk of the block, carrying its load of soakate, acted like a fuel tank, not only emitting more vapour (as a function of its surface area) but also persisting longer (as a function of its volume). This suggests it may be possible to "tune" block performance, selecting precise outcomes in daily killing power (by adjusting soakate concentration or block number) and persistence (by adjusting block size) independently of each other.

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~04/02[GDS]: The Effects of Block Spacing and Density on Catches of Fruit Flies in Southern Gujarat

Stonehouse, JM, Patel, ZP, Jagadale, VS, Verghese, A, Mumford, JD

Abstract

Soaked-plywood methyl-eugenol MAT blocks were deployed in traps in a mango field outside Gandevi, covering the same area with the same volume of lure and insecticide, by using either a smaller number

of blocks soaked in a stronger solution, or a larger number of blocks soaked in a weaker solution. The strongest-soakate-dose blocks, using no ethanol solvent, did not fully absorb liquid to their soaking capacity, and thus could not be accurately compared with the others in terms of performance per unit volume absorbed. Of the others, a set of stronger blocks at 10/Ha caught a significantly smaller number of flies (approximately half) than a set of weaker at 15/Ha (standardised to carry the same lure and insecticide dose per unit area, and it in inferred that within this range a larger number of weaker blocks killed flies more effectively than a smaller number of stronger ones.

Introduction, Materials and Methods

The aim of this experiment was to assess the effects of block spacing on MAT performance. Blocks were assessed spaced at densities of five, ten and fifteen per hectare (ten is the current recommendation). To allow the effects of spacing to be assessed independently of other variables, the concentration of methyl-eugenol and insecticide in the soaking solution was adjusted so that the doses of both per unit area remained the same in all plots. The doses were be adjusted to be the same as obtained from a recommended soaking solution of 6:4:1 of ethanol:lure:insecticide by volume, with the qualification that the insecticide concentration was increased to obtain the same strength (one in eleven) in the lightest-dosed blocks, to eliminate the risk of flies being attracted to these blocks and not killed. The ratios thus chosen were:-

5 blocks/Ha - 0 Solvent : 8 Lure : 3 Insecticide (lure=73%)
10 blocks/Ha - 5.5 Solvent : 4 Lure : 1.5 Insecticide (lure=36%)
15 blocks/Ha - 7.333 Solvent : 2.667 Lure : 1 Insecticide (lure=24%)

This obtained the same total for each ratio set (11) and the same dose of lure and insecticide per unit area when multiplied by trap density. The volume absorbed in soaking was recorded in all cases.

As each plot was estimated to need to be a minimum of one hectare in size, and access was limited, the effects of decay over time were ignored and instead each treatment set up for one week in a one-hectare area, then at weekly intervals the fly catches in all traps counted and the treatments rotated among the three plots, in two cycles over six weeks in a doubled-up Latin Square design. Each plot was protected against “edge effects” by being surrounded by a “perimeter barrier” of standard (6:4:1) soaked blocks (without traps to record catches, as in use solely to kill flies) spaced at 30m intervals all round its perimeter, of 12 blocks for each plot of 1Ha.

The perimeter barrier blocks were not moved but left in position, so variations between them were be attributed to replicates, not treatments.

Results and Discussion

The results are summarised in Table 1. The amounts of soakate liquid absorbed was similar for the two weaker mixtures, but much less for the strongest mixture, intended for use at 5 blocks/Ha. It was concluded that methyl-eugenol without a solvent will not readily soak into plywood to saturation. Subsequently, comparison of the catches for the two weaker, more numerous blocks found a significantly greater catch by the more numerous deployment. The experimental design did not allow a meaningful assessment of duration of different treatments, as the time factor was unreplicated as the rotating design confused the time factor with replication; as it happened, catches for all treatments increased over the experimental period.

Table 1. As the soakate volume absorbed was much less for the 5 blocks/Ha treatment than the others, making strict comparison impossible, its data were not systematically compared with the others, and catches of the other two densities compared only with each other. The lower rows show that the "High density" deployment (15 blocks/Ha) caught more flies than the "Medium density" deployment (10 blocks/Ha) (the difference being equivalent when measured as catch per unit area or catch per unit volume of methyl-eugenol, as the methyl-eugenol dosage per unit area was held the same between the two treatments), and this difference was statistically significant (related *t*=4.9834[5] {*P*=0.0042}).**

Value	Units	Low	Medium	High
Density	Blocks/Ha	5	10	15
Lure content	PerCent	73	36	24
Uptake	ml/block	6.4	15.4	15.6
Lure dosage	ml/Ha	23	56	57
Catch	Flies/Ha	24	32	57
<SD>		<8>	<11>	<20>
Catch	Flies/block	4.8	3.2	3.8
Catch	Flies/ml	1.0	0.6	1

The superior catch of the 5block/Ha treatment to the 10 is discounted because of the inferior absorption of soakate liquid - although the 5-density caught more flies per ml than the 10-density, each of these ml had a larger area from which to draw, due to the lower density of ml/Ha, which is assumed to have inflated the catch per ml in unquantifiable ways.

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~04/12[SCH]: Dose Response of Melonflies to Drops of MAT Lure in Northern Gujarat

Chowdhury, FK, Patel, RK, Stonehouse, JM, Verghese, A, Mumford, JD

Study conducted as part of the IMFFI-associated project

Biology and Management of Pumpkin Fruit Fly

Abstract

Traps containing strawboard blocks with 2,4,6,8 or 10 drops of cue-lure and insecticide were hung in five complete randomised b locks in gourd fields near Palanpur (N=4), and the catches in each counted weekly from January 4th until August 17th, 2004. With increasing strength of lure dose (1) the total number of flies caught increased significantly (*P*<0.0001), (2) the total number of flies caught per drop of lure (i.e. per unit dose) decreased significantly (*P*=0.0001), and (3) the persistence of the block increased, though not significantly (*P*=0.1756).

Introduction, Materials and Methods

This experiment aimed to quantify the relationship between the strength of lure dose in drops on absorbent board MAT blocks, and the size and persistent of fly-catching effect. Traps containing strawboard blocks with 2,4,6,8 or 10 drops of cue-lure and insecticide were hung in four complete randomised blocks in gourd fields near Palanpur, and the catches in each counted weekly from January 4th until August 17th, 2004. Data were assessed as the total numbers caught by each block, and the half-lives of the persistence of catch effect, calculated with fluctuations in the surrounding population discounted by means of a model of a seasonal rise and fall in fly numbers.

Results and Discussion

Table 1 summarises the totals and persistence of fruit fly catches by blocks with the five different strengths of lure doses, and the relationships between these and the dose. While blocks with larger doses caught significantly more flies, they caught significantly fewer flies per unit of dose carried. There was also an indication that more-heavily-dosed blocks persisted for longer.

Table 1. Means and standard deviations (as <SD>; N=4) of the total catches, total catches per drop of lure mixture, and half-life in days, of strawboard blocks with 2,4,6,8 or 10 drops. Half-lives were calculated after the adjustment of catch data by the assumption of a nine-fold rise and fall in the local fly population over the course of the experiment, and so may not represent actual estimates. Below are the results of regressions of these three variables against drop number. Regression was taken after pooling of blocks, once ANOVA had shown no significant differences among them (among total catches treatment *F*=54.0010[4,19]* {P<0.0001} but block *F*=1.1415[3,19]ns {*P*=0.3718}; among half-lives treatment *F*=2.6641[4,19]+ {*P*=0.0844} but block *F*=1.5852[3,19]ns {*P*=0.2444}).**

Drop number	Total catch	Catch /drop	Half -life
2	127 <14>	63 <7>	134 <33>
4	261 <26>	65 <6>	160 <135>
6	214 <20>	36 <3>	234 <79>
8	239 <31>	30 <4>	1625 <1803>
10	404 <41>	40 <4>	386 <278>
Slope	26.6124	-4.0668	98.5130
r^2	0.6547	0.5675	0.0943
F[1,19]	36.0218	24.9324	1.9793
P	<0.0001	0.0001	0.1756

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7A. IPM: Gourds

~03/31[MPM];03/32[MMP]:
Protection of Snake Gourd by BAT and MAT in Southern Kerala

Jiji, T, Nair, B, Stonehouse, JM, Verghese, A, Mumford, JD

Abstract

These experiments assessed the catch of fruit flies, and protection of snake gourd from their depradations, in fields of snake gourd near Thiruvananthapuram. A first experiment (N=3) assessed BAT and MAT by traps containing methyl-eugenol, cue-lure and protein hydrolysate (deployed as both bottle traps and splashes) at 10% and 100% concentration. In spite of large catches of male flies by the parapheromone traps, there were no apparent or significant (*P*=0.4368) differences in percentage infestation obtained by cue-lure (mean infestation 20.8%), methyl-eugenol (20.0%) and protein at 10% (13.0%) and 100% (19.6%). The protein traps did not significantly differ (*P*=0.6784) in their mean catches of 3.0 by 10% and 3.2 by 100% concentrations. A second experiment (n=5) assessed BAT, cue-lure MAT and the two in combination. Mean inferred percentage reductions in infestation, relative to the untreated controls, were all highly significant (*P*<0.0001), of 51% by MAT, 61% by BAT and -80% by interaction between them, implying that the two treatments exerted significant control individually but that together in combination they interacted to obtain a control significantly “less than the sum of its parts”.

Introduction, Materials and Methods

These experiments assessed the catch and control of fruit flies, by bait application technique (BAT) and male annihilation technique (MAT), in complete randomised blocks in snake gourd fields near Thiruvananthapuram.

A first experiment assessed gourd protection by traps containing four different attractant treatments separated by 7m - methyl-eugenol, cue-lure and protein hydrolysate at 10% and 100% in both bottle traps and splashes - in a 0.4Ha field. Catches of flies by traps were counted and sexed, and infested and uninfested gourds per 4sqm counted.

A second experiment assessed BAT (splashes of 10% protein hydrolysate applied in spots at 7m spacing) and MAT (one cue-lure block per treated plot, i.e. 40/Ha), individually and in combination (N=5) in September 2004 in a field of 0.5Ha, each plot and its guard borders occupying approximately 0.025Ha. Assessment was by calculation of the percentage infestation of gourds in each plot, analysed by two-way interactive analysis of variance, after conversion to logarithms.

Results and Discussion

The results of the first experiment are summarised in Table 1. Few of the differences were statistically significant, due to high variability within the samples. It appeared that the very substantial catches by parapheromone lures offered no actual control of infestation, presumably due to the overwhelming predominance of males in their catches and, in the case of methyl-eugenol, their attraction to largely innocent “orchard” flies which do relatively little damage in cucurbits.

Table 1. Means and standard deviations (<SD>; N=3) of the performance of different MAT and BAT in protecting fields of snake gourd in Southern Kerala, as the numbers of uninfested fruit harvested per unit area, percentage infestation of fruit, catch of adults by traps and the sex-ratio of these catches as the percentage of females in the total. Statistical outputs are the *F* and *P* values (all d.f.=[3,6]) of the ANOVA comparison of all four treatments and the *t* values (all d.f.=[2]) of the planned *t*-test comparison of the two protein hydrolysate (PH) treatments. In both total yield and infestation levels there were significant differences between blocks – an indicator of the importance of blocked designs in damping out variation in agricultural field research.

	Means				Comparison analyses			
	Cue-lure	Methyl-eugenol	PH		All four		Two PH	
			10%	100%	*F*[3,6]	{*P*}	*t*[2]	{*P*}
Uninfested Fruit	21.3 <13.1>	33.3 <32.6>	36.3 <45.1>	31.3 <42.2>	0.5446 ns	{0.6696}	1.6667 ns	{0.2375}
% Infestation	20.8 <15.1>	20.0 <17.8>	13 <9.4>	19.6 <16.0>	1.0490 ns	{0.4368}	1.5702 ns	{0.2569}
Total Catch	128.0 <77.7>	98.3 <119.2>	3 <1.0>	3.2 <1.6>	2.5743 ns	{0.1496}	0.4804 ns	{0.6784}
% Females	0.4 <0.4>	1.3 <1.8>	61.1 <34.7>	79.0 <20.1>	15.2534 **	{0.0033}	1.3550 ns	{0.3082}

The results of the second experiment are summarised in Table 2. Infestation levels were reduced by all treatments, compared to no-control. MAT and BAT significantly interacted, in a way which was mutually inhibitory - the two techniques combined together exerted control significantly “less than the sum of its parts.”

Table 2. Means and standard deviations (<SD>; N=5) of percentages of infestation by fruit flies in snake gourd plots protected in four different ways, with inferred percentage reduction in infestation attributed to treatments (%). A two-way interactive ANOVA of the data after transformation to natural logarithms found *F*-ratios due to BAT 203.0610, due to MAT 86.1898 and due to interaction 41.6797 (all with d.f. [1,12]* {*P*<0.0001}).**

None	MAT	BAT	Both
49.5	24.1	19.2	16.8
<4.8>	<3.7>	<2.3>	<2.1>
(0%)	(51%)	(61%)	(-80%)

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~02/01A[SBM]: BAT and MAT in Pumpkin in Northern Gujarat: Comparison and Interaction

Stonehouse, JM, Patel, RK, Joshi, B, Verghese, A, Mumford, JD

Abstract

MAT, BAT and both in combination were assessed for the protection of pumpkin outside Palanpur (N=5). Alone, MAT and BAT exerted broadly similar control levels, with highly significant percentage improvements of, respectively, 29 {P=0.0015} and 26 {P=0.0064} for harvested mass and 45 and 44 for percentage infestation {both P<0.0001}; interaction between MAT and BAT was negative but not significant in any case (for fruit production interaction percent improvement was -13 {P=0.2543}}; for infestation -5 {P=0.1739}).

Introduction

Bait Application Technique (BAT) and Male Annihilation Technique (MAT) impinge on fruit fly pests in different ways, the former by killing all adult flies, the latter by killing males and so depriving females of fathers for larval broods. The question arises of whether, when applied simultaneously, these two may act independently, or interact with each other. Interaction may be by potentiation, obtaining combined control “greater than the sum of its parts”, if the reduced populations of males (thanks to MAT) and females (thanks to BAT) are so low that mating success and reproduction are reduced more than by the sum of the two methods deployed individually. Alternatively it may be by interference, obtaining combined control “less than the sum of its parts”, if the effect of one control is merely removing from the population individuals who would have been removed by the other anyway. This question, and also a direct comparison of the effects of the two methods applied individually, was assessed by a two-way trial of no-control, BAT alone, MAT alone, and BAT and MAT together.

Materials and Methods

BAT, MAT, both and neither were assessed in five complete randomised blocks of 0.6Ha each (i.e. 0.15Ha for each treated subplot) of pumpkin (variety *Katakiya*) sown outside SK Nagar in rows 12x2 feet on 20/7/02 and harvested on 13/10/02.

MAT blocks were 5x5cm squares of local plywood 1.2cm thick, soaked for 48 hours in a mixture of ethanol, cue-lure and insecticide (DDVP) in the ratio 6:4:1. An average of 11.5ml of solution was absorbed by each block. Each block was inside a 1L plastic jar with four holes 4.5x2.5cm in its sides. Six traps were installed in half of each complete block (0.3Ha, obtaining three traps per 0.15Ha plot). One block lasted all season.

BAT spray solution was 30ml protein hydrolysate and 0.3ml DDVP in 1L water. Eight spots (150mL each) were applied with a lever-operated knapsack sprayer in each 0.15Ha plot, to the undersides of crop-plant leaves, as six weekly applications beginning at the time of 50% flowering.

Pumpkin production was recorded as total numbers and mass of harvested fruit from a 10x10M^2 area in each treatment plot. Infestation was recorded one week prior to final harvest, in fruit from a 4x4M^2 area in each treatment plot. Total and damaged fruits of different sizes (ripe, medium, small, forming) were recorded and converted to percent fruit damage.

Results and Discussion

Table 1. Numbers and mass of harvestable pumpkin fruits per plot, and damage as percentages, age-compensation-weighted over four fruit classes (forming, small, medium and ripe), as means and standard deviations <SD> of five blocks, percentage improvement attributed to controls (%), and 2x2 factorial ANOVA *F* and significance level (with [1,12] degrees of freedom) for MAT and BAT and the interaction between them (with percentages converted to logarithms before analysis).

		Neither	MAT	BAT	MAT + BAT
Number of fruit /100sqm	Mean	54.6	62.4	63.0	70.4
	<SD>	<4.3>	<4.9>	<5.1>	<6.4>
	% Improvement	(0%)	(14%)	(15%)	(-2%)
	F		14.7284**	17.1458**	0.0102ns
	{*P*}		{0.0024}	{0.0014}	{0.9212}
Mass (Kg) of fruit /100sqm	Mean	250.0	323.5	312.5	352.7
	<SD>	<43.0>	<21.9>	<21.2>	<33.3>
	% Improvement	(0%)	(29%)	(25%)	(-13%)
	F		16.7164**	10.8733**	1.4339ns
	{*P*}		{0.0015}	{0.0064}	{0.2543}
Percentage infestation	Mean	46.3	25.4	26.0	14.9
	<SD>	<3.6>	<10.1>	<7.7>	<4.6>
	% Improvement	(0%)	(45%)	(44%)	(-5%)
	F		32.0674***	37.8871***	0.1739ns
	{*P*}		{<0.0001}	{<0.0001}	{0.6840}

Pumpkin production and infestation are presented in Table 1. Independent of each other, BAT and MAT produced broadly similar levels of control. The catch data from the traps seemed to confirm this: as a by-product of MAT control, data were available only for the MAT-only and BAT-and-MAT plots, and these found catches in MAT-only of 292.4 <SD±88.2> and BAT-+-MAT of 556.4 <±227.58> (each a mean of ten traps in five blocks, significantly different; related *t*=2.7161[9]*), the former being close to half of the latter (mean 0.6780, 95% confidence intervals of ±0.2422) implying that BAT and MAT removed roughly equivalent numbers of males (though not of females).

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~03/46[ABP]: Fruit Fly Control by Baits and Lures in Isolation and Combination in Little Gourd Farm Fields in Central Gujarat

Sisodya, D, Jhala, RC, Stonehouse, JM, Verghese, A, Mumford, JD

Study conducted as part of the IMFFI-associated project

Biology and Management of Bactrocera cucurbitae *Infesting Bitter Gourd*

Abstract

The infestation of fruit flies in little gourd (*Coccinia indica*) outside Anand was monitored weekly throughout the 21-week growing season of 2003, in individual 0.25Ha farm-field plots protected by three BAT regimes (protein hydrolysate, jaggery and nothing) and four MAT regimes (cue-lure, methyl-eugenol, both and neither) to obtain a total of twelve treatments (N=1). There were no significant differences attributable to treatments, in percentage infestation of in the suppression of infestation progressively over the growing season. The closest to significance was the *P*-value of 0.1840 for a reduction of infestation of 56% by cue-lure MAT, the second the value of 0.3611 for the reduction of 38% by methyl-eugenol. No interaction was significant at *P*<0.4.

Introduction

Fruit fly pests of cucurbits in Gujarat may be attracted to either food baits or parapheromone lures: both of these are available in more than one variant. Among lures, the melonfly *Bactrocera cucurbitae* is attracted to cue-lure, and the orchard flies *B. zonata* and *B. dorsalis*, which also attack cucurbits in Gujarat, to methyl-eugenol. Baits are available in a wider variety, attractive to all species, and jaggery and protein hydrolysate are two of proven attraction to fruit flies in Gujarat. This study assessed the crop protection performance obtained by cue-lure, methyl-eugenol, jaggery and protein hydrolysate alone and in combination in the field in Gujarat.

Materials and Methods

The crop protection abilities of the attractants were assessed in farm fields of little gourd (*Coccinia indica*) outside Anand. The notorious variability among conditions in plots, when assessing pest management treatments in real farm environments, particularly when individual farms and plots are small, was addressed by the use of large experimental plots, of 0.25Ha each, so that each encompassed a variety of different farm plots, in order to obtain representative “average” conditions overall and thus damp down non-treatment variation between experimental plots. The experiment was unreplicated (N=1).

Treatments of cue-lure (CL), methyl-eugenol (ME), jaggery (JG) and protein hydrolysate (PH) were applied as set out in IMFFI protocols. MAT was by commercial plywood blocks soaked in a 6:4:1 by volume solution of ethanol:lure:DDVP for 24 hours, and hung in fields in traps at 15m spacing (4 traps per 0.25Ha plot). Bait sprays were of protein hydrolysate or black jaggery at 5% with fenthion insecticide at 0.1%, applied at 7m spacing. MAT traps were installed once only, bait sprays at weekly intervals (a total of 19 times).

Assessment was by counting infested and healthy fruits in five fixed quadrat plots, 2x1m, in each treatment plot. The first assessment was before treatments are applied, and subsequently twenty weekly assessments throughout the season (a total of twenty-one successive samples on June 11, 18 and 26, July 3, 11, 18 and 25, August 1, 8, 14, 22 and 29, September 5, 12, 19 and 26, and October 3, 10, 16, 23 and 30).

Applications were (1) Nothing, (2) ME, (3) CL, (4) JG, (5) PH, (6) ME+CL, (7) ME+JG, (8) ME+PH, (9) CL+JG, (10) CL+PH, (11) ME+CL+JG and (12) ME+CL+PH.
Data were assessed in two ways. First was as control overall by the average percentage infestation over all sample points after applications began. Second was as the speed with which control was exerted, by converting the percentage data to logs (after the addition of 1 to forestall the calculation of LN(0)), regressing these against days elapsed since controls began, and comparison of the slopes of these regressions.

Results and Discussion

Table 1 shows the values obtained as mean percentage infestation over the growing season, and Table 2 the output of its ANOVA analysis; Table 3 shows the values obtained as declines in infestation, and Table 4 the output of its ANOVA analysis.

Table 1. Percentage infestation of little gourd by fruit flies over twenty weekly assessments throughout the 2003 field season.

		Bait						Cell row means		Table row means
		None		Jaggery		PH				
		ME		ME		ME		ME		
		no	yes	no	yes	no	yes	no	yes	
CL	no	9.3	8.3	20.9	4.7	5.3	5.6	11.9	6.2	9.1
	yes	5.2	5.5	2.8	2.1	4.4	3.9	4.1	3.8	4
Column means		7.3		11.8		4.9		8	5	

Table 2. Three-way ANOVA table for the analysis of the values in Table 1.

Source	*F*	[df]	{*P*}
ME	1.3795	[1,2]	{0.3611}
CL	3.9851	[1,2]	{0.1840}
Bait	0.4540	[2,2]	{0.6878}
Interactions			
- ME x CL	1.1005	[1,2]	{0.4042}
- ME x Bait	1.1672	[2,2]	{0.4614}
- CL x Bait	1.1636	[2,2]	{0.4622}

In terms of percentage infestation, the analysis of variance found no significant effects due to treatments. The closest to significance was the *P*-value of 0.1840 for the reduction of infestation by cue-lure MAT of (9.1-4.0)/9.1=56%, the second the value of 0.3611 for the reduction by methyl-eugenol of (8.0-5.0)/8.0=38%.

Table 3. Slopes (x10 000) of the decay of logarithms of percentage infestation against days after the initiation of controls, over twenty-one weekly assessments throughout the 2003 field season.

		Bait						Row means	
		None		Jaggery		PH			
		ME		ME		ME		ME	
		no	yes	no	yes	no	yes	no	yes
CL	no	-80	-39	-32	-33	-65	-91	-59	-54
	yes	-64	-58	-77	-37	-44	-45	-61	-47
Column means		-72		-55		-54			

Table 4. Three-way ANOVA table for the analysis of the values in Table 3.

Source	*F*	[df]	{*P*}
ME	0.6965	[1,2]	{0.4918}
CL	0.0498	[1,2]	{0.8442}
Bait	0.8317	[2,2]	{0.5459}
Interactions:			
- ME x CL	0.1755	[1,2]	{0.7160}
- ME x Bait	1.0051	[2,2]	{0.4987}
- CL x Bait	2.0591	[2,2]	{0.3269}

In terms of the suppression of infestation over the progress of the growing season, the analysis of variance found no significant effects due to treatments. There was no evidence of any effect due to treatments, as of all the plots over twenty-one weeks the second-steepest decline in infestation was in the unprotected control plot.

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~03/16[BBM];03/12A[VST]:
Bait and Cover Fruit Fly Controls in Bitter Gourd in Orissa and Uttar Pradesh

Singh, HS, Satpathi, S, Mohantha, A, Swamy, S, Rai, S, Stonehouse, JM, Verghese, A, Mumford, JD

Abstract

In Orissa, the protection of bitter gourd against melon flies by cover sprays, cue-lure MAT, protein hydrolysate cover BAT and banana bait traps, relative to an untreated stand, was assessed in farmers' fields outside Bhubaneswar. The inferred percentage reductions in infestation were for cover spray 31, for banana traps 26, for BAT 23 and for MAT 27, though these did not significantly differ. In Uttar Pradesh, an unreplicated experiment assessed the effects of controls of fruit flies on gourds outside Varanasi. Infestation levels obtained were, in increasing order, under protection by MAT and BAT together 34%, by BAT cover spray 36%, by BAT spot spray 37% and by cover spray 40%; the significance of these cannot be estimated due to the lack of replication and relatively low value in the untreated plot (35%).

Introduction, Materials and Methods

In Orissa, the effects on melon fly incidence of cover sprays, MAT, protein-spray BAT and banana traps were assessed in a 2Ha farm field of bitter gourd near Bhubaneswar in March 2003. The field was divided in to two equal halves, one with MAT protection and one without. Each half was divided into four equal complete randomised blocks, each containing four treatments:-

- Cover spray of malathion
- Cover spray of 3%PH (BAT)
- Food bait of Banana
- No control

The 2Ha therefore contained eight blocks each of four treatments, or 32 plots, obtaining a mean plot size, including guard spaces, of 20,000/32=625sqm, or a square 25mx25m. Assessment was at a single visit, when infested fruit in each of the eight plots was recorded as percentage infestation of fruit in four development classes ("Formation", "Small", "Medium" and "Large"). Mean percentage losses were calculated by the synthesis of a single loss figure from these four class-specific losses, on the assumption that losses from one class on passage to the next are made good by the plant in compensation, but that this compensation is never 100%. After discussion of patterns of compensation with fieldworkers, compensation values were set from "Forming" to "Small" as 87.5%, from "Small" to "Medium" as 75% and from "Medium" to "Large" as 50%.

In Uttar Pradesh, an experiment compared the performance of a variety of farm-level controls, in an experimental plot at IIVR, outside Varanasi in autumn 2003. A plot of bitter gourd 20x45m was divided into five plots of 20x7.5m (allowing for buffer areas) treated with different fruit fly protections:

- BAT as spot spray ("IMFFI standard")
- BAT as cover spray, with the same dosage per unit area as the spot spray
- Insecticide cover spray (carbaryl sevin 0.1%) at 1000g a.i./ha
- Untreated
- BAT spot spray and cue-lure-soaked MAT blocks ("IMFFI standard")

Liquid applications were repeated approximately weekly; MAT blocks were installed once only. Restrictions of space did not permit the arrangement of differently-treated plots in independent replicates, and the experiment was unreplicated.

Results

Table 1 gives the mean percentage losses for the four "food" treatments and the two "MAT" treatments, and the outcome of an ANOVA comparison of the four foods in Orissa (the "MAT/No-MAT" distinction could not be tested, in the absence of replication). The inferred percentage reductions in infestation (relative to the untreated control) were for cover spray 31.1, for banana traps 26.4, for BAT 23.0 and for MAT 27.3.

Table 1. Means and standard deviations (<SD>) of percentage infestation by fruit flies under various conditions. There was only one plot each of under MAT and No-MAT so these cannot be statistically analysed; within each MAT/no-MAT plot the four food treatments were replicated four times. Means not followed by the same letter differed significantly ($P<0.05$; Tukey's HSD=2.565).

	Cover	BAT	Banana	None	Row means
MAT	8.7 <2.4>	8.9 <2.0>	9.3 <1.1>	13.0 <1.1>	9.97
No-MAT	11.8 <2.5>	13.9 <1.6>	12.5 <2.5>	16.7 <0.9>	13.72
Column means	10.2a	11.4a	10.9a	14.8b	

Table 2 gives the percentage infestation of gourd fruit under different treatments in Uttar Pradesh. Conclusions on relative performance are difficult to draw, as the relatively low infestation recorded in the unprotected plot casts suspicion on the other values.

Table 2. Percentage infestation of bitter gourd fruit under different fruit fly protection regimes, as means of three sub-plot samples on three successive dates in one plot for each treatment (N=1).

MAT + BAT	Untreated	Cover bait spray	Spot bait spray	Cover spray
33	35	36	37	40

Discussion

The three treatments of cover sprays, protein hydrolysate BAT and banana traps all obtained protection significantly superior to the unsprayed control, but did not significantly differ among themselves. This implies that locally home-made controls may be the equal of cover sprays, and of imported and specialist materials. This is particularly encouraging in the light of the small size of the experimental plots - average 625sqm including guard areas, surrounded by plots differently or inadequately protected. Although unreplicated, the MAT control apparently provided a useful level of plant protection.

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7B. IPM: Mango

~02/01B[SMG]: BAT and MAT in Mango in Northern Gujarat: Comparison and Interaction

Stonehouse, JM, Patel, RK, Joshi, B, Verghese, A, Mumford, JD

Abstract

MAT, BAT and both in combination were assessed for the protection of mango near Palanpur (N=5). No differences were statistically significant. Alone, MAT and BAT exerted broadly similar control levels, as percentage improvements of, respectively, 30 {*P*=0.9382} and 27 {*P*=0.5212} for fruit number and 19

{*P*=0.2072} and 19 {*P*=0.2917} for percentage infestation; interaction between MAT and BAT was negative (for fruit density percentage improvement due to interaction was -34 {*P*=0.1954}; for infestation -3 {*P*=0.6735}).

Introduction, Materials and Methods

The comparative effectiveness and potential interaction (mutually reinforcing or inhibiting) of MAT and BAT was assessed by a two-way trial of no-control, BAT alone, MAT alone, and BAT and MAT together. Treatments were assessed in five complete randomised blocks of 0.6Ha each (i.e. 0.15Ha for each treated subplot) of mango (variety “Kesar”) outside SK Nagar.

MAT blocks were 5x5cm squares of local plywood 1.2cm thick, soaked for 48 hours in a mixture of ethanol, methyl-eugenol lure and insecticide (DDVP) in the ratio 6:4:1. An average of 11.5ml of solution was absorbed by each block. 6 blocks were installed in half of each complete block (0.3Ha, obtaining 3 blocks per 0.15Ha plot). One block lasted all season.

BAT spray solution was 30ml protein hydrolysate and 0.3ml DDVP in 1L water. Eight spots (150mL each) were applied with a lever-operated knapsack sprayer in each 0.15Ha plot, to the undersides of crop-plant leaves, as six weekly applications from marble-size fruit until harvest.

Fruit production was estimated from five trees in each treatment plot. The volume of foliage of each tree was estimated as the area of its “footprint” multiplied by its height. At the time of harvest the total number of fruits on each tree were counted. All fallen fruits beneath each tree were counted from pre-maturing stage to harvest. Both on-tree and fallen fruit counts were divided into the foliage volume estimate to obtain estimates of fruit production per cubic metre of tree canopy, to discount productivity differences attributable to differences in tree size. To discount natural productivity differences between trees, tree fruit production volume was also divided by fallen fruit numbers, to derive an indicator of the trees’ tendency to retain fruit in production rather than shed them. Infestation was estimated at the time of harvesting by the random sampling of 30 fruit from each treatment plot, brought to the laboratory, placed in round iron cages with a 2cm layer of moist soil at bottom and covered with white muslin cloth, and observed every 3 days for the recording of numbers of fruit attacked.

Results and Discussion

Mango fruit production and infestation are summarised in Table 1.

Table 1. Production and infestation of mango, as on-tree fruit numbers per unit cubic metre of canopy, this number divided by the number of fallen fruit per unit cubic metre of canopy, and percentage infestation per sampled batch of 30as means, Standard Deviations (<SD>), and ANOVA output (all with data converted to logarithms and [1,12] degrees of freedom) as *F* and *P*. No differences between treatments were statistically significant.

		Neither	MAT	BAT	MAT+BAT
Fruit density /cubic metre of canopy	Mean	3.7	4.8	4.7	4.0
	<SD>	<0.7>	<1.1>	<2.0>	<1.0>
	% Improvement	(0%)	(30%)	(27%)	(-34%)
	F		0.0063ns	0.4368ns	1.8803ns
	{*P*}		{0.9382}	{0.5212}	{0.1954}
Canopy-fruit /fallen-fruit	Mean	54.3	48.7	74.1	63.1
	<SD>	<17.9>	<3.5>	<20.9>	<21.3>
	% Improvement	(0%)	(-10%)	(36%)	(-5%)
	F		3.8087ns	0.8441ns	0.1740ns
	{*P*}		{0.0747}	{0.3763}	{0.6839}
Percentage infestation	Mean	10.7	8.7	8.7	7.3
	<SD>	<2.8>	<1.8>	<3.8>	<5.5>
	% Improvement	(0%)	(19%)	(19%)	(-3%)
	F		1.7777ns	1.2162ns	0.1866ns
	{*P*}		{0.2072}	{0.2917}	{0.6735}

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~03/21[R5O]: BAT and MAT Fruit Fly Control with Home-made and Imported Materials in Mango in Central Kerala

Stonehouse, JM, Thomas, J, Vidya, CV, Verghese, A, Mumford, JD

Abstract

This study assessed the protection of mango orchards from fruit flies by traps containing food baits and methyl-eugenol lures, of both imported and indigenous origin: baits were assessed as imported protein hydrolysate or as indigenous banana, lures as imported methyl-eugenol or indigenous *Ocimum* extract. MAT obtained a reduction in infestation of 19%, which was statistically significant (*P*=0.0296), but BAT a reduction of 6%, which was not (*P*=0.1155). There may have been positive interaction when both were used together, as obtaining a reduction in infestation of 76%, but this was not significant (*P*=0.1918). Imported methyl-eugenol MAT obtained a reduction in infestation of 52%, and indigenous ocimum MAT a reduction of 43%, but the difference between these was not significant (*P*=0.1600).

Introduction

Mangoes in Kerala are attacked by a variety of fruit fly species, principally *Bactrocera dorsalis*. Protection may be offered by food bait attractants, either in sprayed spots or in traps, or by male annihilation by the parapheromone methyl-eugenol which attracts males. Bait may be imported protein hydrolysate or a variety of home-made alternatives, of which banana is in most widespread use in Kerala. Similarly, methyl-eugenol may be as an imported synthetic product or as crushed leaves of the Holy Basil or *tulsi* plant (*Ocimum sanctum*) which contains methyl-eugenol in a natural state. This experiment aimed (a) to compare BAT and MAT controls, (b) to assess any interaction when the two are used together and (c) to compare home-made and imported materials.

Materials and Methods

The experiment combined four treatments - no-treatment, BAT, MAT and BAT-with-MAT in a 2x2 factorial design. It was deployed on five separate orchards, as complete randomised blocks, spaced about the campus of Kerala Agricultural University, Thrissur. Orchard blocks varied in size between 0.12 and 0.8Ha, and the numbers of trees contained in each between 20 and 90. Each set of four treatments was deployed in each of the five blocks once using imported materials and once using home-made materials, by applying one set in 2003 and the other in 2004, in sequence randomly assigned to each block, to obtain a 2x2x2 three-way factorial of BAT, MAT and origin (imported/indigenous). Bait was applied in traps, as currently carried out with banana traps in Kerala. Banana was applied as 3cm slices of banana with insecticide in traps of half-coconut-shells; protein hydrolysate was applied as 100ml of 3% protein bait in water in traps of 1L disposable drinking-water bottles. Methyl-eugenol was applied in the imported form as 5x5x1.5cm plywood blocks soaked in a soaking liquid of ethanol solvent, methyl-eugenol and malathion in, respectively, 6:4:1 ratio by volume; tulsi leaves were applied as 50g of crushed leaves with insecticide in half-coconut-shell traps.

Adults caught in traps were counted, in 2003 only, weekly over the thirteen weeks of the fruiting season, and converted to mean catches per trap (as due to variation in plot size some plots had two traps and some three). Percentage infestation of mango fruit in treated plots was assessed in 2003 and 2004, by sampling ten fruit on each plot, which were taken to the laboratory for rearing out of adults.

Results and Discussion

Table 1 shows the total trap catches over 13 weeks in 2003, as means per trap in each plot. BAT traps caught very few flies, MAT traps substantial numbers, and there was little indication of interaction between them. Trap catches by imported and home-made materials were subsequently compared, with the data for each trap both with and without the other combined (i.e. BAT trap catches with and without MAT alongside, and vice versa). BAT trap data were untestable (twelve “home-made” banana traps caught two flies, ten “imported” PH traps no flies, all in thirteen weeks). Among MAT traps the mean per-trap catch in the six blocks with “imported” (methyl-eugenol) lure was 5471 <SD=1222>, and in the four blocks with “home-made” (ocimum) lure was 61 <SD=24>. These comparisons were t-tested, after conversion to logarithms to reduce heteroscedasticity (with data untreated the sample variances differed significantly - F=2527.4376[5,3]*** - but with data logged they did not - F=3.5868[3,5]ns) and found to differ significantly (unrelated t=23.6693[8]*** {P<0.0001}). It was concluded another year of trap catch data would produce no further enlightenment and trap catch counting was discontinued in 2004.

Table 1. Catches per trap under different treatment regimes, over 13 weeks in 2003, as means and standard deviations (<SD>; N=5). Assessed by 2x2 factorial ANOVA for complete randomised blocks (with a notional catch of zero inserted for plots with no traps) differences due to MAT were significant (F=16.6030[1,12] {P=0.0015}) but there were no significant differences due to BAT (F=0.1395[1,12]ns {P=0.7153}) or to interaction between MAT and BAT (F=0.1394[1,12]ns {P=0.7154}).**

MAT	BAT	MAT+BAT
3003.9	0.1	3610.1
<2707.3>	<0.2>	<3445.5>

Table 2 shows the percentage infestation levels in the various plots in 2003 and 2004, and Table 3 the outcome of their analysis. MAT provided significant protection (as a reduction in infestation of (27-22)/27=19%), but BAT did not (as a reduction in infestation of (27-25.5)/27=6%). There may have been positive interaction when both were used together (as a reduction in infestation of (27-6.5)/27=76%) but this was not significant. Imported methyl-eugenol MAT (with a mean reduction in infestation of (27-[22+4]/2)/27=52%) may have provided better protection than indigenous ocimum MAT (mean reduction of (27-[22+9]/2)/27=43%) but this was not significant.

Table 2. Means and standard deviations (<SD>; N=5) of percentage infestation in eight treated plots in a 2x2x2 design of MAT, BAT and whether the components were imported or home-made. Five block plots were used in 2003 and again in 2004, each having "imported" treatments in one year, and "home-made" ones in the other.

Origin	Nothing	BAT	MAT	BAT+MAT	Row means
Imported	28 <22>	28 <26>	22 <15>	4 <5>	20.5
Home-made	26 <15>	23 <32>	22 <19>	9 <12>	20
Column means	27	25.5	22	6.5	

Table 3. Summary table of analysis of data from Table 2, by 2x2x2 factorial ANOVA for complete randomised blocks, as *F* and *P* (all d.f.=[1,28]).

Source	*F*	*P*
MAT	5.2577	0.0296
BAT	2.6380	0.1155
Origin	0.0091	0.9246
Interactions:		
- MAT/BAT	1.7891	0.1918
- MAT/origin	2.083	0.1600
- BAT/origin	0.0091	0.9246
- All three	0.0000	1.0000

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~04/09[BCT]: Insecticide, Food Bait and MAT Fruit Fly Control in Mango in Southern Orissa

Singh, HS, Mohapatra, KC, Stonehouse, JM, Mumford, JD, Verghese, A

Abstract

The infestation of mango by fruit flies was assessed on a large farm in an area near Rayagada where fly infestation is very serious. Assessment was by the farmer and the experiment unreplicated (N=1). Treatments were MAT by soaked blocks, PCI traps and ocimum traps, and three food baits soaked into hessian gunny bags and hung in trees. Relative to the unprotected infestation level of 30%, inferred percentage reductions were minimal by ocimum and PCI protections (both <2% improvement), but better by methyl-eugenol (ME) alone (34%), ME with protein hydrolysate (38%), ME with banana (56) and ME with jaggery (60). The farmer considered these levels of protection greatly inferior to that obtained by ME with jaggery bait sprays (0-3%) the previous year, and attributed this to the inadequacy of the gunny-bag application. It was concluded that, when fly attack is severe, MAT alone may not provide satisfactory control and reinforcement by BAT sprays be required.

Introduction, Materials and Methods

This study examined the effects of methyl-eugenol MAT and various baits as BAT in a large farm orchard near Kashipur, Rayagada, Orissa. Over a number of years different controls, unreplicated, were assessed in a 16-acre orchard of the elite mango variety *Amrapalli*.

In 2000 and 2001 the farmer carried out local practices of one or two cover sprays of carbaryl insecticide. In 2002 soaked blocks of local plywood were used for MAT at 16 per hectare, installed in the month of May before the onset of maturity in mango. Parallel BAT protection as by local jaggery at the rate of 30 gm/l was diluted in water with malathion added at the same concentration as used for cover sprays. It was applied as cover spray to leaf undersurfaces at all heights in the canopy, and repeated every week. In 2004, MAT were used at 4 per acre, and local jaggery (30gm/l) BAT was used for three times at 10-day interval as BAT in spots or "squirts" with a high volume sprayer to the undersides of leaves. Squirts were placed on a grid at 15m spacing - approximately 50 per hectare. Each squirt was of 300ml (15l/Ha); squirts were applied to leaf undersurfaces at all heights in the canopy. Assessment was done by taking a sample of fruits at the point of the principal harvest and of maximum fruit fly infestation. Five trees were selected, near the middle of the treated area. Percentage infestation was quantified from a sample of 30 fruits from each plant, taken for individual rearing-out. The information on farmers practice and it efficacy in preceding years was worked out through interview.

In 2003 a more varied programme of controls was installed, as in Table 2. The experiment was installed and assessed by the farmer and the treatments were unreplicated (N=1). Methyl-eugenol blocks were installed on May 9th, 2003, the PCI trap on May 25th; ocimum traps were replenished every ten days. Food bait were installed as soaked into hessian gunny bags hung in trees. All blocks, traps and bags were intalled at a rate of 10/Ha. Assessment was by the estimation of infestation of 100 mango fruit at five different places within each treated plot. The previous year (2002) the farmer had used food bait spray (with jaggery) twice along with MAT and obtained exceptionally satisfactory control estimated by him as from 0-3%; in previous years, with no protection, infestation was estimated as typically of 25-50%.

Results and Discussion

Four years estimates of fruit fly infestation in mango has been presented in Table –1 which includes farmers practice (2000 and 2001), and large area application of MAT and BAT (2002 and 2004). Data reveals that that before application of treatment the incidence of fly was high (up to 40 percent fruit damage) and unfortunately farmers were ignorant about fly control except application of one or two cover spray with carbaryl. In one year that Mat blocks were enclosed in traps (2002) catches were all of *Bactrocera zonata*

Table 1. Infestation level of fruit fly in an Orissan mango orchard under various types of treatments over a four-year period.

Year and treatment	% infestation
2000 - Carbaryl cover spray (farmers practice)	15-20*
2001 - Carbaryl cover spray (farmers practice)	35-40*
2002 - MAT; BAT cover spray	0-3**
2004 - MAT; BAT spot application	0-3**

* Farmer’s estimation; ** Rearing-out data

The levels of percentage infestation from the treatments assessed in the 2003 experiment, and the inferred percentage improvement above the level observed in the unprotected area, are summarised in Table 2. In the opinion of the farmer the level of infestation would have been greater in the unprotected, PDI and ocimum plots had it not been for the effects of the MAT in neighbouring plots.

Table 2. Percentage infestation of mangoes under various treatment regimes, and the inferred percentage reduction in infestation by treatments relative to the unprotected plot.

	ME + jaggery	ME + banana	ME + PH	ME alone	Ocimum trap	PCI trap	No control
% infestation	12.2	13.4	18.8	20	29.6	31.2	30.2
% improvement	60	56	38	34	2	-3	0

Although the experiment was unreplicated, the farmer was convinced that the methyl-eugenol treatment was valuable, but the ocimum, PCI and bait treatments were of very limited use. Comparison with the previous year led him to the firm conclusions that (1) MAT alone is not enough to provide adequate protection when fly attack pressure is heavy, and that BAT reinforcement is therefore sometimes necessary but also that (2) the gunny-bag application was greatly inferior to the sprayed-bait BAT used the previous year.

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~05/03[BPP]: Protection of Mangoes by BAT and MAT in Jharkhand

Singh, HS, Kumar, S, Stonehouse, JM, Verghese, A, Mumford, JD

Abstract

In a comparison of BAT and MAT in isolation and combination for fruit fly protection of mangoes near Ranchi, (N=4), inferred reductions in infestation were 31% by MAT, 38% by protein hydrolysate BAT and 49% by jaggery BAT; there were significant effects attributed to BAT (*P*=0.0043) and MAT (*P*=0.0191) but not to interaction between them (*P*=0.8454). The slight superiority of jaggery to protein hydrolysate BAT was not significant (*P*=0.3793).

Introduction, Materials and Methods

This experiment aimed to assess the protection of mango fruit from fruit flies by MAT and BAT in isolation and combination. The experiment took place in four complete randomised blocks in a mango orchard at Horticulture and Forestry Research Programme, Ranchi, Jharkhand during May 2004. MAT blocks were nailed to tree trunks at approximately 10/Ha. BAT was used in two forms, protein hydrolysate local jaggery; both were mixed at 0.3% (30gm/l) and applied three times, at 10 day intervals, in spots or "squirts" on a grid at 15m spacing (approximately 50/Ha); each squirt was of 300ml (15l/Ha), applied with a high volume sprayer to leaf undersurfaces at all heights in the canopy. Assessment was by the random removal of 60 fruit (in two batches of 30) from each plot at the time of harvesting to the laboratory for fly rearing.

Results and Discussion

Table 1. Means and standard deviations (<SD>; N=4) of percentage infestation of mangoes when protected by six fruit fly controls as in the text.

Un-protected	BAT (PH)	BAT (Jaggery)	MAT alone	MAT+BAT (PH)	MAT+BAT (Jaggery)
16	10	8	11	5	4
<4>	<5>	<5>	<3>	<2>	<1>

Table 2. Means from Table 1, converted into inferred percentage reductions in infestation from the level obtained in the unprotected plots, and recast as a two-way table. By two-way ANOVA (of data from Table 1 converted to logarithms) there were significant effects due to BAT (*F*=8.0116[2,15] {*P*=0.0043}) and MAT (*F*=6.8985[1,15]* (*P*=0.0191}) but not to interaction between them (*F*=0.1698[2,15]ns {*P*=0.8454}). By a planned related test of all relevant values, the difference in performance between PH and jaggery baits was not significant (*t*=0.9498[7]ns {*P*=0.3793}).**

	No BAT	BAT(PH)	BAT(Jag)	Row means
No MAT	0	38	49	29
MAT	31	69	74	58
Column means	15	54	62	

Mean levels of infestation and improvement are summarised in Tables 1 and 2. Overall, MAT obtained reductions in infestation of approximately 30% and BAT of 40%, with no apparent interaction between them. A slight superiority in control of jaggery BAT to protein hydrolysate BAT was not statistically significant.

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B. Semi-Structured Interview (SSI) Survey

Farmer opinions of fruit fly management options were highly localised and dependent on local tradition, particularly the sources of pest management information such as extension agencies and cooperatives.

Traps were often favoured, over spray applications of attractants, because of the satisfaction of seeing dead flies. Farmers often expressed enthusiasm for traps, and spent money on buying and charging them, even when their actual pest management effects were highly questionable, as in the cases of methyl-eugenol used in gourd fields and tulsi traps in mango orchards. This attraction of traps was one of the great advantages of non-chemical methods over pesticides.

Farmers were more exercised and concerned about pest management in mango orchards than in other crop systems. Cover insecticide sprays, when available, were only rarely used in gourds when directed at fruit flies alone.

As the conditions which favour the cultivation of fruit fly hosts - orchard fruit and cucurbits - tend to be quite particular and specific, their cultivation tends to be carried out by large numbers of farmers across suitable areas, creating an effect of relative monoculture. In this environment, and, indeed, largely leading to it, farmers tend to imitate one anothers' use of technology, with improvements in the management of crops spreading naturally between neighbours. This tendency is expected to favour the adoption of efficient pest management practices even when, as is often the case, there is little social solidarity or constructive communication among the farmers in an area.

Many traps have already been introduced by bodies such as cooperatives and particularly energetic extension services. It is suspected that these are not adequately strong to obtain real protection other than the satisfaction to the farmer of seeing dead fies.

3. Village-Level Fruit Fly Management

Introduction

In many parts of the world fruit flies are controlled in a coordinated way over large areas (e.g. Mauritius, Israel, USA, South Africa), and there is a role for a study of the extent to which economies of scale accrue when control is area-wide as opposed to on individual plots, and of how the benefits of area-wide controls may be most efficiently realised.

Noticeably, larval and pupal controls (parasitoids, fruit destruction, ploughing etc) all implicitly make assumptions about the mobility of emerged adults, as it is only ovipositing females whose reduction leads to savings of fruit (the destruction of eggs and small larvae, allowing their fruit to be saved, is assumed not to be practical, and assuming that emerging parasitoids damage fruit as much as flies) in assuming that reductions of populations of larvae and pupae lead to reductions in ovipositing adults which are not replaced by immigration from outside the treated area. Yet these authors know of no study, in India or anywhere else, which has specifically tested how much immigration may replace losses to the population by such controls.

In addition to the central role of official extension and support agencies, India is particularly rich in associations such as NGOs, cooperatives and farmers' associations, which offer different opportunities to provide farmers with key resources such as information, material inputs, group organisation and access to markets, transport and other essentials for agricultural development.

In general, much fruit fly research on a global scale is on quarantine and risk assessment, and less on cost-effective on-farm suppression, particularly imperfect but cheap controls suitable for small farmers (Stonehouse, 2001). The world literature is particularly scanty in addressing farmers' opinions and perceptions of the practical usefulness of the methods recommended to them. There are also only very few studies of the quantified cost-benefit values of practices when carried out on farms. This pattern also holds true for India, where the published information on the social and economic usefulness of control alternatives is less abundant than that on technical findings of controls in operation. The realistic assessment of farmers' perceptions of the usefulness and practicality of control operations was another objective of this study.

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~[DEL]1. Returns to Scale in Pest Suppression and Eradication:
Issues for the Wide-Area Management of Fruit Flies in India

JM Stonehouse, JD Mumford, A Verghese

In: Subrahmanyam, B, Ramamurthy, VV, Singh, VS (Eds) *Proceedings of the National Symposium "Frontier Areas of Entomological Research", IARI, New Delhi, November 5-7, 2003* (New Delhi, India: Golden Printers & Publishers for Entomological Society of India): 151-8.

Abstract

“Area-wide pest control” is not a unitary concept but incorporates a number of related but distinct axes. First, wide-area management by itself effectively increases the distances to be travelled by reinvaders from outside the area, and eradication of the pest is not necessarily needed. Second, the comprehensive treatment of the totality of the cleared area may obtain more efficient suppression but opens the question of sourcing the resources to treat uncultivated and similar areas. Third, wide-area management benefits when it allows the protected area to be defended by a perimeter. Fourth, wide-area management may permit sophisticated technologies to be used, which are more powerful in their eradicative abilities, and typically environmentally benign, but require a high level of information and technical expertise support, and wide-area use as posing only limited danger to immigrants. Fifth, economic and social considerations often entail the use of mechanisms to control “free riders”. When neither eradication within an area nor the impermeability of a buffer surrounding it is perfect, computer modelling has indicated that the approach may work by delaying the onset of attack until the harvest has passed, and re-establishing temporary control the following season in a process of “deciduous” controls. The implications of these issues are considered for two wide-area controls under consideration in India, intermediate between private field-level control and the eradication of isolated pest populations in “classic” wide-area control. In village-level suppressive control comprehensiveness and eradication may be sought only as matters of degree, and so social confrontation minimized, if the approach is found to be robust, and forgiving of a few isolated pest population remnants. In wide-area deciduous eradication in Pest-Free Zones it may be necessary both that isolation be effective and that control be eradicative. Both strategies may offer considerable advantages if conditions are right.

Introduction

In many situations, the effectiveness of pest management is maximized by its conduct on area-wide scales, instead of in immediate localities. Some situations are better suited than others to this approach, and the understanding of why this is so requires the distinction of the different elements which may be combined to comprise wide-area control. This paper seeks to analyse these different elements, and to consider the implications for the suitability of area-wide management of fruit flies in India.

The minimum scale of pest management is at field level (although adventurous farmers may apply to single plants or targets) and aims at suppression, rather than eradication, over a restricted area which has no natural protection against reinvasion . At the other extreme is the eradication of a species over an entire area, within a defensible (or impenetrable) perimeter, subsequently protected against reinvasion by quarantine controls, such as pest eradication on isolated islands in “classic” wide-area control. An example is the eradication of the Melonfly Bactrocera cucurbitae in Seychelles, to be attempted in 2004 by the Government of Seychelles and Imperial College London. The plan for this eradication envisages (1) initial population reduction by bait sprays, followed by (2) the complete stopping of reproduction by parapheromone lure blocks to eradicate males and thus prevent oviposition by females and (3) intensive surveying, by traps and fruit inspection, until it can be certain that the pest is entirely eradicated.

There are also intermediate cases, and these have special aspects, in addition to their intermediate positions on a continuum between the two extremes. There are several different axes on this continuum, and the distinction of these may indicate the features likely to dictate success or failure. Wide-area control has different characteristics which combine with each other.

1. Wide-Area Management by Itself

With no development other than the extension to larger areas of conventional farm-level controls, without systematic and thorough treatment of all possible pest refuges within that area and not protected by natural or artificial barriers to reinvasion, wide-area control increases the distances to be travelled by reinvaders from outside the area - essentially the outer areas act as a barrier for the inner ones. Returns to scale are primarily determined by the mobility of the pest, and the range of travel of potential re-immigrants. In this scenario, area-width is the only factor added to conventional farm-level control, and the eradication of the pest is not necessarily considered.

Such pest suppression at local level, such as by cooperating villagers, has not, however, been much at the forefront of area-wide techniques, but is currently being studied by ICAR and Imperial College London in the Project Integrated Management of Fruit Flies in India (IMFFI). The principle of this particular "village-scale" control is the denial to female fruit flies of resources needed for laying - (a) protein food (in the case of protein bait control) or (b) fathers (in the case of parapheromone lures used for male annihilation). The risk is the immigration of already-satiated females, and so the principle is to increase the distance these satiated immigrants must travel. The technology is the same as farmer technology, and as such not in itself scale-dependent: the wide-area benefit is due to control coordination, not control technology, and there is no natural or artificial perimeter to prevent reinvasion, other than the border of the protected area itself.

2. Treatment of Non-Economic Refuges within the Treated Area

Wide-area control also implies the treatment not only of a large area but also in a comprehensive way, pursuing pest populations into uncultivated areas and generally beyond the immediate economic commodity to be protected. This is directly associated with the principle of wide-area control, so that the two together obtain “Uniform suppressive pressure applied against the total population of the pest over a period of generations [which] will achieve greater suppression than a higher level of suppression on most, but not all, of the population each generation” (Knipling, 1992). This manifests itself in an attitude to pest management which is both comprehensive and aggressive; instead of being reactive, defensive and protective of the target commodity alone, this attitude is proactive, offensive, and takes the fight to the enemy (Lindquist, 2000) (this is in contrast to the entire philosophy of thresholds and economic injury levels). It explicitly requires continuing control efforts beyond those which obtain a specific economic return at the time, and entails consideration of role of wild hosts and access to uncultivated areas where these may be treated.

3. Isolation from Reinvasion Sources

Additionally, wide-area management allows (but does not necessarily require) the protected area to be defended by a perimeter, either (a) by extending the area to a natural barrier (e.g. the coast around an island in “classic” wide-area eradication) or (b) by facilitating buffer defence by shortening the perimeter-length/protected-area ratio. Returns are therefore largely dictated by ecological isolation from reinfestation sources. If quarantine defences can prevent reinvasion, eradication even if expensive may be highly economic.

This isolation is an essential component of “classic” area-wide eradication. The eradication of melonfly in Seychelles will be attempted concurrently with actions by the Government of Seychelles to strengthen quarantine procedures and legislation to prevent the reentry of the pest, to reinforce its natural isolation from the nearest infestation source by thousands of miles of open ocean.

4. The Use of Eradicative Technologies

Wide-area management also permits (but does not necessarily require) more sophisticated technologies to be used, which are more powerful in their eradicative abilities, but which require wide-area deployment as posing less danger to immigrants than less sophisticated controls.

In most cases, eradication as opposed to suppression depends on the eradicative capacity of controls used. This depends critically, in large part, on controls which may work by positive feedback, i.e which can intensify the reduction they effect on a target population the more that population has already been reduced. This property is not the norm for pest controls, but is a characteristic of some wide-area applicable controls. Controls with this first characteristic property generally have others. Second, in general, controls with this property are also specific as to their target, which both reduces damage and risk to non-target species but also requires the precise identification of a limited number of target species. Third, these controls tend to be environmentally benign, in minimizing the use of pesticides and similar indiscriminate methods. Fourth, they typically have a raised role for biological knowledge and scientific expertise - a higher information density; this is characteristic of sophisticated technologies in general, and increases their reliance on a base of knowledge and expertise among implementing personnel. Sex attractant technologies, parasitoids and the Sterile Insect Technique (SIT) all possess these characteristics.

The roles of different technologies may be seen with reference to the four which are commonly used against fruit flies (Diptera: Tephritidae), as shown in Table 1.

Table 1. Four technologies used against Tephritid fruit flies, with the characteristic elements which differ among them. Operational Level describes the level at which the control is typically deployed. Fly Cycle Component Affected is the part of the fly's ecological niche and activities which is disrupted. The Eradicative Capacity of techniques, and their Specificity, Environmental Risk and Information Needs are also indicated. Persists Lethal To denotes the pest population subset which is susceptible to the persisting control on entering the treated area; Susceptible To Penetration By is the inverse of this, indicating the subset of the pest population which may pass unharmed into an area protected by the technique.

Type:-	Cover sprays	Bait application	Male annihilation	Sterilized males
Operational Level:-	Plant	Field	Farm	District
Fly Cycle Component Affected:-	Whole environment	Food	Sex (kills males)	Sexual activity
Eradicative Capacity (Positive Feedback):-	None	None	Intermediate	High
Specificity:-	All insects	All fruit flies	Species group	(Sub-) Species
Environmental Risk:-	High	Intermediate	Low	Very low
Information Content and Needs:-	Low	Low-intermediate	High-intermediate	High
Persists Lethal To:-	All insects	Unfed fruit flies	Male fruit flies	Fruit fly mating activity
Susceptible To Penetration By:-	No insect	Fed male and female fruit flies	Mated female fruit flies	Mated female and wild male fruit flies

The table indicates how the critical capacity of SIT and, to a lesser extent, MAT to exert continuous or increasing lethality as the pest population contracts (positive feedback) is associated with their high specificity in targeting and with lethality to a smaller subset of the target of population and its life cycle. The reason some technologies require the wide-area approach is the low danger they pose to immigrants.

Interactions of Issues 1 to 4

The completeness of eradication of pests in an area prevents against resurgence of the native population, or the reappearance of pest on a time scale; the completeness of isolation of the protected area from outside prevents against the arrival of immigrants, of the reappearance of the pest on a spatial scale. The concern common to both cases is the prevention of reestablishment. It follows that the maximum intensity for obtaining complete pest exclusion by one (eradication or isolation) will only obtain the best possible return when exclusion by the other is also complete. Thus a cleared area protected by a buffer will benefit by complete internal eradication only if the buffer is also perfect; if it is not, a more rational approach may be control reapplied at regular intervals, in a programme of repeated resuppressions, successively carried out to forestall the population expansion. Buffers rarely are perfectly impermeable, and no barrier is completely impermeable to quarantine breaches such as infested produce secreted in travellers' luggage. Imperfect but reapplied controls make it possible to tolerate both (a) an imperfectly-impermeable buffer and/or (b) imperfect initial eradication. It may be that an economic optimum is not to pursue total eradication but to delay the onset of attack until after the harvest season has passed, whereon the pest may be allowed to reestablish itself until the control cycle begins again at the start of the following crop season, in a cyclical time-management process of what may be called "deciduous" controls.

The relationship between the perfection of buffering, the perfection of eradication and the role of imperfect management in delaying infestation time were explored by a computer model developed in the Pascal programming language by Imperial College London (Stonehouse, 2001). This studied the economic returns to a number of variables in the strategy of "eradicate-and-buffer" whereby a pest is initially annihilated in a protected area, and then protection in this area relaxed, while continuing control in a buffer perimeter prevents reinvasion. Model outputs were of the relative effects on cost-benefit returns to buffer management, in comparison with equivalent wide-area management, when each in turn of a suite of 14 variables was changed from a lower to a higher hypothetical value over an order of magnitude. These were (1) biological values (the pest reproduction rate, host yield, host loss per day per pest, and pest invasion pressure); (2) management effectiveness values (the initial pest population, the buffer penetrability, area-wide kill rate, and decay rate of spray effectiveness); (3) management operations values (diameter of protected core, thickness of protective buffer, and spray schedule); and (4) Economic values (the value of produce and cost of sprays). Two in particular of the model's findings are of interest here.

First, the complete eradication of native pests in the buffer-protected area was found to bring considerable benefits, in comparison with even very intense suppression; without this, the repeated reapplication of incomplete eradication served little purpose.

Second, as long as either initial suppression or buffer impenetrability are incomplete, pest management in all cases ultimately works by delaying pest attack – a suppressive, rather than eradicative strategy, but one which may be highly effective in returns to costs.

5. Economic and Social Aspects

All use of area-wide controls requires a social component, and social operations, and the cohesiveness of society and its institutions, for the management of costs and benefits within society, are generally critical. Particularly important, and difficult, is the capturing of returns - how to use the benefits of wide-area control to pay for its activities, so that these are funded by beneficiaries, rather than (by general taxation) everybody (Mumford, 2004). The problems of "free riders" in social-level pest control are well known, and taking the fight away from the commodity to the pest population often entails control operations in wilderness areas outside individual property. Mechanisms for public and social participation are crucial. Deciduous controls may have advantages in this regard - as beneficiaries may pay for a steady supply of services into the future, letting these future income payments pay off the large initial capital cost (Mumford, 2000).

Conventional approaches to social obstacles such as free riders traditionally include formal instruments such as subsidies and/or penalties applied by processes of law. The principle is that if society wishes an individual to do something they would not do otherwise, society may make it more attractive (by subsidy) or not doing it less so (by penalty) to make up the difference. At village level, there may be less formal approaches, which do not rest on legal authority with the ultimate sanction of force - replacing coercion with cohesion. Villages in countries such as India have a variety of complex and subtle social institutions, which may be instrumental in providing the social cohesion needed for village-level participation.

The exertion of social control depends strongly on the reasons why comprehensivity is sought and "free riders" pose a danger. Comprehensive eradication may be sought (1) to prevent resurgence of pests in thorough suppression, (2) to reduce pesticide use to capture a market sensitive to residues, as is largely the case in pest-free zones against the Oriental Fruit Fly Bactrocera dorsalis in Thailand (Quinlan et al, 2002) or (3) to ensure produce free from pests to capture a market sensitive to quarantine breaches and the introduction of viable pests capable of establishing themselves (as a bonus, these markets are often, though not necessarily, also restrictive in permissible pesticide residues in produce, and so disposed to favour protection by pesticide-minimal means).

In this last case, eradication must be complete and guaranteed, and so the financial returns to it may be substantially greater than those to suppression. These financial returns may be required to generate the income necessary to pay the high costs of SIT establishment and maintenance..

Conclusions

These issues of wide-area, isolation, eradication, comprehensiveness, isolation, technology and socio-economics may be considered together in the consideration of two intermediate wide-area control strategies of possible use in India – village-level cooperative control and the establishment of "Pest-Free Zones" (PFZs) for the protection of export-produced fruit, such as in the Western Cape of South Africa (Barnes et al., 2004), which deploys SIT as an eradication technique, in an area which is well but imperfectly isolated from reinvasion from outside, and reapplies the control annually in synchrony with the protection requirements of the crop. Table 2 shows the interaction of these issues in the cases of non-wide-area field control, "classic" eradication, and these two intermediates.

Table 2. Influence of characteristics in the pest management scenarios of farm-field-level control, "classic" wide-area control, and two intermediate cases - village-level cooperative control, and the seasonal but eradicative maintenance of specific but area-wide Pest-Free Zones for export. The role of socio-economic factors is labelled "authoritarian" to reflect the importance of social control of the behaviour of individuals.

Case	Field-level	Village-level	"Deciduous PFZ"	"Classic"
1. Wide area	No	Yes	Yes	Yes
2. Comprehensive	No	Partly	Yes	Yes
3. Isolated	No	No	No	Yes
4. Eradicative	No	No	Partly*	Yes
5. Authoritarian	No	Partly	Yes	Yes

* - depending on the purpose of eradication – intense suppression, pesticide-residue-sensitive or quarantine-sensitive export market access.

The cases and analysis above lead to the following conclusions for the establishment of the two scenarios indicated.

A. In village-level suppressive control comprehensiveness and eradication may be sought only as matters of degree, not absolutes, and so social confrontation minimized, if the approach is found to be robust, and forgiving of a few isolated pest population remnants.

1. The area must be as large as possible.
2. The area must be as isolated as possible.
3. Some social coordination must be attainable without formal legal methods.
4. The presence of wilderness and other areas, hospitable to pests, within the treated area should be minimal, or a social organisation to treat such areas should be feasible.
5. The destination of produce should not be a quarantine-sensitive market.
6. The crop should be sufficiently valuable to justify the additional costs of socially-coordinated control.
7. The level of additional pest suppression obtained by social controls, in comparison with private ones, should be adequately clear to justify its added costs in the minds of all participants.

If the above can be obtained, the socialisation of control is a promising way to add value - environmental as well as financial - without the intensification of technology, and so offers improvement in control without rising costs such as an increased intensity of pesticide use.

B. In wide-area deciduous eradication in Pest-Free Zones, such as of fruit flies by SIT, it is necessary that, for the duration of control, both isolation be effective and control be eradicative.

1. The area must be as large as possible.
2. The area must be as isolated as possible.
3. The high knowledge and expertise demands of sophisticated technology will require a good base of technical personnel, equipment and institutions.
4. There must be a minimum number of target species and sub-species (ideally one).
5. A high financial value of the protected produce (such as for export to quarantine-sensitive markets) may be required to generate the income to fund the control.
6. An institutional system will be required for the coordination of producers and the collection of revenue. This will generally be favoured by relatively small numbers of relatively large, export-oriented farms, and that the area be homogeneously filled with such farms, as a scattered minority of farms without export ambitions may see no reason to contribute to the added costs of eradicative management.
7. If the objective is quarantine-sensitive market capture, control must be sustained over the whole season and the whole area.

If these conditions may be met, deciduous eradicative control may offer a cost-effective management of pests over a wide area, and may be the only way to obtain access to sensitive markets.

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A. Quantification of Returns to Farm-Level and Village-Level Fruit Fly Management

~[IWA]2. Village-Level Wide-Area Fruit Fly Suppression in India: Bait Application and Male Annihilation at Farm Level and Village Level

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Introduction

Dispersion of organisms is an ecological imperative, and farmers frequently observe pests invading recently-treated fields from untreated neighbouring farms. The control of mobile pests such as insects may therefore be more efficient when applied over areas larger than the individual farm, with cooperative, synchronised area-wide control at village or locality level, on a smaller scale than comprehensive regional or national programmes (Stonehouse et al., 2005).

Pest fruit flies (Diptera: Tephritidae) may be managed by the bait application technique (BAT) whereby adults are attracted to spots of protein bait with insecticide and so killed (Roessler, 1989). BAT may benefit in particular from village-level control, as flies which have found protein food elsewhere may be less strongly attracted to protein (Manrakhan et al., 2002) and so, as females already protein-fed may enter the area with their appetites satiated and their requirements met, and thus be immune to controls; the principal of area-wide control is to increase the distance that these “satiated immigrants” will have to travel.

BAT can be used for the protection of cucurbits from Tephritids in South Asia (Stonehouse et al., 2002) and this experiment aimed to quantify its crop protection returns when used at farm and village level.

Materials and Methods

The study assessed the effects of farm-level and village-level tephritid control by BAT in cucurbits and by MAT in orchard fruit, each in six locations in India, with varying conditions in both agricultural background and research procedures. To ensure the meaningful analysis and comparison of data, in the light of considerable differences in terrain, vegetation types and vegetation density, a photographic record was made of the general outlook of each research village, and some representative pictures, expressing the main characteristics, are given in Appendix 3 [File: iy5fwi2].

“Village-level” management was carried out over areas of one square kilometre; farm-level management depended on the size of farms which varied between regions. At village level, at each Centre one square kilometre was treated, and another not so treated, with an equal number of farms assessed in each. At farm level, inside and outside the treated square kilometre at each Centre farms were divided into halves, one half treated and one half untreated. Some farms were inside square-kilometre-protected villages and others not, so that pest damage could be assessed outside protected areas, on half-farms which were unprotected (fv), the other halves of the same farms protected at farm level (Fv), and inside protected areas on half-farms protected at village-level only (fV) and the other halves of the same farms protected at both farm-level and village-level (FV), to obtain a two-by-two factorial design of (1) unprotected (fv), (2) protected at farm-level only (Fv), (3) protected at village-level only (fV) and (4) protected at both farm-level and village-level (FV). This allowed the comparison of control at farm and village level and the assessment of interaction between the two, to see whether the efficiency of one may be augmented by the use of the other as well, or whether one alone is adequate without the other. Data were assessed by two-way factorial ANOVA for complete randomised blocks, after conversion to natural logarithms as the effects of control were taken to be multiplicative rather than additive.

Wide-area controls are demanding of financial and time resources, and in consequence were replicated relatively sparingly, and so data from non-wide-area-treated plots were manipulated to “damp out” non-experimental variation, by using two villages in each of two years, but only treating one in one year. The villages were termed A and B, and years 1 and 2. Village-level control was deployed in A2 only, but infestation levels additionally assessed in three areas without village-level protection - A1, B1 and B2. The reasoning to justify this design was as follows. First, consider a trial in only one village but in two years, comparing the results in Village A in Year 2 and the same village in Year 1. It may be that an observed difference was due not to the treatment but to background differences between years: this may be checked by inspection of the results in the same two years in Village B, which was untreated in both years. To discount the between-years difference, therefore, the "control" data (Village A Year 1) may be adjusted by multiplication by the ratio between the same two years in Village B: so the data for A2 may be compared not with that for A1 but with

(A1.[B2/B1]) (Equation 1)

Second, consider a trial in two villages but in only one year, comparing the results of Village A in Year 2 and the same year in Village B. It may be that an observed difference was due not to the treatment but to background differences between villages. This may be checked by inspection of the results in the same two villages in Year 1, which were both untreated that year. To discount the between-villages difference, the "control" data (Village B Year 2) may be adjusted by multiplication by the ratio between the same two villages in Year 1, so the data for A2 may be compared not with that for B2 but with

(B2.[A1/B1]) (Equation 2)

It may be observed that Equations 1 and 2 are the same, and this equation was used to allow data from three plots without village-level control for each plot with village-level control, to correct for background differences between villages and years. (It was assumed that differences between years and differences between villages were independent of each other, without interaction). The experimental design also assisted the acceptance of wide-area intervention by villagers, as the farmers who had hosted the farm-level-only trials in Year 1 were able to testify that the control had beneficial and no adverse consequences, when the purpose and nature of the village-level applications were explained and discussed with villagers. The design was also intended to allow the use of compensation along only one axis (either villages or years but not both) if one cell in the design was unavoidably empty. Where possible, data between years were re-visits to the same plot; where not, different plots were used.

Data were gathered as percentages of loss of fruit to flies. Assessment methods were at the discretion of the local research manager following experience under local conditions. Assessment of infestation was by inspection of fruit for oviposition punctures - this method does not obtain an accurate estimate of actual losses, but is unbiased and thus can be used to assess the reduction in losses by controls (Stonehouse et al., 2004).

In each village each cell was replicated on two farms, which also allowed some redundancy, to allow data to be obtained when, as frequently happened, individual plots were lost to mishap. Replication at the plot level followed local research practice. In some areas this was by inspection of fruit numbers in a specified unit area (obtaining mean sample sizes varying between 37 and 124); in others this was by inspection of a specified number of fruit (varying between 30 and 250). Data were taken from a number of harvests, varying between three and twelve.

Where both replicates were obtained in untreated plots for either both villages in Year 1 or Village B (without wide-area treatment) in both years, these could also be used to quantify the differences between villages and years, in the absence of controls, and thus retrospectively to assess the need for the calibration process to damp out between-village and between-year differences, by comparative ANOVAs of the infestation level in the unprotected plots between pairs of villages in year one or the untreated village between years.

I - Protein hydrolysate BAT in cucurbit fields

The locations and conditions of the sites are summarised in Table BAT1. Crops grown were pumpkin (*Cucurbita pepo* L.), bitter gourd (*Momordica charantia* L.), snake gourd (*Trichosanthes cucumerina* L.) and musk melon (*Cucumis melo* L.). Flies attacking in every case were mostly *B. cucurbitae* Coq., accompanied in some cases by a minority of other species, including *Dacus ciliatus* Loew. There were local differences in cultivation system, growing season length (and therefore number of harvests), local research practice (sample size, data-gathering) and fortune (losses of data).

Table BAT1. Summaries of the locations and characteristics of the cucurbit cultivation and BAT protection regimes at the six experimental sites in India.

Site	Location	Crop	Spray number	Plot size (Ha)	% Area of hosts	% Area sprayed
Palanpur	24°10'N, 72°26'E	Pumpkin	6	3.2	50	58
Anand	22°34'N, 72°56'E	Bitter gourd	12	0.1	73	78
Thrissur	10°31'N, 76°13'E	Bitter gourd	7.5	0.1	90	96
Thiruvananthapuram	08°29'N, 76°55'E	Snake gourd	4.3	0.1	50	80
Bhubaneswar	20°14'N, 85°50'E	Bitter gourd	4	0.5	35	45
Varanasi	25°20'N, 83°00'E	Musk melon	8	0.4	13	100

Given for each site is the location (coordinates taken from www.astro.com/atlas), the number of sprays carried out, the mean size of farm plots in hectares, and fieldworkers' estimates of the percentage area coverage by host cucurbits and by all vegetation which was sprayed.

BAT was in all cases by spot sprays of 3% protein hydrolysate (International Pheromone Systems, Units 10-15, Meadow Lane, Meadow Lane Industrial Estate, Ellesmere Port, South Wirral, L65 4TY, UK; www.internationalpheromone.co.uk), with local insecticide at the volume rate used for cover sprays, applied at a rate of 8L.Ha^{-1}. All applications were of 200 spots.Ha^{-1} each of 40ml, spacing between spots being approximately 7m, except in Palanpur and Bhubaneswar where in Year 1 (but not Year 2) spacing was 15m (50 spots.Ha^{-1}) each of 160ml to obtain the same volume per unit area.

Village-level BAT was applied to all cucurbit fields, bushy vegetation such as fruit orchards, other trees and hedges, and surfaces such as fences, walls and electricity and telephone poles. It was not applied inside dwellings and their gardens or anywhere below a height of five feet above the ground - bare ground, roadways, and graminaceous crops such as rice - as considered to be little frequented by flies and bringing spots within the reach of animals and children.

II - Methyl-eugenol MAT in fruit orchards

MAT was by blocks of plywood, 5x5x1cm in size, soaked in a 6:4:1 (v:v:v) mixture of ethanol (solvent), methyl-eugenol (lure) and malathion (insecticide). Blocks were deployed throughout treated farm and village areas at 10/Ha, across the entire area, nailed or hung at or above 2m above the ground to keep them from the reach of children, animals and the idly curious.

Table MAT1. Summaries of the locations and characteristics of the fruit cultivation and MAT protection regimes at the six experimental sites in India {Gandevi 20km S of Navsari}**.**

Site	Location	Crop	Setting number	Plot size (Ha)	% Area of hosts
Palanpur	24°10'N, 72°26'E	Mango	1	1	20
Navsari	20°51'N, 72°55'E	Mango	1	1.5	94
Navsari	20°51'N, 72°55'E	Sapota	2	1.5	94
Thrissur	10°31'N, 76°13'E	Mango	1		
Lucknow	26°51'N, 80°55'E	Mango	1		
Kanpur	26°28'N, 80°21'E	Guava	1		

Given for each site is the location (coordinates taken from www.astro.com/atlas), the number of settings of blocks carried out, the mean size of farm plots in hectares, and fieldworkers' estimates of the percentage area coverage by host orchards (in Navsari mango and sapota are grown alongside each other and infestation of each was assessed over the same area).

Results

The exploratory assessment of natural background variation between localities and years, with no controls, required replication to be complete in all experimental cells; for the areas where this was achieved the results are summarised among cucurbits in Table BAT2 and among orchard fruit in Table MAT2. It appeared that significant differences between localities and years were commonly found, and consistency between either of these cannot be reliably assumed.

Table BAT2. The analysis of differences in gourd infestation levels, with no controls applied, between villages in Year 1 and between years in Village B, in separate areas of India.

Site	Between villages	Between years
Anand	1.4712ns	19.4791*
Thiruvananthapuram	0.9719ns	37.0120*
Bhubaneswar	50.1053*	1.7376ns

In all cases N=2. Given are *F*-ratios (all degrees of freedom = [1,2]) and significance levels.

Table MAT2. The analysis of differences in fruit infestation levels, with no controls applied, between villages in Year 1 and between years in Village B, in separate areas of India.

Site	Host	Between villages	Between years
Navsari	Mango	25.8302*	6.8113ns
Navsari	Sapota	3.1947ns	

In all cases N=2. Given are *F*-ratios (all degrees of freedom = [1,2]) and significance levels.

I - BAT against cucurbit fruit flies

Among the different treatments and cases, data were lost from a variety of causes, including floods, fungal diseases and transport problems. In two areas (Palanpur and Varanasi) only one replicate was obtained in each cell; in one (Thrissur) one cell replicate was lost and the remaining datum used instead of the mean of two. In two cases entire cells were lost: in one (Palanpur) one cell (treated at farm-level only in Year 2) could not be filled and calibration between Years 1 and 2 was by the ratio between years in the neighbouring (untreated) cell; in another (Varanasi) all data were lost in Year 1, and outcome calculated for Year 2 without calibration for between-village background variation after discussion with local farmers and fieldworkers indicated a broad similarity of typical infestation levels. The results of the comparisons, with these difficulties addressed as described, are summarised in Table BAT3.

Table BAT3. Means and confidence intervals (95%) of percentage infestation by fruit flies of cucurbits (all bitter gourd except Palanpur, where pumpkin) protected by bait application technique (BAT) at scales of the farm and village at six sites in India, and the inferred percentage reductions in infestation attributed to controls.

Site		Infestation (%) under protection at level of				Inferred reduction (%) by protection at level of		
		No control	Farm only	Village only	Farm and village	Farm only	Village only	Farm-village interaction
Palanpur		56.6	28.2	25.8	21.0	50	54	-63
Anand		9.4	5.0	3.1	1.5	47	67	10
Thrissur		12.4	8.3	2.1	1.7	33	83	-19
Thiruvananthapuram		32.4	14.6	7.7	5.8	55	76	-67
Bhubaneswar		19.4	7.2	0.2	0.1	63	99	-19
Varanasi		73.3	48.3	39.0	21.2	34	47	18
Mean		33.9	18.6	13.0	8.5	47	71	-27
Confidence intervals	- Upper	54.5	30.5	23.4	15.1	56	90	Not computed
	- Lower	13.3	6.2	1.3	0.9	37	55	

Significant differences were attributed to village-level control (ANOVA for complete randomised blocks, performed with data converted to logarithms, *F*=22.3923[1,15]*) but not to**

farm-level control (*F*=2.6365[1,15]ns) or interaction between them (*F*=0.0863[1,15]ns). Infestation levels were converted into inferred levels of reduction by controls in the following way: infestation under farm-level control alone was given as farm-level infestation divided by infestation without control; infestation under village-level control alone was given as village-level-control infestation divided by infestation without control; from these an expected value was obtained for the two together assuming them to be independent, as their product (multiplied by each other), and the reduction by interaction was given as the ratio between this expected value and that found; these values for fractional reductions in losses were then converted to fractional levels of control by subtraction from one, and then converted to percentages. Confidence intervals were calculated with data converted to arcsines.

The lack of significance attributed to farm-level BAT control in Table BAT3 was a reflection of the organisation of the data; when compared over all plots where farm-level BAT and no-control were compared side-by-side (i.e. dismantling the factorial layout and calibration structure to allow the plots to form a larger number of replicates) the mean percentage reduction in infestation was 44 (between 95% confidence intervals calculated from arcsine-transformed data of 36 and 51) and the differences between infestation levels highly significant (related *t*=9.4460[13]***).

II - Methyl-eugenol MAT in fruit orchards

The levels of protection obtained under the four regimes in various localities are summarised in Table MAT3.

Table MAT3. Means and confidence intervals (95%) of percentage infestation by fruit flies of orchard fruits protected by male annihilation technique (MAT) at scales of the farm and village at six sites in India, and the inferred percentage reductions in infestation attributed to controls.

		Infestation (%) under protection at level of				Inferred reduction (%) by protection at level of		
Site	Fruit	No control	Farm only	Village only	Farm and village	Farm only	Village only	Farm-village interaction
Palanpur	Mango	9.6	1.3	11.0	1.0	86	-15	33
Navsari	Mango	46.2	31.9	11.4	5.3	31	75	33
Navsari	Sapota	30.0	26.4	13.2	7.9			
Thrissur	Mango					12	56	4
Lucknow	Mango	3.0	0.5	1.3	0.0	83	57	0
Kanpur	Guava	29.0	2.3	1.0	2.5	92	97	0
Mean		23.6	12.6	7.6	3.3	61	54	1

Infestation levels were converted into inferred levels of reduction by controls in the following way: infestation under farm-level control alone was given as farm-level infestation divided by infestation without control; infestation under village-level control alone was given as village-level-control infestation divided by infestation without control; from these an expected value was obtained for the two together assuming them to be independent, as their product (multiplied by each other), and the reduction by interaction was given as the ratio between this expected value and that found; these values for fractional reductions in losses were then converted to fractional levels of control by subtraction from one, and then converted to percentages. Confidence intervals were calculated with data converted to arcsines.

Discussion and Conclusion

BAT fruit fly control at village-level was more effective than when at farm-level alone. These levels of improvement (47% from control at farm-level, 73% when at village-level) may give encouragement to cooperative village-level controls.

There was little evidence for interaction between farm- and village-level control. This suggests that even when village-level controls are in operation, there may still be an added return to the farmer (of a further 47% reduction in infestation) from additional private controls.

Cooperative social-level controls often encounter their greatest obstacles in social organisation and the establishment of institutions to encourage individuals to participate, and in particular in addressing the “free rider problem”. These findings offer tentative encouragement in this regard, for two reasons. First, the applications at village-level were by no means comprehensive and eradicative: in Anand nearly 5% and in Thrissur nearly 20% of the cucurbit area was the property of uncooperative individuals who refused to allow treatment (though in Thrissur the success of the treatments led to full participation for the majority of the growing season) and in all zones some areas - for example domestic areas - were left untreated. The significant improvements attributed to wide-area control were achieved in spite of this, implying that the approach, of wide-area suppression rather than eradication, may be relatively forgiving of imperfection and still able to provide economic returns when imperfectly applied. Second, the continuing return to farm-level controls even when village-level ones were in place, suggested that individuals would still have an incentive to conduct controls when village-level control was being carried out - e.g. everybody else was controlling in a coordinated way - and so no incentive to be a “free rider”.

Acknowledgments

This work could not have been carried out without the support of the villagers hosting the study, and of G Kalloo, SN Pandey, DS Rathore, SK Chauhan, RK Dwivedi, RD Sharma and L Saini. This document is an output from a project funded by the UK Department for International Development (DFID) for the benefit of developing countries (R8089, Crop Protection Programme). The views are not necessarily those of DFID, and all errors and omissions remain the responsibility of the authors.

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B. Patterns of Extinction in Wide-Area MAT Control

3. ~03/55[STH]. Village-Level Wide-Area Fruit Fly Suppression in India: Patterns of Extinction and Invasion under Male Annihilation Control in a Mango Orchard

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Keywords: fruit fly, male annihilation, area-wide, mango, India

Running title: Patterns of wide-area fruit fly suppression in mango

Abstract: The management of pest fruit flies (Diptera: Tephritidae) in South Asian orchards by the male annihilation technique (MAT) is thought to benefit when deployed at areas larger than that of the individual farm. This experiment assessed the spatial distribution of fly extinction and reinvasion during the use of MAT over a one-square-kilometre area of mango orchard in Gujarat, India, by the placement of each MAT block in a trap to allow the spatial and temporal distribution of male fly survival and penetration to be examined over a six-week period. The MAT controls considerably reduced the fly population in the inner parts of the protected area, while the outer areas found higher populations. Even after six weeks the population in the inner core was not completely eradicated. Reinvasion was by characteristic and persistent “fingers” of males intruding from the same areas of the perimeter. It was concluded that MAT management over an area of 1km^2 may be much more efficient than over smaller areas, and that use over even larger areas may obtain further efficiency benefits.

Introduction

Control of fruit flies by male annihilation technique (MAT) offers benefits when applied over areas larger than the individual farm. This experiment aimed to assess what are the patterns of extinction and reinvasion of flies when MAT by parapheromone-and-insecticide-soaked wooden blocks were used over the area of a square kilometre.

Materials and Methods

The experiment took place in a one-square-kilometre extent of mango trees forming part of the experiment station of SDAU, Sardarkrishinagar, Gujarat. The stand was protected by MAT blocks installed at the density of ten per hectare on a regular grid thirty blocks by thirty-four. Blocks were made of 5x5x1.2cm plywood pieces, soaked in a 6:4:1 (volume) mixture of ethanol:methyl-eugenol:malathion. Each block was contained in a trap made from a 1L plastic drinking water bottle, each marked with a red ribbon streamer to facilitate its location, and all traps were emptied, and the catch counted, weekly for six weeks after installation (each emptying took a team of six approximately 40 hours). Due to restrictions of space, time and labour the experiment was unreplicated.

Results

The total numbers of flies caught were 3963 in week 1, 1557 in week 2, 1656 in 3, 2051 in 4, 2350 in 5 and 934 in 6, an overall total of 12 511. The Tables and Figures below show the patterns of distribution in the six successive weeks. (Fruit infestation was not quantified, but the orchard managers said that infestation was negligible and protection virtually complete). The Tables show the distribution of catches by trap. The Figures provide a graphic representation of the same data using the coding system shown in Table 1, with the trap distribution delineated into four zones in each image - the outermost ring, three traps deep, inside this second and third rings each also three traps deep, and an inner core. Table 2 shows the means in each of the four zones in each of the four successive weeks.

Table 1. Coding system for graphic representation of spatial distribution of catches. Given for each of the six code categories is the code, the range of weekly catch totals per trap and the symbol to denote it.

Code	0	1	2	3	4	5
Range	0	1	2-3	4-7	8-15	16+
Symbol	(blank)	.	-	+	#	@

Table 2. Mean weekly catch per trap in successive weeks in each of four zones into which the treated area was delineated - the outermost ring, three traps deep, inside this second and third outer "screen" rings each also three traps deep, and an inner core.

Traps counted from outside			Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Outer screens	Outermost	1-3	8.0	2.7	2.1	3.2	3.8	1.3
	Second	4-6	2.5	1.3	1.7	2.4	2.7	1.4
	Third	7-9	1.5	0.5	1.2	1.0	1.0	0.4
Inner core		>9	0.9	0.7	1.2	0.4	0.4	0.1

Discussion

The MAT controls considerably reduced the fly population in the inner parts of the protected area, while the outer areas found higher populations throughout the season.

Even after six weeks of deployment, however, the population in the inner core was not completely eradicated

The population in the inner core area was reduced almost at once to the level at which it stabilised, while that in the outer areas was more variable.

In general, fly populations were reduced, by 200m into the protected area, to levels similar to those in the core, although periodically "fingers" of intrusion penetrated as far as 500m in towards the core.

Intrusions into the protected area were in clearly-defined “fingers” indicating large numbers of flies moving from point sources outside the perimeter. This highly “lumpy” and “patchy” spatial distribution has implications both for monitoring (as a series of transects, for example, may misrepresent actual overall levels of penetration by either hitting or missing intrusive fingers) and for implementation (as unlucky farmers whose plots may lie within the fingers will benefit considerably less than their neighbours from wide-area control as a whole).

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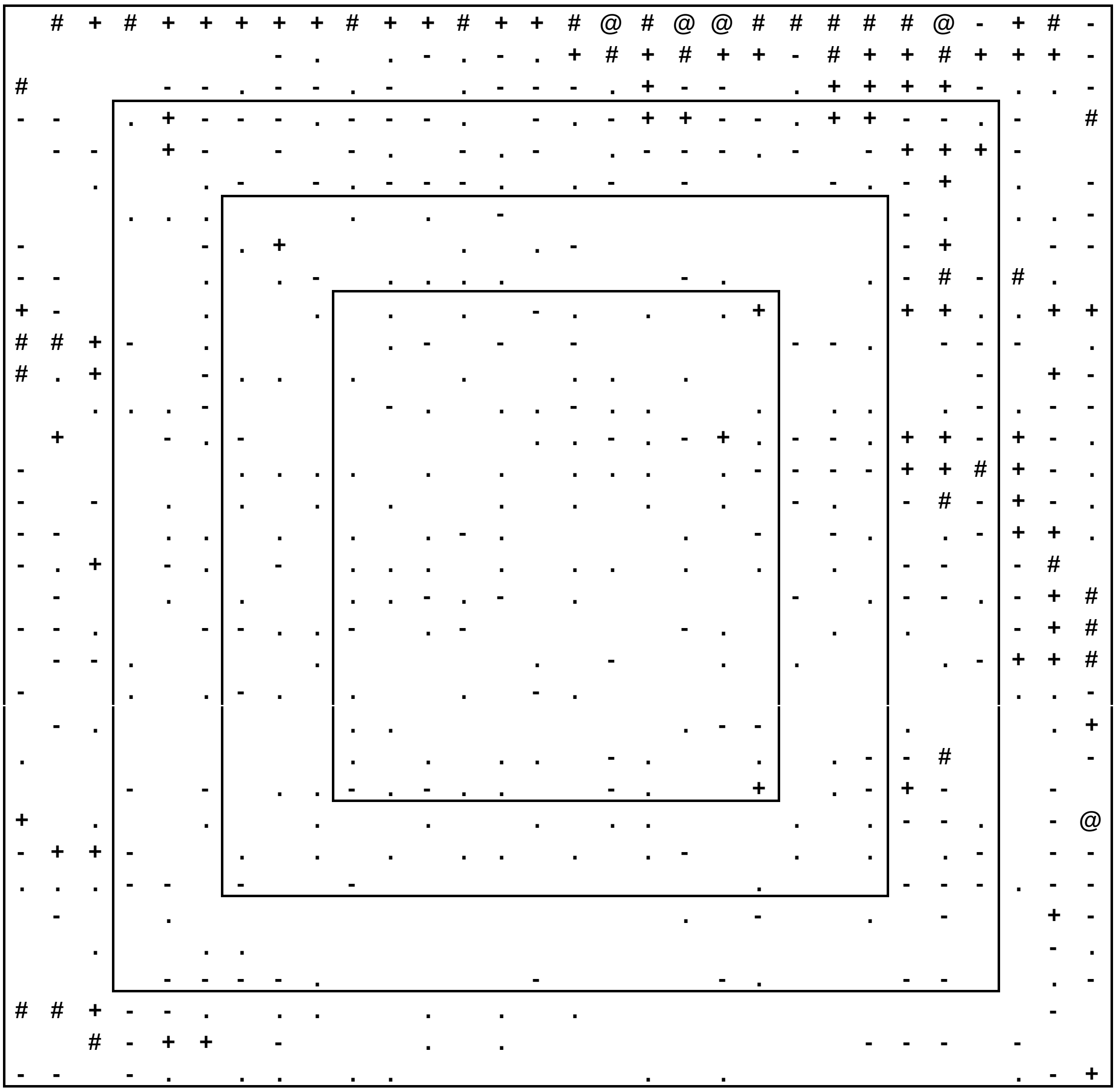

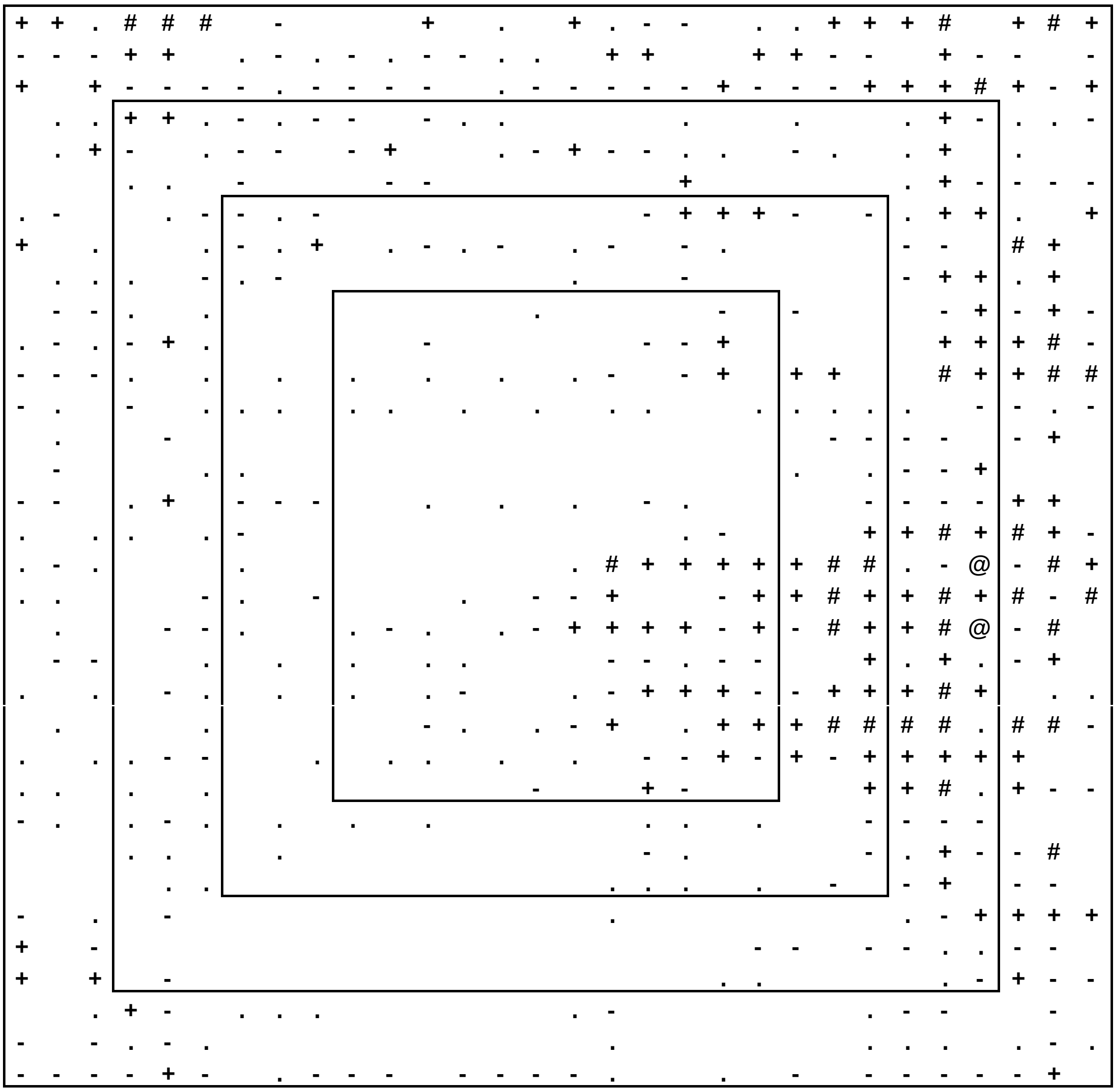

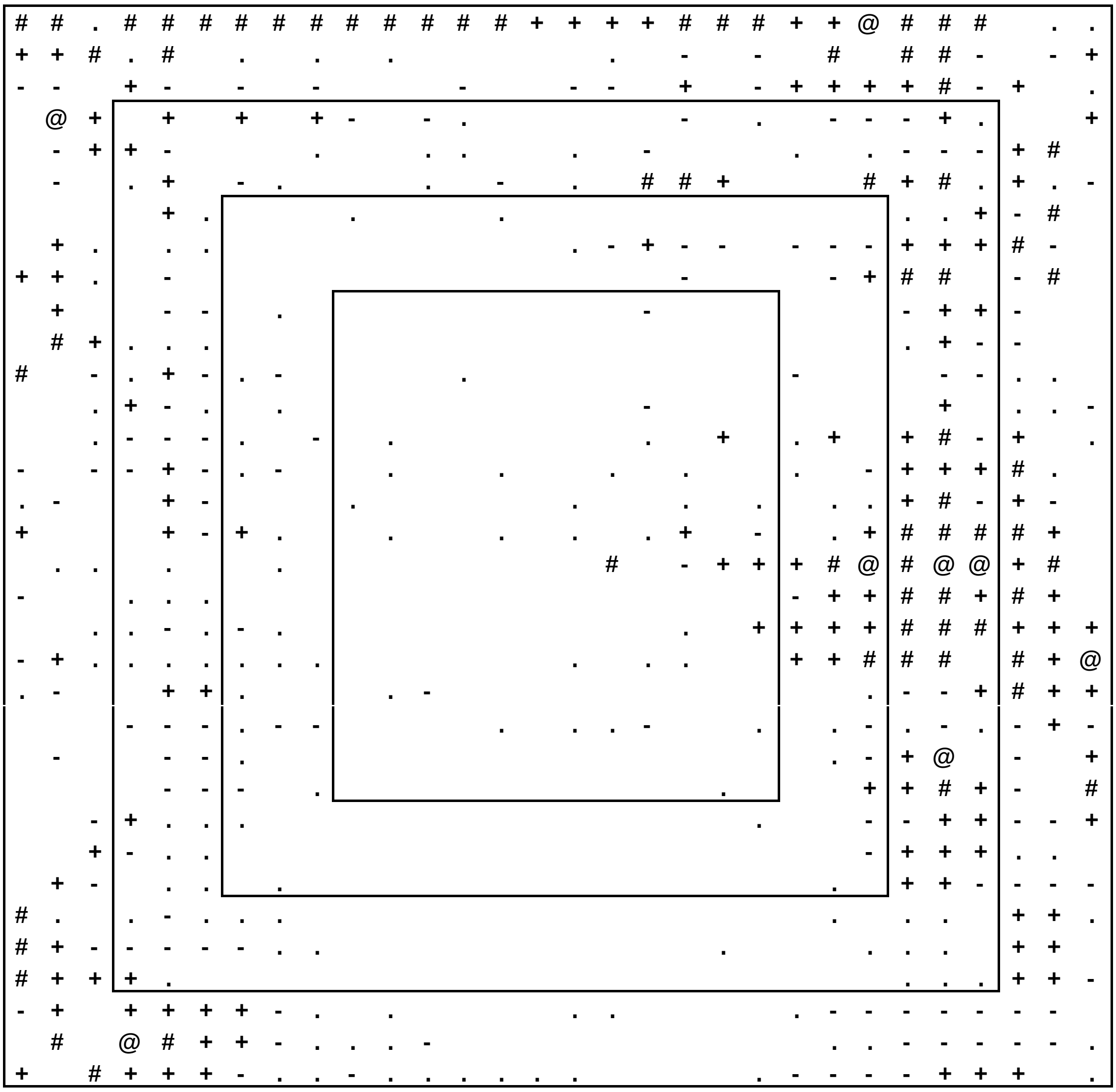

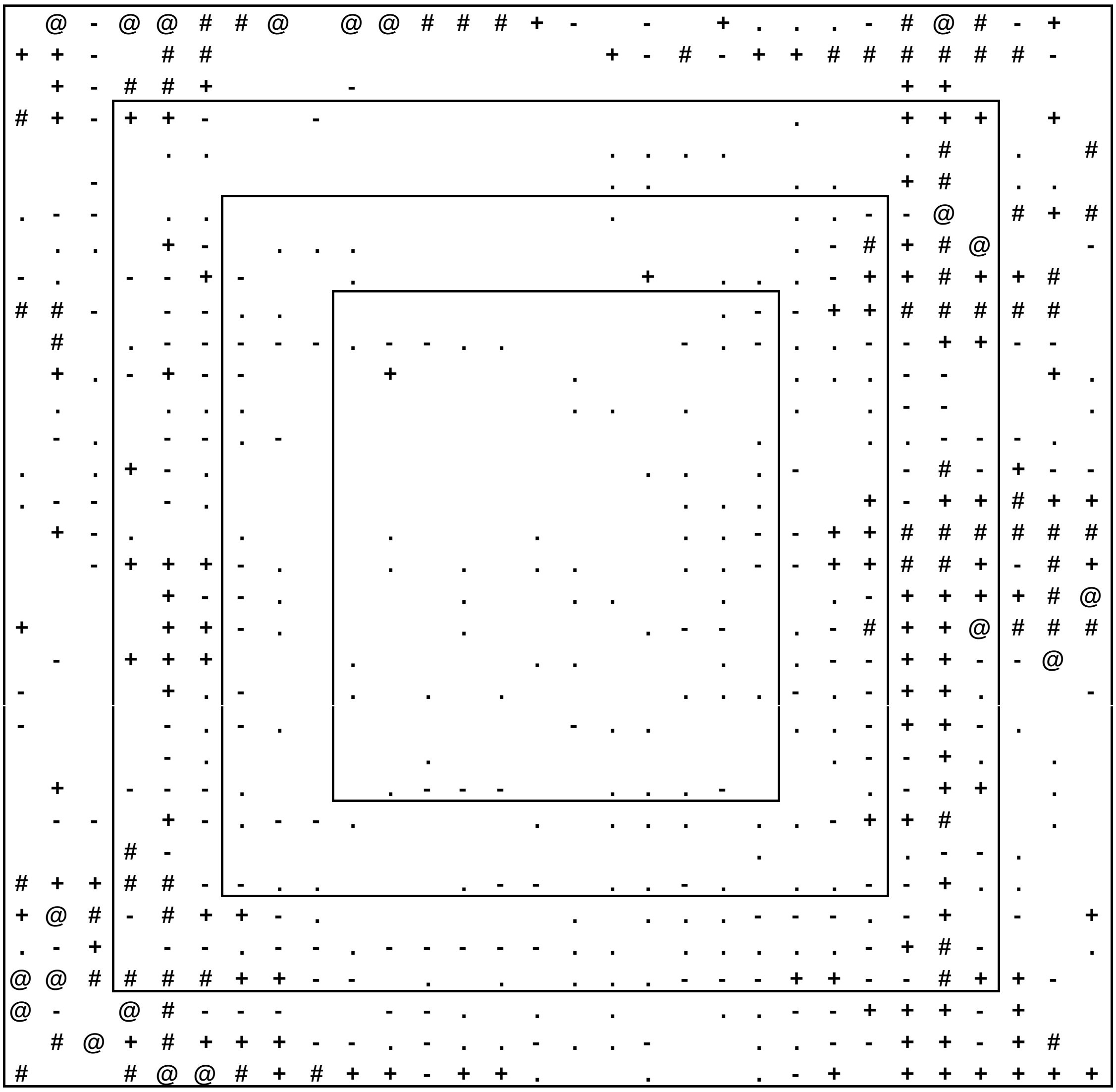

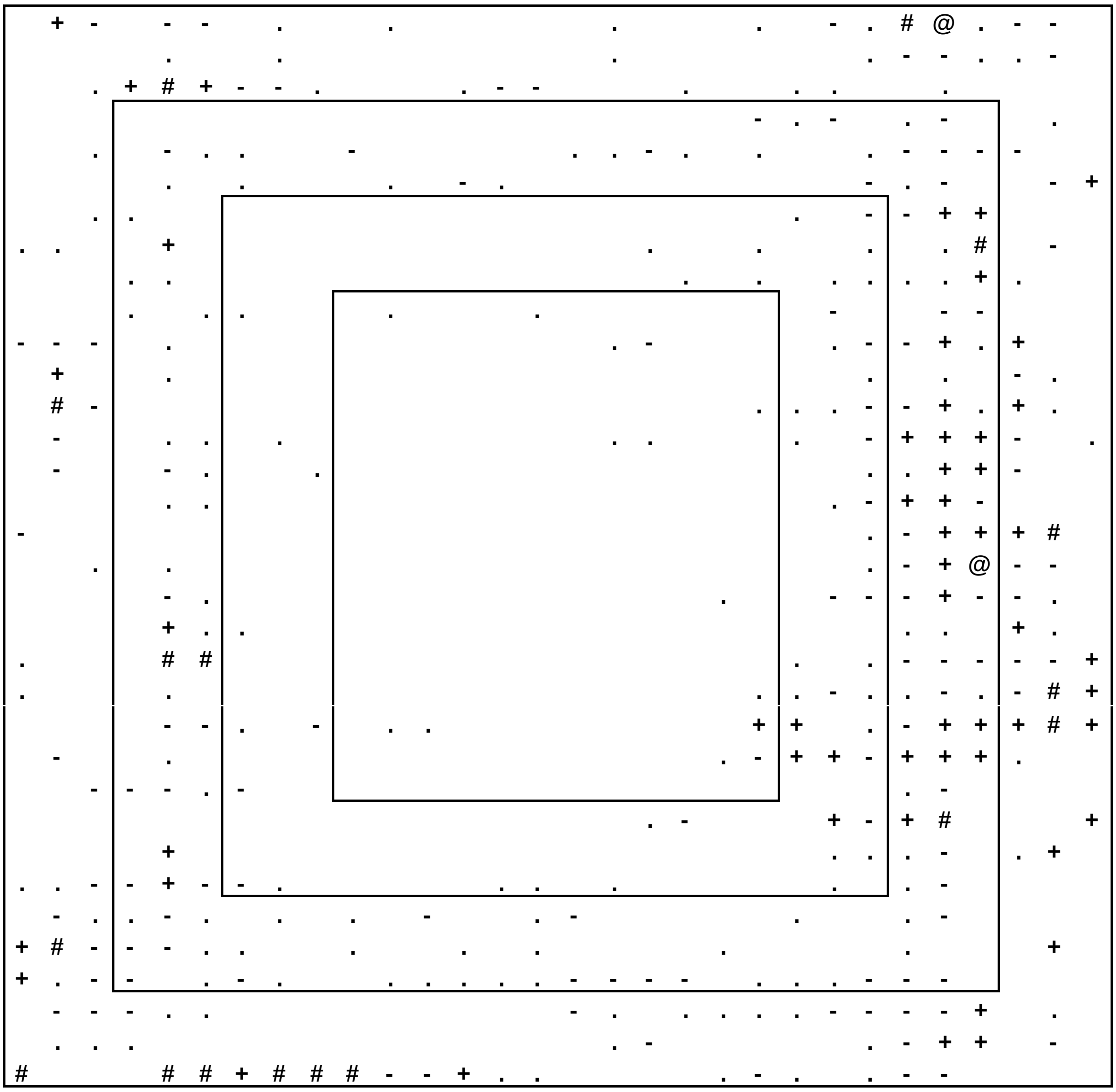

C. Semi-Structured Interview Survey

~[VEN]4. VILLAGE-LEVEL WIDE-AREA FRUIT FLY MANAGEMENT IN INDIA: ISSUES DETERMINING THE SCALE AND SUSTAINABILITY OF COOPERATIVE CONTROL

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SUMMARY

The benefit of the coordinated wide-area control of agricultural pests is not always dependent on the use of very large areas, or of eradicative, high-technology applications such as SIT. A study of the ecological and social implications of village-level fruit fly management in India found five keys necessities for sustainability. (1) Farm size, if large, reduces the number of farmers needed to obtain cooperative control but, if small, stimulates cooperation as individual-farm-level control may be ineffective. (2) The problem of the pest must be perceived as serious, and this seriousness apply for as many residents as possible. (3) Sustainable cooperative control is enhanced when it can be “grafted” or “piggybacked” onto other cooperative activities - such as marketing – rather than begun from scratch. (4) A level of social cohesion and mutual trust is important. (5) “Forgivingness” of incomplete application of area-wide controls, so their effect is not destroyed by a few isolated untreated areas, is important where there are truculent individuals who will not cooperate with a group effort. When cooperative control aims to be suppressive, rather than eradicative, private control by each individual can still obtain a return, regardless of the participation of neighbours, undermining the “free rider” strategy. This “forgivingness” is a function of the ecology of pests with relatively low mobility and/or which are relatively “*K*” rather than “*r*” selected.

INTRODUCTION

The benefit of the coordinated wide-area control of agricultural pests is not always dependent on the use of very large areas, or of eradicative, high-technology applications such as SIT. Technologies which work at farm level are often more effective when applied at village level, even when suppressive rather than eradicative in object, as reducing re-immigration of pests into treated areas from adjacent fields. Stonehouse *et al*. (2004) identified five separate but linked concepts associated with “wide-area pest management” - (1) wide-area management *per se*, (2) the comprehensiveness of treatment of the area, (3) isolation of the protected area from reinvasion, (4) the use of sophisticated eradicative technologies such as SIT and (5) the need for social or state intervention for funding and/or coercion. These five are not necessarily associated, and not all are needed to bring benefits to area-wide management.

The selection of spatial scale for the management of farm pests may be seen as on a continuum from the level of the individual field, through those of the farm, village, and locality, to a fully-isolated self-contained ecosystem. Along this continuum are“tipping points” where one combination of scale and technology gives way to another as the overall economic optimum. Unless other considerations intrude, the optimum will tend to be the smallest possible unit: this minimizes the risks of including tracts of non-crop hosts or different ecological conditions, and of political problems, as the numbers of farmers involved are smaller and likelier to be on neighbourly terms. Larger areas may be necessitated by pest ecology, critically determined by both the mobility of the pest and the imperviousness of immigrants to controls, for example mated females into areas protected by SIT. The minimum practical scale for a technology is therefore the smallest at which it can function; the maximum is where it becomes less efficient than an alternative, i.e. the minimum for that alternative.

THE STUDY OF VILLAGE-LEVEL FRUIT FLY MANAGEMENT IN INDIA

This work aimed to identify the factors which make village-level wide-area suppressive pest management sustainable, and determine the scales at which it may be effective. The Project *Integrated Management of Fruit Flies in India* (IMFFI) compared the suppressive management of fruit flies (Diptera: Tephritidae) at farm and village level at twelve sites, and found that control over an area of one square kilometre roughly doubled its effectiveness over that of the same controls applied at farm-level only (Stonehouse, in prep. a). The experimental villages also served as case studies, along with a programme of semi-structured interviews with villagers, to explore the social features which make cooperative control easier or harder at different scales of organisation.

Cooperative control may be seen as spread out at points along a scale of area sizes, participant numbers, and associated social structures.
1. A “family” scale where farmers are actually related, as such as extended families in the semi-desert on the Gujarat-Rajasthan border. It is clear who is the head of the family structure and to whom the group defers for decisions affecting all.
2. A “neighbourly” scale where cooperating parties know each other closely, such as small self-help groups in Kerala which are traditionally limited to the area over which a voice can carry so that members can hail each other.
3. A “village institutional” scale where participants know each other by sight but are coordinated by a village institution such as traditional leader. The personality and authority of the individual or group responsible is critical in making these partly-informal institutions function smoothly.
4. An “area institutional” scale, larger than the village, where formal institutions, with more rigidly-defined powers, are required.

Several controversial social components, often associated with wide-area management and discussed elsewhere in this volume, do not apply to village-level suppressive management, as not functions of wide-area management *per se*:
1. The need for coercion is a function not of wide-area management but of the need for management to be eradicative rather than suppressive, and so is not necessarily needed for village-level management.
2. State funding may be needed for economies of scale or because the pest persists in areas of uncultivated land where no private individual has an interest in controlling it, and so is not necessarily needed where management is confined to an area cultivated by neighbours growing similar crops.
3. A need for education of the public or farmers is a function of the complexity, novelty and unfamiliarity of technology, and so is not necessarily needed for the village-level use of farm-level technologies, where farmers often understand the principles and advantages, and indeed may grumble about reinvading pests from neighbouring fields after they have treated their own.

FIVE CHARACTERISTICS DECIDING THE SUSTAINABILITY OF LOCAL-LEVEL COOPERATIVE CONTROL

Sustainable cooperative control must overcome inertia, apathy and, often, antagonism and hostility, and the tendency of all successful pest management programmes (including quarantine) to become the "victims of their own success" as, if they succeed, nothing happens and so the memory of losses fades. In order to over come these most if not all of the following conditions must be met.

1 - Farm Size
Coordinated control encounters particular problems when individual farms are small. First, the number needed to obtain effective cooperative control is relatively large. Second, farm size may affect the level of benefit by individual participants: an IMFFI study of the penetration of flies into a single square kilometre of mango orchard (Stonehouse et al., in prep. b) found distinct “fingers” of intrusion, leading to very “patchy” distribution of fly populations, indicating that some farmers may benefit more than others. Third, small farm sizes exacerbate the tendency of those on the edges of the treated area to see their benefit as less than that of their fellows. On the other hand, neighbourhoods of small farms often have

powerful incentives to cooperate, as the returns to farm-level control may be so low, as reimmigration from neighbouring plots is virtually immediate, that only cooperative control is effective.

2 - Problem Seriousness
To overcome villagers' inertia, it is important that the pest be perceived as particularly serious - as one of the three or four critically limiting factors which come to farmers' minds when first asked. Additionally, wide-area management must be seen as providing substantial additional benefits over farm-level management. These perceptions must also be uniformly distributed. Farmers are most reluctant to carry out control operations on any ground which is not their own crop, including hedges, and for farmers in an area to participate, all must cultivate crops susceptible to the pest.

3 - Shared Economy
Sustainable cooperative control is greatly enhanced when it can be "grafted" or "piggybacked" onto other cooperative activities. Farmers in India cooperate for a variety of reasons - such as marketing and hiring or buying inputs - and cooperative pest management is more easily added on to these existing structures than begun from scratch. Farmers also tend to trust cooperatives' recommendations for cultivation when these also then buy their produce, as the farmer can see a vested interest by the cooperative in the success of production rather than the sale of the input. The dynamism or energy of any cooperative is of paramount importance.

4 - Social Cohesion
Cultivation of the same crop over an area is not by itself enough to support cooperative pest management, and for village-level cooperative control some social cohesion and mutual trust are important. Often, neighbours cultivate the same crop in the same ways because of confluent conditions - typically characteristic presence or shortage of water, labour, market access (such as a road) and technology, often spreading among neighbours by imitation once an idea was first introduced - giving a false impression of social cohesion. Farmers using identical cultivation practices may be divided, by religion, caste, political affiliation and village groupings such as the patronage of competing local leaders, and unifying social codes or structures (such as a popular village mayor with a powerful personality) are needed to stimulate widespread cooperation.

5 - Forgivingness of Imperfection

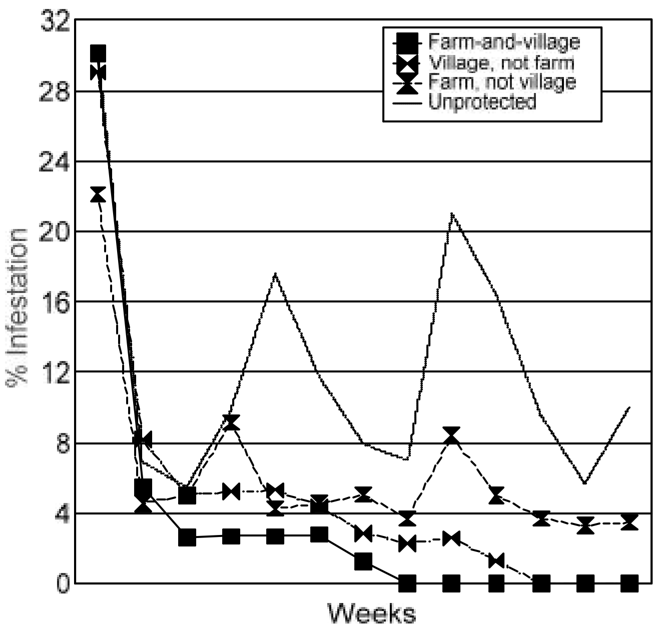

Figure 1. Progress over twelve weeks of the percentage infestation by fruit flies of bitter gourds in Central Gujarat, India, protected by bait application technique at four different levels as indicated.

In any village there may be at least one truculent individual who will not under any circumstances cooperate with a group effort. These are often bearers of grudges against specific individuals, which override economic benefit in perceived importance, rooted in a history of village feuds, and have led to the taking of an uncooperative positions from which retreat is impossible without a disastrous loss of face. For village-level management coercion is almost never an option, and in these cases it is therefore only made feasible by a level of "forgivingness" of imperfection, by which the benefits of coordinated control are not destroyed by a few isolated recalcitrants. A critical component of success is therefore the degree to which pest suppression benefits from coordination without eradication.

Village-level control therefore differs qualitatively from SIT and similar controls in that it must in all cases tolerate some imperfection of eradication, as all but the most static of pests may penetrate the protected area to some extent. Beyond this qualitative distinction, the extent to which the system may tolerate reintrusion of pests will interact with the level of participation to dictate success or failure. This "forgivingness" is basically a function of the ecology of pests with relatively low mobility and/or which are "*K*-selected", such as fruit flies, rather than "*r*-selected" such as many hemiptera, and so the ecology of the pest bears on the social sustainability of village-level cooperative control.

The IMFFI study found that under village-level management pest damage, though reduced, was still present and that farm-level controls, even over and above village-level controls, still obtained positive returns. This may enhance incentives to cooperation, as participation in control brings returns to the practitioner regardless of the participation of the neighbours, undermining the "free rider strategy". Over time, in addition, even suppressive wide-area management may obtain eradicative effects. Figure 1 shows the decline of fly infestation in a village-level-protected area of bitter gourd in Central Gujarat, where the non-cooperation of one recalcitrant individual prevented application to nearly 10% of the area. In the protected area, after several weeks infestation dropped to zero even without complete coverage or eradicative treatment.

ACKNOWLEDGEMENTS

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4. Fruit Fly Management Plans

A. Farm-Level Management of Fruit Flies in Cucurbits

Fruit fly management by bait sprays is roughly equivalent in effect to management by cover sprays, so the advantage of bait control is its greatly reduced costs and workload. It should be emphasised that bait control does not immediately reduce fly populations to very low levels, and so the advantage of its ease of deployment should be maximised by very frequent applications - ideally twice a week.

The most suitable baits in any situation may depend on local conditions and the preferences of local flies, so an initial check on the effects of individual candidate baits is advisable before wide-scale use. Farmers have a preference for baits in traps, but these are generally less effective and convenient than liquid baits applied to foliage as "squirts". The recommendation is for a mixture, with the majority of crop protection undertaken by squirts and with some traps to allow the farmer to check that flies are present and being destroyed.

Traps or squirts should be used just below the level of the pandal, and with emphasis on the field borders, which are frequented by flies which roost in hedges and surrounding vegetation.

B. Farm-Level Management of Fruit Flies in Orchards

In order to be effective, management of orchard fruit flies by methyl-eugenol MAT appears to need doses substantially greater than those used in India at the moment, and much more powerful than those obtainable by the use of ocimum. Farmers should be made aware of the dangers of "psychological control" whereby the appearance of dead flies in traps is taken as evidence of "success"

- farmers should be aware that these are males, and that a dozen or so dead in a trap in a week is having little effect on oviposition - the catch in a trap baited with a powerful methyl-eugenol block, which can catch several hundred flies in few days, is a graphic and effective illustration of how many flies are left alive when a weak trap is killing small numbers.

The evidence suggests that methyl-eugenol MAT, while effective at crop protection in most conditions and most seasons even on quite small plots, may not be relied on to provide reliable control under all conditions, and that BAT as a back-up should always be borne in mind. In most cases, the likelihood is that an economic return in mango protection would be obtained by using both soaked-block MAT and banana-pulp liquid bait application on a weekly basis.

C. Village-Level Management of Fruit Flies

The requisites for successful and sustainable village-level fruit fly management were identified in the social studies accompanying the experimental evaluation. (Disregarding the ecological characteristics of pests, which are taken to apply to fruit flies).

The initiative should be taken by either an existing cooperative or by an energetic, popular and effective local mayor. A cooperative which purchases produce or otherwise assists in marketing, and already has a role in the distribution of inputs, is the most promising starting point.

Farms should either be quite large and technified, or quite small and intensively cultivated.

Fruit flies should be perceived as particularly serious - as one of the three or four critically limiting factors which come to farmers' minds when first asked.

The local community should possess some aspects of social cohesion and, in particular, institutions in which all participate.

5. The South Asia Fruit Fly Network

The Network was set up in January 2005 with its website formally opened by Dr G Kalloo, DDG (Horticulture and Crop Science) of the Indian Council of Agricultural Research. The activities of the network are expressed on its website www.southasiafruitfly.net

Conscious decisions were taken (1) to give the Network no formal legal status, but a set of principles instead of a formal constitution and (2) provisionally at least to charge no money but to base the Network around its website and the distribution of the *Newsletter* by e-mail only. These decisions were made to maximise the ease of reach of the Network's communications, particularly to South Asian countries outside India, and are open to review should a need for a paper version of the Newsletter become apparent.

The first edition of the Newsletter described the activities and main implications of the IMFFI Project, and is appended as Appendix 4 [File iy5bnws].

III. References and Bibliography

Not all the references listed below are cited in the text of this Report. The list represents a comprehensive bibliography of references relevant to Indian Fruit Flies, and includes the literature items summarised in the Knowledge Review.

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IV. Appendices

The following is a full list of Appendices to this report. Appendices 1,2,3,4 and 5 are routinely printed to accompany the document; Appendices 6 and 7 give full details of experimental notes and past reports and are large and of only specialised interest so are routinely provided on disc rather than as printed copy.

1. Key Informant Survey Questionnaire - [iy5fkit]
2. Photographic Record of Wide-Area Study Villages [iy5fwi2]
3. Photographic Record of Laboratory Cages [iy5ffr2]
4. South Asia Fruit Fly Network *Newsletter* - First Issue [iy5bnws]
5. Poster Presentations at the IAEA Conference in Vienna, May 2005
 - 5a - Overview of the IMFFI Project [iy5evns]
 - 5b - Issues Determining the Scale and Sustainability of Cooperative Control [iy5evnb]
6. Semi-Structured Interview Survey file [isxxssi.wpd]
 (This large file gives the full transcripts of the Semi-Structured Interview Survey)
7. IMFFI reports produced
 (These files give the full text of previous Reports produced by this Project, including the original Project Document and the Workplans which give more detail on methodology and training materials for research described)
 - 7a - Project Document (2002) [iy2lprj]
 - 7b - 2003 Workshop - New Delhi I: *Programme and Round-Table Proceedings* [iy39int]
 - 7c - 2003 Workshop - New Delhi IIa: *Fruit Fly Research and Management in India* [iy39prs]
 - 7d - 2003 Workshop - New Delhi IIb: *Research Results from 2002* [iy39exp]
 - 7e - 2003 Workshop - New Delhi III: *2003 Workplan* [iy39wkp]
 - 7f - 2004 Workshop - Thiruvananthapuram I: *Programme and Summary* [iy4iint]
 - 7g - 2004 Workshop - Thiruvananthapuram II: *Incidence and Management Studies* [iy4ii55]
 - 7h - 2004 Workshop - Thiruvananthapuram III: *Knowledge Review* [iy4idkr]
 - 7i - 2004 Workshop - Thiruvananthapuram IV: *2004 Workplan* [iy4iiwk]